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PRELIMINARY EVALUATION OF ELECTRONIC STABILITY CONTROL EFFECTIVENESS IN AUSTRALASIA

by

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Abstract:

Electronic Stability Control (ESC) is an in-vehicle technology aimed at improving primary safety by assisting the driver in avoiding loss of control of the vehicle. The aim of this study was to use available crash data from Australia and New Zealand to evaluate the effectiveness of ESC systems in reducing crash risk and to establish whether benefits estimated from overseas studies have translated to the Australian and New Zealand environments.

A methodology was developed to identify ESC equipped vehicles from Australian and New Zealand crashed vehicle fleets. This resulted in the identification of 7,699 crashed vehicles that were fitted with ESC. This sample comprised of 90 different models, making this evaluation the first to include such a broad range of models in its sample of ESC-fitted vehicles. The induced exposure methodology was used to measure the effect of ESC on crashes on Australian and New Zealand roads. Vehicles involved in rear end impacts were used as the measure of induced exposure while Poisson regression was used to test whether the differences in the observed and expected crash counts for ESC fitted vehicles were significant.

It was found that the fitment of ESC to vehicles in the Australian and New Zealand fleet was associated with a statistically significant 32% reduction in the risk of single vehicle crashes in which the driver was injured. It was also found that ESC was more effective at preventing single vehicle crashes for 4WDs than for passenger cars, with ESC reducing the risk of single vehicle crashes in which the driver was injured by 68% for 4WDs compared with 27% for passenger cars. The effect of ESC on multiple vehicle crashes in Australia and New Zealand was not clear from this preliminary analysis. The long-term benefits of fitting ESC to all vehicles in Australia were also investigated based on the estimated single vehicle crash reductions.

Key Words:

Electronic Stability Control
Vehicle Fleet
Evaluation
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Preface

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EXECUTIVE SUMMARY

Electronic Stability Control (ESC) is an in-vehicle technology aimed at improving primary safety by assisting the driver in avoiding loss of control of the vehicle. A number of overseas evaluations of the effectiveness of ESC systems in reducing crash risk have been completed, mostly in the USA or Europe. In general, these international studies have estimated very positive benefits from the technology in reducing crash risk. Based on the results of these studies and prompted by the current low fitment rate, ESC has been promoted heavily across Australia and New Zealand in a range of consumer information programs as having major potential for significantly reducing road trauma.

Previous studies have shown that the effectiveness of ESC is dependent on a number of factors including the mix of vehicles in a fleet and the road environment. These factors differ between countries. It was therefore important that estimates of the effectiveness of ESC in Australia and New Zealand were derived using on-road experience of the technology in these countries. Therefore, it is timely to complete an evaluation of ESC using Australasian crash data.

The aim of this study was to use available data to evaluate the effectiveness of ESC systems in reducing crash risk and to establish whether the benefits of this feature estimated from overseas studies has translated to the Australian and New Zealand environments. In order to fulfil this aim, a methodology was developed to identify ESC equipped vehicles from Australian and New Zealand crashed vehicle fleets. As well as providing overall measures of effectiveness, the study estimated the effectiveness of ESC in reducing crash risk for key crash types targeted by the technology. Past and projected future ESC fitment rates were also used to infer the potential future benefits of the technology.

The crash data used to assess the effectiveness of ESC were police-reported crash data from five Australian states and New Zealand which had been collected as part of the Monash University Accident Research Centre's (MUARC's) *Used Car Safety Ratings* project. The data included crashes occurring in the period 2001-2005. Vehicles belonging to some market groups were excluded because some market groups had very low ESC fitment rates. The sample of crashed vehicles was further restricted to cars manufactured more recently than 1997 because there are very few vehicles manufactured prior to 1997 that are equipped with ESC. Including such vehicles in the sample to be analysed could have resulted in a biased sample. Finally, vehicles in which the ESC status could not be determined were excluded from the sample to be analysed. This left a sample comprising of 7,699 ESC fitted vehicles and 203,186 vehicles without ESC. The sample of 7,699 vehicles fitted with ESC comprised 90 different models. This is the first evaluation of ESC to include such a broad range of models in its sample of ESC-fitted vehicles.

This evaluation of the effect of ESC on crashes on Australian and New Zealand roads used the induced exposure methodology, which has been used by researchers to evaluate ESC in international jurisdictions (e.g. Dang, 2004; Bahouth, 2005; Page & Cuny, 2006 and Lie, Tingvall, Krafft & Kullgren, 2006). This methodology uses the proportion of vehicles involved in crashes that are assumed not be influenced by ESC fitment to estimate the expected number of other types of crashes if ESC was presumed to have no effect on crash occurrence. Any deviation from the expected number of crashes can be considered to be the result of the fitment of ESC provided that the characteristics of the two samples of crashed vehicles only differ with respect to ESC fitment. In this study, vehicles involved in rear end impacts were used as the measure of induced exposure. Based on previous international evaluations of ESC, it was assumed that rear-end crashes would not be affected by ESC. Poisson regression was used to test whether the differences in the observed and expected crash counts for ESC fitted vehicles were significant. A technique demonstrated by Bruhning & Ernst (1985) allows the effect of ESC on different types of crashes to be analysed separately. It also enabled treatment and control pairs to be matched to each other based on shared characteristics that would otherwise confound the estimate of effectiveness. In the present analysis, year of manufacture and vehicle type were controlled for. The likely influences of other potential confounders are also discussed.

