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EVALUATION OF VEHICLE SIDE AIRBAG SYSTEM EFFECTIVENESS

by

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Abstract:

Side airbags were first introduced into vehicles around 1995 to help protect passenger car occupants from serious injury in struck side crashes. International studies have shown that side airbags are effective at reducing the risk of death in near side impacts. They can also provide benefit in other types of crashes, such as vehicle rollovers. However, serious injuries can still occur when side airbags deploy. The aims of this study were to quantify the effectiveness of side airbags in reducing the risk of death and injury for occupants involved in side impact crashes in Australasia using Police crash data alone; and to use detailed injury information linked to Police reported crash data to determine the effectiveness of side airbags in reducing the risk of death and injury for occupants involved in side impact crashes in Victoria. It was found that the use of injury outcomes from Police crash data alone was inadequate for the evaluation of side airbag effectiveness. However Police reported crash data linked to higher resolution and validated injury data by body region available from injury compensation claims data produced much more stable analyses and more informative outcomes. In particular, *combination airbags* were associated with statistically significant reductions of 61% in the odds of death and injury to the head, neck, face and thorax in struck side crashes (with a 95% confidence interval of 27% to 79%). In comparison, *torso-only* protecting airbags appeared less effective with no statistically significant injury effects found. However there was some indication of an increase in the odds of death and injury to the thorax region associated with torso only side airbags requiring further investigation.

Key Words:

Side airbags
Statistical evaluation
Head protecting airbags
Torso protecting airbags
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Preface

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EXECUTIVE SUMMARY

Side impact crashes are both common and harmful: accounting for 25% of vehicle casualties and 28% of fatalities in Australia (Fildes, Sparke et al. 2001). To help protect occupants in side impacts, Volvo introduced side airbags designed to protect the torso in 1995, while BMW introduced head-protecting side airbags in 1998. The majority of vehicle manufacturers have since followed in introducing side impact airbag systems in vehicles either as standard or optional fitment. International studies have shown that side airbags can reduce the risk of death in struck side impacts by up to 50% (Braver and Kyrychenko 2004; Insurance Institute for Highway Safety 2006). Despite side airbags reducing the risk of death, serious injuries still commonly occur even when a side airbag deploys. Furthermore, side airbags offer poorer protection to some occupant groups: for example older females (Braver and Kyrychenko 2004). There was a need to investigate whether side airbag systems are effective outside of the vehicle populations already studied and particularly in the Australian and New Zealand vehicle fleets. Further evaluation also offered the potential to investigate how side airbags can be improved to reduce the severity of non-fatal injuries.

The aims of this study were to quantify the effectiveness of side airbags in reducing the risk of death and injury for occupants involved in side impact crashes in Australasia by injury outcomes reported directly in police crash reports in Australia and New Zealand and using detailed injury information linked to Police reported crash data in Victoria. The study aimed to determine the effectiveness of side airbags in reducing the risk of death and injury for occupants involved in side impact crashes in Victoria.

Based on the analysis of police reported injury outcomes in crashes, overall measures of side airbag effectiveness in terms of injury reduction in struck side crashes were derived using Police reported crash data from New Zealand and five Australian states. For each crashed vehicle, side airbag fitment status was determined by decoding Vehicle Identification Number (VIN) contained in the crash data. The sample of vehicles fitted with side airbags identified from the data comprised of 199 different models. To determine overall measures of effectiveness, logistic regression models were fitted to the Police reported crash data. These logistic models could separate the effects of side airbags on driver safety from confounders such as other vehicle safety features, vehicle size and differences in the fragility of occupants of different demographic groups. The logistic models contained terms related to whether side airbags were fitted, the type of impact the vehicle was involved in and the level of injury sustained to the focus occupant. Estimated model parameters were used to determine the difference in the side impact secondary safety between vehicles with side airbags and vehicles without side airbags when involved in side impact crashes.

The second stage of the analysis utilised detailed injury information linked to Police reported crash data to estimate side airbag effectiveness. International Classification of Diseases (ICD) injury codes enabled the presence of injury by body region, namely head, face, neck, thorax, abdomen, spine, upper extremity, lower extremity & external and other to be determined. As per the first part, VIN was used to determine airbag fitment. Logistic regression models were also developed for the estimation of side airbag effectiveness that used higher resolution injury information by body region. In particular, the identification of injury by body region meant that more specific models directly related to the body regions side airbags were designed to protect, namely the head, face, neck and thorax, were able to be estimated. As for the earlier analysis, models were developed that could measure

differences between the secondary safety provided by vehicles with side airbags compared with vehicles without side airbags adjusted for confounding factors.

Unlike the first analysis, the second analysis found clear statistical evidence that side airbags were effective in reducing death and injury in struck side crashes. In particular:

- The use of injury outcomes from Police crash data alone was found to be inadequate for the evaluation of side airbag effectiveness in Australasia.
- Police reported crash data linked to higher resolution and validated injury data by body region produced much better targeted analyses and more informative outcomes.

Results of the second analysis may be summarised as follows:

- *Combination airbags* designed to protect the head, neck, face and thorax are highly effective in reducing injury due to side struck crashes. Combination airbags were associated with statistically significant reductions of:
 - 51% in the odds of death and injury to all body regions (with a 95% confidence interval of 25% to 68%);
 - 61% in the odds of death and injury to the head, neck, face and thorax (with a 95% confidence interval of 27% to 79%); and
 - 53% in the odds of death and injury to the head, neck and face (with a 95% confidence interval of 6% to 77%).
- *Torso-only* protecting airbags appeared less effective than combination airbags. There was:
 - no statistically significant injury effects associated with airbag fitment; and
 - some indication of an increase in the odds of death and injury to the thorax body region associated with thorax airbag fitment, a result requiring further investigation.

EVALUATION OF VEHICLE SIDE AIRBAG SYSTEM EFFECTIVENESS IN AUSTRALASIA

1.0 INTRODUCTION

1.1 BACKGROUND

Side impact crashes are both common and often lead to serious injury outcomes, particularly in the side impacted vehicle. For example, Bédard et al. (2002) found that 31% of fatal crashes in America were side impacts, while Fildes et al. (2001) report that, in Australia, side impact crashes account for 25% of vehicle casualties and 28% of fatalities. The definition of a side impact crash can include single vehicle crashes and multiple vehicle crashes where the side of the vehicle is the primary impact point. Furthermore, within each of these categories, researchers often differentiate between struck-side and non struck-side crashes. In struck-side crashes, the primary point of impact of the side-struck vehicle is on the same side as the case occupant seating position, while for far side crashes, the point of impact is on the opposite side of the vehicle to the case occupant's seating position. A side impact crash can be both struck side and far side if there is more than one occupant in the side struck vehicle.

The introduction of side impact crash tests to vehicle safety standards such as the US FMVSS 214 and to vehicle ratings programs such as NCAP and EuroNCAP in the 1990s increased efforts to minimise occupant trauma from side impacts. Early research concentrated on ways of minimising injuries to body regions that were most commonly injured in side impacts: in particular the head and chest (e.g. Mackay et al. 1992; Morris et al. 1995).

In 1995 Volvo introduced side airbags designed to protect the torso. Having a vehicle manufacturer lead efforts to improve secondary safety lent some validation to the inclusion of side impact crash tests in the various regulatory and consumer information crash test protocols. Manufacturers continued to lead the way in the development of side airbag technology, with BMW introducing head-protecting side airbags in 1998 (Braver & Kyrychenko 2004). Since then, most manufacturers have fitted side impact airbag systems in their vehicles either standard or as an optional extra. Different types of side airbag systems are presently available: those that are designed to protect the torso only which deploy from either the side of the seat or the interior of the front occupant's door; or airbag systems that protect both the head and torso. The latter type can consist of two separate airbags, one deploying from the seat side or door to protect the torso and a separate curtain or tubular structure deploying from the roof railing to protect the head. Alternatively some larger side airbags that deploy from the seat are designed to protect both the head and torso although this design is less common. Side airbag technology has continued to develop. For example, in the last decade there have been advances in calibrating rollover sensors in vehicles to maximise the protection provided by curtain side airbags during rollover events (Takahashi et al. 2003; Viano & Parenteau 2004).

Studies conducted internationally have shown that side airbags can reduce the risk of death in struck-side impacts. For example Braver and Kyrychenko (2004) estimated that side airbags that protected the head and torso reduced the risk of death in struck side impacts by nearly 50%, while a more recent study estimated that side airbag systems that protected

both the head and torso reduced fatality risk by 37%, with airbags that only protected the torso achieving a reduction of 26% (Insurance Institute for Highway Safety 2006).

Despite the measured benefits of side airbags, serious injuries still commonly occur even when a side airbag deploys, with the most-commonly injured regions being the chest, abdomen and head (Yoganandan et al. 2007). McGwin et al. (2003) found that the risk of a minor injury in a struck side impact was similar for front seat occupants with and without side airbags. This result also held when restricted to more serious injuries. Non-fatal injuries contribute an enormous cost to the community and often leave occupants with long term debilitating injuries. Braver and Kyrychenko (2004) also demonstrated that side airbags do not provide uniform protection to all occupant groups, with torso-protecting side airbags being associated with an increased risk death for older females.

There is a need for continued research that both validate the results of the existing studies in other populations and also focus on how side airbags can be improved so that the severity of non-fatal injuries are reduced and so that they offer better protection to all occupant groups. Yoganandan et al. (2007) highlighted the need for continued study of side airbag systems using innovative techniques when recalling how, in the 1990s, anecdotal and field investigations helped identify that first generation frontal airbags were causing injuries for out-of-position and young occupants. These investigations enabled less-aggressive frontal airbags to be developed before a sufficient quantity of mass data was available to conclusively identify deficiencies in the first-generation airbags. With respect to side airbag performance, Yoganandan et al. (2007) present considerable evidence to suggest that there is scope for improvement in protecting older, more-fragile populations.

Side airbag performance can be improved through investigation of the effect of side airbags on the risk of different types of injuries, including injuries to different body regions. Aside from a study by McGwin et al. (2008) of the relationship between side airbag and the risk of injuries to upper extremities, a review of the scientific literature demonstrated there are few studies that measure the risk of non-fatal injury for different body regions. Perhaps this is because analysing injury risk for different body regions requires crash data that contains injury information of a sufficient level of detail. Such data are difficult to find. Secondly, establishing which vehicles in crash data have side airbags fitted can be difficult, often requiring exclusion of a large proportion of the sample for which fitment status cannot be determined thus reducing the power of subsequent analyses. This study sought to address the first obstacle by matching crash data from Victoria with detailed injury data from insurance injury compensation insurance claims records. The second obstacle was addressed by maximising the sample of crashed cars with valid fitment status by decoding Vehicle Identification Number (VIN) data contained in the crash data.

1.2 STUDY AIMS

This study had two objectives:

- 1) To quantify the effectiveness of side airbags in reducing the risk of death and injury for occupants involved in side impact crashes in Australasia; and
- 2) To use detailed injury information linked to Police reported crash data to determine the effectiveness of side airbags in reducing the risk of death and injury for occupants involved in side impact crashes in Victoria.

The first objective aimed to quantify effectiveness using measures of injury derived from Police crash data whilst the second objective aimed to use higher resolution injury information linked to Police crash data to allow estimation of side airbag effectiveness based on the specific body regions that side airbag systems are designed for.

2.0 DATA

The crash data used to assess the effectiveness of side airbags for Australasia were Police reported crashes from New Zealand and five Australian states which had been collected as part of the Monash University Accident Research Centre's (MUARC's) *Used Car Safety Ratings* project, a primary activity of the Vehicle Safety Research Group (VSRG) research program. Newstead, Watson et al. (2009) provide a detailed description of these crash data. The data included information on the age, sex and injury status of 1,984,480 drivers that were involved in crashes in the period 2001-2008.

Vehicles without a valid Vehicle Identification Number (VIN) were excluded because VINs were used to determine whether a vehicle had side airbags fitted. Commercial vans and vehicles manufactured prior to 1999 were also excluded from the analysis as only a very low proportion of these vehicles had side airbags and including them could bias estimates of effectiveness. When these groups of vehicles were omitted, there remained 482,275 vehicle records eligible for inclusion in the analysis.

2.1 DETERMINING SIDE AIRBAG FITMENT STATUS

The type of side airbags available in each vehicle in the analysis sample was determined using the Redbook Lookup Guide (Automotive Data Services 2007) which provides data on the VIN and specifications of vehicles sold in Australia. The data available only allowed classification of side airbags into two groups: *torso-only* side airbags; and *combination* side airbags. Combination side airbags were defined as multiple airbag systems with separate elements of the system providing protection to the torso and head areas respectively. This includes the typical combination of a thorax airbag and a curtain airbag. It was not possible to distinguish between different types of head-protecting side airbags (e.g. curtain airbags or tubular structures). Torso-only side airbags were defined as a single airbag providing protection predominantly to the torso deploying from the seat side or door skin. Torso-protecting side airbags with a head extension were classified as torso-only.

An SPSS syntax (SPSS 2009) was prepared to classify vehicles according to what types of side airbags were fitted using the make and model value of each vehicle as well as the year of manufacture and VIN. Using this syntax, 482,275 vehicles were assigned to one of four categories: combination airbags fitted (n=23,788); torso-only side airbags fitted (n=26,274); no side airbags fitted (n=294,216); and fitment status unknown (n=137,997). The "unknown" category were models in which side airbags were either offered as optional extras or only on a trim level that could not be distinguished from other trim levels through the VIN decoding process. The sample of vehicles where side airbag fitment type was successfully identified comprised 199 different models (Appendix A). It should be noted that Appendix A does not list the numbers of crashed vehicles by model without any side airbags fitted.

2.2 DETERMINING CRASH TYPE STATUS

To separate the protection that side airbags offer occupants involved in side impacts from protection due to other vehicle safety systems and the structural strength of the vehicle, it was necessary to define a group of crashes in which side airbags are designed to provide added protection from injury to occupants. Any predicted benefits of side airbags could then be normalised against the performance of the vehicles fitted with side airbags in crashes in which the presence of side airbags are unlikely to provide additional safety benefits. For this study, crashes in which side airbags are designed to provide added protection are referred to as *target crashes*, while those for which side airbags are unlikely to affect occupant safety are referred to as *non-target crashes*. Only crashes where the impact occurred on the same side of the vehicle as the occupant was positioned were considered. As the crash data consists of drivers only, it followed that target crashes were side crashes where the impact occurred on the driver side of the vehicle (the “struck side”), with side crashes where the impact occurred on the passenger side of the vehicle excluded from the analysis.

Using crash configuration variables collected by each jurisdiction, drivers were categorised according to whether they were involved in a single vehicle impact in which the side of their vehicle was struck by an external stationary object (e.g. a tree or a pole); or whether they were involved in a multiple vehicle crash in which the side of their vehicle was struck by another vehicle (see Table 1). Only drivers were considered since it was not possible to identify reliably whether other vehicle occupants were present in the vehicle if not injured.

Table 1: Summary of the data available for analysis by crash type and jurisdiction

	NSW	VIC	QLD	WA	NZ	SA
Single vehicle crash						
Struck side	N/A	69	147	N/A	44	N/A
Unknown impact point	8,807	124	57	5,497	0	4,183
Not single vehicle side impact	102,628	23,744	38,686	97,521	8,312	54,235
Multiple vehicle crash						
Struck side	N/A	584	1,692	3,570	207	N/A
Hit side of another vehicle	N/A	2,053	6,549	8,260	388	N/A
Unknown impact point	21,922	1,615	5,017	6,912	0	11,567
Not a multiple vehicle side impact	89,513	19,443	24,373	81,464	7,651	46,851
Total	111,435	23,993	39,003	103,018	8,411	58,418

For single vehicle crashes in New South Wales (NSW), Western Australia (WA) or South Australia (SA) it was not possible to determine whether the side of the vehicle was the primary impact point. Similarly, for multiple vehicle side impact crashes in NSW and South Australia it was not possible to determine which of the vehicles involved in the crash was side struck since only the broad crash configuration is given.

It was necessary to exclude cases in which it could not be determined whether the side of the case vehicle was struck. Therefore all cases from NSW and SA were excluded. Furthermore, vehicles that involved rollover events not caused by an initial side impact were also excluded as only some side airbags deploy during rollover. To enable the logistic models used in the analyses to reach convergence, groups of vehicles with low cell counts

were also excluded (i.e. some groups of four wheel drives (4WDs), people movers and commercial utilities). This left 129,350 vehicles remaining in the analysis sample: 5,537 struck side (target group) cases and 123,813 in the non-target group.

2.3 LINKED DATA

The second objective of the project aimed to use detailed injury information linked to Police reported crash data to estimate side airbag effectiveness. For this analysis *Used Car Safety Ratings* project data for Victoria for the period 2001-2009 was linked to Transport Accident Commission (TAC) injury compensation claims data. TAC data contains International Classification of Diseases (ICD) injury codes for injuries from the claim, with hospital injury records including ICD codes provided to the TAC for claims management. Injury by body region, namely head, face, neck, thorax, abdomen, spine, upper extremity, lower extremity & external and other was based on the ICD injury codes present. As per the first analysis, vehicles without a valid Vehicle Identification Number (VIN) were excluded because VINs were used to determine whether a vehicle had side airbags. In addition, only cases where the vehicle impact occurred on the driver side (including front and rear corner) and front and rear of the vehicle were included with impacts on the passenger side of the vehicle were excluded. Once these exclusions were made, there remained 52,203 records eligible for inclusion in the analysis of which 11,499 records were linked to a corresponding TAC claim.

3.0 METHOD

Section 3.1 explains the methodology used to estimate the effect of side airbags in reducing the risk of injury from the Police crash data. The methodology involves fitting logistic models to the Police reported crash data described in section 2.2. These logistic models were used to separate the effects of side airbags on driver safety from confounders such as other vehicle safety features, vehicle size and differences in the fragility of occupants of different demographic groups. Section 3.2 explains the methodology used to estimate the effect of side airbags in reducing the risk of injury using higher resolution injury information linked to Police reported crash data.

3.1 ESTIMATING SIDE AIRBAG EFFECTIVENESS USING MEASURES OF INJURY DERIVED FROM POLICE CRASH DATA

Logistic regression models were developed to measure differences between the secondary safety of vehicles with side airbags compared with vehicles without side airbags. The models developed considered secondary safety in both target crashes as well as in non-target crashes. This enabled normalisation by the component of secondary safety related to other vehicle safety features or because the vehicles were better able to resist crash forces in all types of impacts. Normalisation was achieved by considering the relative secondary safety performance of vehicles in the target crash types versus the non-target crash type with the difference in this relativity between vehicles with side airbag systems compared to those without representing the net secondary safety effects of the side airbag system. Formulating the analysis in this way effectively used the non-target crashes as a type of control to represent the general safety performance of the vehicle independent of side airbag fitment.

The logistic regression models were based on the *injury risk* and *injury severity* covariate models developed by Newstead, Watson et al. (2009) for their *Used Car Safety Ratings*. The injury risk model estimated the risk that a driver was injured when involved in a tow-

away crash, while the injury severity model estimated the risk that an injured driver was seriously injured (hospitalised) or killed.

Each covariate model contained main effects parameters as well as first, second and third order interaction terms involving driver characteristics (sex and age) and crash characteristics (the year of crash, number of vehicles involved, speed zone and jurisdiction). The process used to determine which non-vehicle parameters were included in each covariate model is described in detail by Newstead, Watson et al. (2009).

By adding a variable that differentiated between vehicle models, Newstead, Watson et al. (2009) were able to estimate injury risk and risk of serious injury for each model. In this evaluation, instead of adding a vehicle model variable, interaction terms involving the following variables were added:

- *sidestruck* (struck side, not side struck);
- *sideairbag* (combination, torso-only, or no side airbags fitted);
- *market* (Large/Medium/Compact 4WD, Light/Small/Medium/Large Car, People Mover or Commercial Utility); and
- *YOM* (year of manufacture).

The interaction terms added were a first order interaction term (*sidestruck*sideairbag*) and two second order interaction terms (*market*YOM*sidestruck* and *market*YOM*sideairbag*). The two second order interaction terms are added to each covariate model so that vehicles fitted with side airbags were effectively being compared against similar non-fitted vehicles.

The parameters of the variables forming the interaction term *sidestruck*sideairbag* can be used to estimate the difference in the secondary safety between vehicles with side airbags and vehicles without side airbags when involved in side impact crashes. For example, the logit function of the injury risk model can be written as

$$\begin{aligned} & \text{logit}(\textit{sidestruck}, \textit{sideairbags}, \textit{market}, \textit{YOM}, Y_1, \dots, Y_k) \\ &= \beta_s \textit{market} * \textit{YOM} * \textit{sidestruck} + \beta_a \textit{market} * \textit{YOM} * \textit{sideairbag} \\ &+ \beta_{sa} \textit{sidestruck} * \textit{sideairbag} + F(Y_1, \dots, Y_k) \end{aligned} \quad (1)$$

where β_s , β_a and β_{sa} are coefficients of the model and $F(Y_1, \dots, Y_k)$ is the linear combination of model coefficients and main effect and interaction variables that do not involve variables *sidestruck* or *sideairbag*.

If the variable *sidestruck* is coded as 0 for non-target (not side struck) cases and 1 for target (struck side) cases and *sideairbag* is coded as 0 for vehicles without side airbags and 1 for vehicles with side airbags, the log of the odds ratio of a driver being injured in a struck side impact when side airbags are available compared to if side airbags are not available is equal to

$$\text{logit}(1,1, \textit{market}, \textit{YOM}, Y_1, \dots, Y_k) - \text{logit}(1,0, \textit{market}, \textit{YOM}, Y_1, \dots, Y_k),$$

which simplifies to

$$\beta_a \text{market} * YOM + \beta_{sa} . \quad (2)$$

The term β_a represents the difference in the secondary safety of vehicles with side airbags and those without side airbags for non-target crashes, while β_{sa} represents the difference in the secondary safety for vehicles with side airbags compared to those without side airbags when involved in a struck side crash. The odds ratio (OR) of a driver being injured in a struck side impact when they have side airbags compared to drivers without side airbags is estimated to be

$$OR = \exp(\beta_{sa}) \quad (3)$$

with 95% confidence intervals equal to

$$\exp[\beta_{sa} \pm 1.96 * SE(\beta_{sa})] \quad (4)$$

where $SE(\beta_{sa})$ is the standard error of β_{sa} .

The percent reduction in the odds of injury risk is equal to

$$(1 - OR) * 100 . \quad (5)$$

This transformation can also be applied to the confidence limits of the odds ratio to derive the confidence limits for the estimated percent risk reduction.

The odds ratio and percent reduction in the risk that an injured driver is seriously injured can be derived in the same way, using the parameters of the terms added to the injury severity covariate model.

Both the injury risk and injury severity odds ratios can be converted into probabilities relating to the base set of covariate profiles using the transformation

$$P(OR) = \frac{OR}{1 + OR} . \quad (6)$$

From these probabilities, the crashworthiness probability can be estimated. Newstead, Watson et al. (2009) defined crashworthiness as “the measure of the risk of death or serious injury to a driver of that vehicle when it is involved in a crash” (p.2). Each of the injury risk and injury severity probabilities can be normalised by the overall risk of injury or serious injury, irrespective of side airbag status. By Newstead, Watson and colleagues’ (2009) definition of crashworthiness, the product of these normalised probabilities gives the probability of serious injury given involvement in a Police reported crash for drivers with side airbags, normalised by the overall risk across all types of vehicles (including those without side airbags). It is then simple to convert this crashworthiness probability into an odds ratio.

Newstead et al (2006) explain that the confidence limits of the crashworthiness odds ratio can be estimated by calculating the variance of the natural logarithm of the crashworthiness probability, which can be approximated by

$$\text{Var}(\log_e C) \approx \frac{\text{Var}(\alpha)}{(1 + e^\alpha)^2} + \frac{\text{Var}(\beta)}{(1 + e^\beta)^2} \quad (7)$$

where C is the crashworthiness probability and α and β are the respective values of the logistic function for injury risk and injury severity for (in this case) drivers with side airbags who were involved in struck side impacts.

3.2 ESTIMATING SIDE AIRBAG EFFECTIVENESS USING HIGHER RESOLUTION INJURY INFORMATION BY BODY REGION

Logistic regression models were also developed for the estimation of side airbag effectiveness that used higher resolution injury information by body region. As for the earlier analysis, models were developed that could measure differences between the secondary safety provided by vehicles with side airbags compared with vehicles without side airbags. The models were set up so that estimates of effectiveness were given for target crashes relative to non-target. This again enabled normalisation by the component of secondary safety related to other vehicle safety features or because the vehicles were better able to resist crash forces in all types of impacts.

The models used for the linked data analysis also included non-vehicle factors and their interactions as part of a covariate model to adjust for their influence on driver injury outcome as per the calculation of Used Car Safety Ratings (Newstead, Watson et al. 2009). However the number of cases available for analysis meant that only main effects and 1st order interactions were included in order to ensure model stability. Non-vehicle factors included were *age*, *sex* and *year of crash*, however the examination of injury outcome by specific body region allowed the factors *number of vehicles involved* and *speed zone*, which adjust for crash severity to an extent, to be replaced by a single improved crash severity adjustment variable, *sevadj*. For the body region models, *sevadj* was coded 1 if an injury occurred in any of the *other* body regions, or 0 otherwise.

As for the previous analysis, the models include a 1st order interaction term involving the following variables:

- *sidestruck* (struck side, not side struck);
- *sideairbag* (combination, torso-only, or no side airbags fitted);

i.e. *sidestruck*sideairbag* that can be used to estimate the difference in the secondary safety between vehicles with side airbags and vehicles without side airbags when involved in side impact crashes.

For example, the logit function of the model by body region can be written as

$$\begin{aligned} & \text{logit}(\text{sidestruck}, \text{sideairbags}, \text{sevadj}, Y_1, \dots, Y_k) \\ & = \beta_s \text{sidestruck} + \beta_a \text{sideairbag} + \beta_{sa} \text{sidestruck} * \text{sideairbag} + \beta_{sev} \text{sevadj} + G(Z_1, \dots, Z_k) \end{aligned} \quad (8)$$

where β_s , β_a , β_{sa} and β_{sev} are coefficients of the model and $G(Z_1, \dots, Z_K)$ is the linear combination of model coefficients and main effects and 1st order interactions that do not

involve the variables *sidestruck* , *sideairbag* or *sevadj*, i.e. included non-vehicle factors. Further methodology for transforming the outcomes of the logistic regression models is as provided in Section 3.1.

4.0 RESULTS

4.1 INJURY OUTCOMES USING MEASURES OF INJURY DERIVED FROM POLICE CRASH DATA

Table 2 shows the parameter coefficients, standard errors and Wald statistics for the three interaction variables added to the injury risk and injury severity covariate models developed by Newstead, Watson et al. (2009). In this table, drivers with combination airbags were grouped with drivers with torso-only airbags. Therefore, the coefficients shown in Table 2 represent the effectiveness of side airbag systems averaged across torso only and combination configurations within the vehicle sample analysed. Details for the parameters that Newstead, Watson et al. (2009) originally included in each covariate model and the variables related to market group and year of manufacture have not been included for reasons of brevity. However, both models satisfied convergence criterion of the logistic regression module in SAS statistical package (SAS Institute Inc. 2003).

Table 2: Parameters added to the injury risk and injury severity covariate models used to isolate the effect of any types of side airbag on secondary safety

Parameter name	Categories	β_{sa}	s.e.	Wald Chi sq.	<i>sig.</i>	Odds Ratio
Injury risk						
<i>sidestruck*sideairbag</i>	Struck side * fitted	-0.0707	0.165	0.1837	0.668	0.932
Injury severity						
<i>sidestruck* sideairbag</i>	Struck side * fitted	-0.1133	0.254	0.199	0.655	0.893

Table 3 shows the parameter coefficients for the covariate models where combination side airbags are analysed separately to torso-only side airbags.

Table 3: Parameters added to the injury risk and injury severity covariate models used to isolate the effect of combination side airbags and torso-only side airbags on secondary safety

Parameter name	Categories	β_{sa}	s.e.	Wald Chi sq.	<i>sig.</i>	Odds Ratio
Injury risk						
<i>sidestruck*sideairbag</i>	Struck side * combination	0.1645	0.2121	0.6014	0.438	1.179
<i>sidestruck*sideairbag</i>	Struck side * torso-only	-0.2951	0.2065	2.0408	0.153	0.744
Injury severity						
<i>sidestruck*sideairbag</i>	Struck side * combination	-0.0682	0.3579	0.0363	0.849	0.934

sidestruck*sideairbag	Stuck side * torso-only	-0.2437	0.3157	0.5962	0.440	0.784
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In all the models presented in this study, the reference categories were no side airbags for *sideairbag* and non-target crashes for *sidestruck*.

All data were analysed using the logistic regression procedure of the SAS statistical package and the coefficients of both models and their associated standard errors, were obtained by maximum likelihood estimation. The parameters presented in Table 2 were derived using a subset of the data described in Sections 2.1 and 2.2. However it was necessary to exclude cases that had missing values in one or more of the variables included in the original covariate models. For the injury risk model, vehicles from New Zealand and Victoria were excluded as data for crashes resulting in property damage only are not collected in these jurisdictions. As a result, the injury risk model was based on data from 73,194 drivers and the injury severity model was based on data from 28,210 injured drivers.

Section 3.1 showed how the coefficients of Table 2 could be used to estimate the effectiveness of all types of side airbags in reducing the risk of injury and the risk that an injured driver is seriously injured. Table 4 also shows estimates for how side airbags improve the crashworthiness of vehicles involved in struck side crashes.

Table 4: Estimated odds ratios and percent reductions in the risk of (serious) injury in struck side impacts associated with all types of side airbags

	Logit difference		Odds Ratio	Reduction (%)	95% CL	
	β_{sa}	s.e.			Lower	Upper
Injury risk	-0.0707	0.1659	0.932	6.83	-28.75	32.57
Injury severity	-0.1133	0.254	0.893	10.71	-46.92	45.74
Crashworthiness			0.864	13.61	-40.80	46.13

Tables 5 and 6 use the coefficients from Table 3 to estimate these reductions and their confidence intervals for vehicles fitted with combination airbags and vehicles fitted with torso-only airbags respectively. In each case, the vehicles fitted with combination (or torso-only) side airbags are compared against vehicles without any form of airbag.

Table 5: Estimated odds ratios and percent reductions in the risk of (serious) injury in struck side impacts associated with combination side airbags

	Logit difference		Odds Ratio	Reduction (%)	95% CL	
	β_{sa}	s.e.			Lower	Upper
Injury risk	0.165	0.212	1.179	-17.88	-78.64	22.21
Injury severity	-0.068	0.358	0.934	6.59	-88.38	53.68
Crashworthiness			1.07	-6.71	-109.92	43.76

NB: Negative reductions indicate an estimated increase in injury risk or severity

Table 6: Estimated odds ratios and percent reductions in the risk of (serious) injury n struck side impacts associated with torso-only side airbags

	Logit difference		Odds Ratio	Reduction (%)	95% CL	
	β_{sa}	s.e.			Lower	Upper
Injury risk	-0.2951	0.2065	0.744	25.55	-11.59	50.33
Injury severity	-0.2437	0.3157	0.784	21.63	-45.51	57.79
Crashworthiness			0.65	34.90	-21.13	64.32

4.2 INJURY OUTCOMES USING HIGHER RESOLUTION INJURY INFORMATION BY BODY REGION

Change in injury outcomes associated with side airbag fitment from the models that used higher resolution injury information by body region are shown in Tables 7-10 below. Table 7 shows injury outcomes for *all* body regions. The results differ from those presented in Section 4.1 as the first analysis used non-body region specific definitions of injury derived from Police reported data whereas results presented in this section are based on the presence of injury by body region as identified using ICD injury codes.

It can be seen from Table 7 that for injury overall, the fitment of side airbags is associated with a statistically significant estimated reduction in the odds of death and injury of 28.1%. Disaggregation of airbag type into combination and torso-only showed a statistically significant reduction of 51.1% associated with combination airbags for all body regions with torso-only airbags associated with a slight increase in the odds of death and injury however this result was not statistically significant.

Table 7: Estimated reduction in the odds of death and injury for all body regions associated with side airbag fitment and type

Category	β_{sa}	s.e.	Odds Ratio	Reduction (%)	95% CL		sig.
					Lower	Upper	
Fitted	-0.330	0.1388	0.719	28.1	5.6	45.2	0.018
Combination	-0.716	0.2214	0.489	51.1	24.6	68.3	0.001
Torso-only	0.002	0.1772	1.002	-0.2	-41.8	29.2	0.989

Table 8 shows key injury outcomes for the head, face, neck and thorax being the body regions that side airbags are designed to protect. These models included a severity adjustment as described in Section 3.2 with *sevad_j* coded 1 if an injury occurred in the complementary body regions of abdomen, spine, upper extremity, lower extremity & external, or 0 otherwise. For the head, face, neck and thorax, the fitment of side airbags is associated with a statistically significant estimated reduction in the odds of death and injury of 33.1%. Disaggregation of airbag type into combination and torso-only showed a statistically significant reduction of 60.5% associated with combination airbags for the head, face, neck and thorax with torso-only airbags associated with a slight increase in the odds of death and injury however this result was not statistically significant.

Table 8: Estimated reduction in the odds of death and head, face, neck & thorax injury associated with side airbag fitment and type

Category	β_{sa}	s.e.	Odds Ratio	Reduction (%)	95% CL		sig.
					Lower	Upper	
Fitted	-0.402	0.1905	0.669	33.1	2.8	53.9	0.035
Combination	-0.928	0.3125	0.395	60.5	27.1	78.6	0.003
Torso-only	0.001	0.2388	1.001	-0.1	-59.8	37.3	0.996

Table 9 shows injury outcomes for the head, face and neck body regions only. These models included a severity adjustment with *sevad* coded 1 if an injury occurred in the complementary body regions of thorax, abdomen, spine, upper extremity, lower extremity & external, or 0 otherwise. For the head, face and neck, the fitment of combination airbags is associated with a statistically significant estimated reduction in the odds of death and injury of 53.4%. Only results for combination airbags are shown as torso-only airbags do not relate to the body regions included in the model and inferences regarding their effectiveness in reducing head, face and neck injury should not be drawn.

Table 9: Estimated reduction in the odds of death and head, face & neck injury associated with combination side airbags

Category	β_{sa}	s.e.	Odds Ratio	Reduction (%)	95% CL		sig.
					Lower	Upper	
Combination	-0.764	0.3585	0.466	53.4	5.9	76.9	0.033

Table 10 shows injury outcomes for the thorax being the body region that torso-only airbags are most likely to protect. These models included a severity adjustment with *sevad* coded 1 if an injury occurred in the complementary body regions of head, face, neck, abdomen, spine, upper extremity, lower extremity & external, or 0 otherwise. For the thorax, the fitment of torso-only airbags is associated with an increase in the odds of death and thorax injury of 17.4% however this result was not statistically significant. Only results for torso-only airbags have been shown as the purpose of the model was to examine any association between thorax injury and the presence of torso-only airbags.

Table 10: Estimated reduction in the odds of death and thorax injury associated with torso-only airbags

Category	β_{sa}	s.e.	Odds Ratio	Reduction (%)	95% CL		sig.
					Lower	Upper	
Torso-only	0.160	0.3288	1.174	-17.4	-123.5	38.4	0.626

5.0 DISCUSSION

The objective of the first analysis undertaken was to estimate the effects of vehicle side airbag systems on overall risk and severity of injury to drivers in struck-side impacts. Due to limitations of the data, the first analysis was not specific to injuries to any particular body region but focused on average risk and severity of injury across all body regions. Despite the relatively large quantities of data available for the analysis of police reported

crash data across Australia and New Zealand, the results of the analysis were generally inconclusive. Analysis of the average effectiveness of all side airbag types estimated reductions of driver injury risk and severity in a struck-side impact of around 7% and 11% respectively giving an improvement in crashworthiness (i.e. overall risk of death and serious injury in a crash) of around 14%. However, none of these estimates were even close to being statistically significant, meaning these estimates could have been obtained by chance variation in the data with no real underlying effectiveness of the technology. Lack of statistical significance was also found for the estimates of overall side airbag injury effects by type of side airbag system. This does not mean that the analysis of police crash reports has found side airbag systems to be ineffective in reducing overall injury risk and severity, but rather that there was insufficient data to draw robust conclusions from the analysis.

Although statistically significant results were not found, results from the first analysis could be interpreted as being generally consistent with earlier work that also used overall definitions of injury derived from Police crash data. In comparing previous side airbag evaluations it is noted that less than one percent of the sample of injured drivers used in the first analysis were killed. Many of the previous evaluations of side airbags have demonstrated significant reductions in terms of fatality risk (Braver and Kyrychenko 2004; Insurance Institute for Highway Safety 2006). However there have been few that have estimated effectiveness in terms of the risk of non-fatal injuries. A conclusion that side airbags do not reduce the risk of non-fatal injuries in struck side impacts is in line with the results of McGwin et al. (2003), also based on injury information from Police reported crashes, who demonstrated the risk of injury in a near side (struck side) crash was similar for front seat occupants with side airbags as front seat occupants without side airbags. They concluded that future research was necessary to determine the effectiveness of side airbags in preventing the injuries for which they were specifically designed.

In contrast to the first analysis, the second analysis did assess the effectiveness of airbags in reducing injury based on the body regions that they were designed to protect, namely the head, neck, face and thorax. The analysis, which used Police reported crash data linked to higher resolution injury information in the form of ICD codes, did find clear statistical evidence that side airbags were effective in reducing death and injury in struck side crashes. In particular, key outcomes being those relating to the head, neck, face and thorax (Table 8) showed that the overall fitment of side airbags, representing an average effect across both combination and torso-only airbags, was associated with a statistically significant estimated reduction in the odds of death and injury of 33.1%. However perhaps of greater interest, disaggregation of airbag type into combination and torso-only airbags showed that combination airbags, which specifically protect the body regions considered by the model, are associated with a statistically significant reduction in the odds of death or injury of 60.5%. With regards to torso-only airbags alone, there was an indication that they are associated with an increase in the odds of death and injury however this result was not statistically significant.

Similar results were also found for the estimation of the odds of death and injury based on all body regions (Table 7), however as expected these results were not as pronounced. In a broad sense, it might be expected that as these models included all body regions, outcomes similar to those produced in the first analysis could be expected. However what the comparison of the analyses actually demonstrates is that the injury outcomes utilised for the first analysis, i.e. injury derived from Police crash reports alone, are clearly inadequate for the determination of side airbag effectiveness. In particular, ambiguity in the definition

of injury versus serious injury (requiring hospitalisation) often occurs in Police reported crash data and this would have a direct impact on the outcomes produced from the models utilised in the first analysis. It was earlier noted that less than one percent of the sample of injured drivers used were killed, so it was critical for the first analysis that injury and serious injury were reported correctly. This is especially the case as whilst side airbags may prevent injuries that have a high risk of death, they do not necessarily reduce the risk of less harmful injuries that still result in hospitalisation. A clear advantage in the use of higher resolution injury information for the second analysis was that the use of ICD codes to identify the presence of injury provided consistent, and importantly validated, measures of injury enabling clearer outcomes to be achieved. In addition, identification of injury by body region meant that more specific models directly related to the body regions side airbags were designed to protect were able to be formed. As a consequence, the second analysis, through the use of linked data, was able to offer much more informative outcomes than models based on Police crash data alone.

Results examining the effectiveness of combination airbags in reducing injuries to the head, face and neck but not including the thorax are presented in Table 9. As expected, associated reductions in the odds of death and injury for combination airbags were not as pronounced as the model that included the thorax, however were greater than the model that considered all body regions. These results reflect the difference in the body regions included in each analysis compared to the body regions that combination airbags are designed to protect.

Finally, results from the disaggregated models shown in Table 7 and 8 suggested that torso-only airbags were associated with a slight increase in the odds of death and injury however these results were not statistically significant. Considering the differences in the body regions included in each model and the area thorax bags are designed to protect, it followed that a further examination of the effectiveness of torso-only airbags based on the thorax body region alone should be performed. As shown in Table 10, the fitment of torso-only airbags was found to be associated with an increase in the odds of death and thorax injury of 17.4% however this result was not statistically significant. However the results are consistent with findings from previous research that torso-only airbags confer lesser benefits to drivers in struck side crashes (Braver and Kyrchenko, 2004). It would be worthwhile conducting further research examining these results more closely including the types of injury that occur in the torso region. This could lead to a better understanding of how torso-only airbags interact with the vehicle occupant and improvements in torso-only airbag design to minimise thorax injury.

Like previous studies, this study encountered the difficulty that it was not possible to reliably identify in the data whether a large number of crashes vehicles had side airbags fitted. This meant that a considerable amount of crash data was excluded from the analyses which not only reduced the power of the analyses but limited to some degree the extent to which the results of effectiveness can be generalised across all vehicle models. One of the primary reasons for excluding vehicles due to unknown airbag fitment status was due to the side airbag system being an optional fitment. It is generally the case that the VIN used to identify vehicle model does not contain sufficient information to identify airbag fitment status or even vehicle trim level. Only those vehicles using the standard for VINs specified in the USA had information on restraint fitment, including airbags, which is mandated in the US Federal vehicle standards. Given that this study identified 199 different vehicle models either with or without side airbag systems fitted, the results of the study are reasonably likely to be able to be generalised to other populations. However, the effects

estimated in this study do represent an average across those vehicle models studied. Given it is likely that side airbag effectiveness will not be heterogeneous across all vehicle types, it is possible that reproducing this study on a different population of vehicles would yield different estimates of average effectiveness. Nonetheless, the strength of the injury reduction effects from the specific body region analyses suggests the introduction of side airbags into any population of vehicles would yield significant injury reduction benefits.

From a policy perspective, the results indicate that combination thorax and head protecting side airbag systems in vehicles are a highly effective technology for reducing the risk and severity of injuries to vehicle occupants in struck-side crashes. The magnitude of the injury reduction benefits estimated indicate that fitment of this technology to all vehicles should be a high priority and will yield significant savings in overall road trauma. The benefits of thorax only side airbag systems are more questionable and hence this configuration should not be encourage, particularly given the demonstrated additional benefits of including head protection.

6.0 SUMMARY

- The use of injury outcomes from Police crash data alone was found to be inadequate for undertaking a robust evaluation of side airbag effectiveness in Australasia at this point in time.
- Police reported crash data linked to higher resolution and validated injury data by body region produced much more stable analyses and more informative outcomes.
- *Combination airbags* designed to protect the head, neck, face and thorax are highly effective in reducing injury due to side struck crashes. Combination airbags were associated with statistically significant reductions of:
 - 51% in the odds of death and injury to all body regions (with a 95% confidence interval of 25% to 68%);
 - 61% in the odds of death and injury to the head, neck, face and thorax (with a 95% confidence interval of 27% to 79%); and
 - 53% in the odds of death and injury to the head, neck and face (with a 95% confidence interval of 6% to 77%).
- *Torso-only* protecting airbags appeared less effective than combination airbags. There was:
 - no statistically significant injury effects; and
 - some indication of an increase in the odds of death and injury to the thorax region requiring further investigation.

7.0 REFERENCES

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APPENDIX A – LIST OF VEHICLES WHERE SIDE AIRBAG FITMENT TYPE WAS IDENTIFIED

Table A.1: Market group, make, model and year of manufacture of the vehicles where side airbag fitment type was successfully identified

Market Group	Model	Year of Manufacture	Combination side airbags	Torso-only side airbags
4WD - Compact	MAZDA TRIBUTE	2003-2005	43	
	MAZDA CX-7	2006-2008	150	
	MAZDA TRIBUTE 2	2006-2008		29
	NISSAN X-TRAIL	2008	1	
	HONDA CRV 01 on	2005-2006		335
	HONDA CR-V RE	2007-2008	10	18
	LANDROVER FREELANDER 2	2007-2008	6	
	SUBARU FORESTER	2000-2001		212
	SUBARU FORESTER II	2005-2008		573
	SUZUKI GRAND VITARA JT	2008	2	
	TOYOTA RAV4 30 SERIES	2006-2008	327	
4WD - Large	AUDI Q7	2006-2008	19	
	BMW X5 E53	2000-2008	671	
	FORD EXPLORER	2000-2001		3
	FORD EXPLORER 2	2000-2001		17
	MAZDA CX-9	2007-2008	22	
	MERCEDES M-CLASS W163	1999-2000		245
	MERCEDES M-CLASS W164	2001-2008	110	
	MERCEDES R-CLASS W251	2006-2007	7	
	PORSCHE CAYENNE	2003-2008	44	
	RANGE ROVER 95 on	1999-2002		66
	RANGE ROVER 02-05	2002-2006	81	
	RANGE ROVER III	2005-2008	47	

	TOYOTA LANDCRUISER 200 SER	2007-2008	41	
	VOLKSWAGEN TOUAREG 03-05	2003-2008	106	
4WD - Medium	HOLDEN ADVENTRA	2002-2007		173
	HYUNDAI SANTA FE	2004-2006		45
	HYUNDAI SANTA FE CM	2007-2008	4	
	NISSAN MURANO	2004-2008	168	
	HONDA MDX	2003-2004		74
	SUBARU TRIBECA	2006-2008	30	
	TOYOTA KLUGER	2008	3	
	TOYOTA PRADO 120 SERIES	2003-2005	411	
	LEXUS RX330	2002-2006	281	
	LEXUS RX350/400h	2006	9	
	TOYOTA KLUGER	2007-2008	91	
	VOLVO XC90	2002-2007	168	
Commercial - Ute	FORD RANGER	2007-2008		3
	HOLDEN COMMODORE VY/VZ UTE	2003-2008		444
Large	ALFA 166	1999-2002		39
	AUDI A5/S5	2007-2008	2	
	AUDI A8 SERIES 2	2003-2006	8	
	BMW 6 SERIES E63	2004-2005		4
	BMW 7 95-01	1999-2001	20	
	BMW 7 02 on	2002-2007	85	
	SSANGYONG CHAIRMAN	1999-2006		3
	FAIRLANE & LTD BA 03 on	2003-2006		190
	HOLDEN COMMODORE VT/VX	2000-2002		3728
	HOLDEN STATESMAN/CAPRICE WH	1999-2005		1906
	HOLDEN COMMODORE VY/VZ	1999-2008		6206
	HOLDEN MONARO	1999-2006		1145

HOLDEN STATESMAN/CAPRICE WK/WL	2001-2006		272
HOLDEN COMMODORE VE	2000-2008	328	
HOLDEN STATESMAN/CAPRICE WM	2006-2008	60	
HYUNDAI GRANDEUR TG	2005-2007	19	
MITSUBISHI MAGNA VERADA TE-TJ/KE-KJ	2005		1
MITSUBISHI MAGNA/VERADA TL/TW/KL/KW	2003-2005		2101
MITSUBISHI 380	2002-2008		698
JAGUAR XJ8 98-03	2003		1
JAGUAR XK8	2003		1
JAGUAR S-TYPE	1999-2002		148
JAGUAR XJ X350	2003-2004	4	
JAGUAR XK	2006-2007		3
MERCEDES S-CLASS W220	1999-2005	199	
MERCEDES CL500/600 W215	2001		6
MERCEDES S-CLASS R230	2002-2005	26	
MERCEDES SLK W171	2004-2006	52	
MERCEDES CLS W219	2005-2008	24	
MERCEDES S-CLASS W221	2004-2008	17	
MERCEDES CL W216	2007	1	
HONDA LEGEND 99-04	1999-2002		79
HONDA LEGEND KB	2006	1	
PEUGEOT 607	2001-2003	14	
SAAB 9-5 II 06 on	2000-2006	48	
LEXUS ES300	1999-2001		81
LEXUS LS400	1999		11
LEXUS LS430	2000-2006	57	
LEXUS ES300 II	2001-2005		121
LEXUS SC430	2001-2006		29
LEXUS GS 190 SERIES	2005-2007	45	

	TOYOTA AURION	1999-2008	547	
	LEXUS LS460	2007	4	
	VOLVO 850/S70/V70/C70	1999-2007	69	
	VOLVO S80	2000-2005	71	
	VOLVO S80 A	2007	3	
	VOLVO V70 / XC70 00-07	2000-2007	66	
	VOLVO V70 / XC70	2008	1	
Medium	ALFA 156	2001		76
	ALFA 147	2001-2008	297	
	ALFA 159 / BRERA	2005-2008	29	
	AUDI TT 8J	2007-2008		5
	AUDI A6/S6 95-04	2001-2004	16	
	AUDI A6/S6 05 on	2005-2008	22	
	AUDI A4	1999		135
	AUDI TT	1999-2007		163
	BMW Z3	1999-2002		52
	BMW Z4	2003-2008		66
	BMW 5 SERIES E60/61	2001-2008	211	
	BMW 3 SERIES E90/91/92	1999-2008	448	
	BMW 3 99-06	1999-2006	3911	
	BMW 5 96-03	1999-2003	429	
	CHRYSLER PT CRUISER	2000-2008		285
	CHRYSLER CROSSFIRE	2003-2007		22
	CHRYSLER SEBRING	2007-2008	7	1
	CITROEN C5	2001-2007	113	
	FORD MONDEO	2000		37
	FORD COUGAR	1999-2008		600
	HOLDEN EPICA	2007		10
	HYUNDAI ELANTRA XD	2005-2006		338

HYUNDAI TIBURON	2000-2007		115
HYUNDAI SONATA NF	2005-2008	178	
JAGUAR X-TYPE	2001-2008	167	
KIA MAGENTIS	2006-2007	19	
MAZDA 6	2004-2008	1462	
MAZDA RX8	2003-2008	273	
MERCEDES C-CLASS W202	1999-2000		193
MERCEDES CLK W208	1999-2005		259
MERCEDES E-CLASS W210	1999-2006	242	
MERCEDES SLK W170	1999-2004		107
MERCEDES C-CLASS W203	1999-2007	1315	
MERCEDES CLK C209	1999-2001		4
MERCEDES E-CLASS W211	2001-2008	379	
MERCEDES C-CLASS W204	1999-2008	41	
NISSAN 350Z	2003-2007		45
HONDA ACCORD EURO	2003-2007	908	
HONDA ACCORD US	2004-2007		386
HONDA ACCORD EURO 08 on	2008	3	
PEUGEOT 407	2004-2008	83	
PEUGEOT 406	2000-2003	22	
PORSCHE BOXTER 986	2001		1
PORSCHE BOXTER 987	2005	1	
PO5 Z	2000-2002		5
RENAULT GRAND SCENIC	2006-2007	5	
RENAULT LAGUNA 02-08	2002-2006	60	
ROVER MG ZT	2002-2005	24	
ROVER 75	2000-2005	131	
SAAB 900/ 9-3 94-02	1999-2003		447
SAAB 9-5 98-05	1999-2001		181

	SAAB 9-3 II 03 on	2001-2008	144	
	SUBARU LIBERTY 99-03	2000-2003	6	144
	SUBARU LIBERTY 03 on	2004-2008	551	
	LEXUS IS200	1999-2005		514
	LEXUS IS250 / IS F	1999-2008	172	
	VOLVO S60	2000		3
	VOLVO C30	2007-2008	5	
	VOLKSWAGEN PASSAT 98-05	2001		80
	VOLKSWAGN PASSAT 3C	2006-2008	85	
	VOLKSWAGN EOS	2007-2008	22	
	SKODA OCTAVIA	2007-2008	4	
People Mover	CHRYSLER GRAND VOYAGER	2002-2004		41
	MITSUBISHI GRANDIS	2004-2008	67	
	MAZDA MPV 00 on	2004-2006		38
	HONDA ODYSSEY 2004 on	2004-2008	245	130
	TOYOTA TARAGO 2000 on	2004-2005		6
Small	AUDI CABRIOLET	2001	2	
	AUDI A3 GEN2	2004-2008	79	
	AUDI A4 B6	1999		46
	MINI	2002-2006	264	
	BMW 1 SERIES E87	2003-2008	189	
	CITROEN C4	2005-2008	93	
	CITROEN XSARA	2001-2005		11
	FORD FOCUS LR	2003-2004		16
	FORD FOCUS LS / LT	2006-2008	83	
	HOLDEN ASTRA AH	2006-2008		30
	HOLDEN VIVA JF	2002-2008		732
	HOLDEN TIGRA	2005-2007		43
	HYUNDAI i30	2008	4	

	MAZDA 3	2006-2008	376	
	MAZDA MX5 02 on	2005-2008		71
	MERCEDES A-CLASS W168	1999-2000		203
	MERCEDES A-CLASS W169	2000-2008	46	
	MERCEDES B-CLASS W245	2005-2008	45	
	HONDA CIVIC GEN 7 00-05	2004-2005		21
	HONDA CIVIC GEN 8	2006-2008	107	70
	HONDA INTEGRA 01 on	2004-2006		102
	PEUGEOT 306	2000-2002		63
	PEUGEOT 307	2001-2007	687	
	PROTON WAJA	1999-2004		31
	RENAULT MEGANE CABRIOLET	2001-2005		81
	RENAULT MEGANE II	2003		1
	RENAULT MEGANE II CABRIOLET	2004-2007		31
	RENAULT SCENIC II	2004-2005	12	
	RENAULT SCENIC	1999-2004	339	
	SUBARU IMPREZA 2001-2007	2001-2007	970	
	SUBARU IMPREZA 2008 on	2008	26	
	TOYOTA COROLLA 120 SERIES	2007	19	
	TOYOTA COROLLA 150 SERIES	2007-2008	87	
	VOLVO S40/V50	2004-2008	107	
	VOLVO V40/S40	1999-2006	170	
	VOLKSWAGEN GOLF 5	2004-2008	1051	
Light	CITROEN C3 PLURIEL	2004-2006		13
	CITROEN C2	2004-2006		19
	CITROEN C3	2002-2008		141
	FIAT PUNTO	2006-2008	26	
	HONDA JAZZ GE	2008	4	
	PEUGEOT 207	2007-2008	25	9

PEUGEOT 206	1999-2007		424
RENAULT CLIO	2001-2005		269
SUZUKI SWIFT RS415	2006-2008	48	