Estimates of effectiveness in preventing all types of crashes are given along with separate estimates of effectiveness in preventing single vehicle and multi-vehicle crashes. These measures of effectiveness are given for both police reported crashes of all severities as well as police reported crashes in which the driver of the vehicle is injured. Each measure of effectiveness is also given for passenger cars and 4WDs separately.

The evaluation shows that the fitment of ESC to vehicles in the Australian and New Zealand fleet resulted in a significant 32% reduction in the risk of single vehicle crashes in which the driver was injured.. It was also found that ESC was more effective at preventing single vehicle crashes for 4WDs than for passenger cars, with ESC reducing the risk of single vehicle crashes in which the driver was injured by 68% for 4WDs compared with 27% for passenger cars. All these results are in line with results from international studies. However, the effect of ESC on multiple vehicle crashes in Australia and New Zealand was not clear from this preliminary analysis.

Using various assumptions about future overall crash rates, vehicle exposure and future market penetration of ESC, the effectiveness of ESC in preventing single vehicle crashes involving passenger cars and 4WDs were used to predict that ESC would prevent nearly 500 serious injury crashes in Australia over the period to 2015.

The study also made several suggestions of how a follow-up study of ESC could provide more accurate estimates of effectiveness and help determine whether the expected future benefits of ESC will be susceptible to a learning effect. The additional years of crash data will also enable potential confounders to be controlled as well as providing estimates of effectiveness for more specific types of crashes, such as rollovers.

PRELIMINARY EVALUATION OF ELECTRONIC STABILITY CONTROL EFFECTIVENESS IN AUSTRALASIA

1 INTRODUCTION

1.1 BACKGROUND

Electronic Stability Control (ESC) is an in-vehicle technology aimed at improving primary safety by assisting the driver in avoiding loss of control of the vehicle. Known by a raft of different names, including Electronic Stability Program, Active Handling System and Vehicle Dynamics Control to name a few, the technology is essentially an extension of the technology used in anti-lock braking and traction control systems and as such effectively incorporates the functions of both these systems whilst adding others. As described in the Swedish evaluation of the technology Lie, Tingvall, Krafft & Kullgren (2004), ESC identifies loss of control of the vehicle when one or more wheel is moving faster or slower than calculated from the steering input and turning angle of the vehicle and rectifies this by applying braking to one or more wheel and reducing engine power where necessary. By doing so, ESC is able to correct over or understeer situations in the vehicle hence reducing crashes caused by loss of vehicle control. Crash types of particular relevance to the technology include run off road and rollover crashes and particularly those where the road surface is poor, wet or icy.

ESC was first introduced in mass produced cars around 1998. Whilst uptake of the feature has been swift in some European countries, in Australia and New Zealand the penetration of the technology into the new vehicle market has been slow. At the end of 2005, only around 10% of new vehicles in Australia were fitted with ESC. This is projected to have risen to between 30% and 40% by the end of 2007 suggesting majority coverage of the new light vehicle market is many years away. As shown in Appendix B, ESC fitment rate also varies significantly by market group with the feature being much more prevalent on larger and more expensive vehicles, where fitment rate is over 60% for some vehicle classes by mid 2007, than it is on smaller and cheaper vehicles where fitment rate could be as low as 2% or less.

A number of overseas evaluations of the effectiveness of ESC systems in reducing crash risk have been completed, mostly in the USA or Europe. Whilst these will be discussed in more detail later, generally they have estimated very positive benefits from the technology in reducing crash risk. Reductions in crash risks of around 20% for all crashes and 40% for single vehicle crashes have been estimated. Estimates of single vehicle crash reductions of over 60% for 4WDs have been made. Based on the results of these studies and prompted by the current low fitment rate, ESC has been promoted heavily across Australia and New Zealand in a range of consumer information programs as having major potential for significantly reducing road trauma.

1.2 BRIEF LITERATURE REVIEW

A number of studies have been published in the international literature which evaluate or attempt to otherwise quantify the effectiveness of ESC systems in reducing crash rates. These studies fall into two distinct categories: prospective and retrospective studies.

1.2.1 Prospective Studies of ESC Effectiveness

Prospective studies of ESC effectiveness aim to estimate the likely effectiveness of the technology based on the observed profile of different crash types in the real world and their causal characteristics in conjunction with the known operational characteristics of the technology. The methodology requires knowledge of how the technology operates and in what situations it is likely to activate and furthermore result in a beneficial outcome. To be used to assess a technology such as ESC, this methodology also requires a data source that provides sufficient detail on the circumstances leading up to the crash as well as the road environment at the crash location and ideally, the steering and braking inputs of the driver during the pre-crash phase. If this information is available, the methodology enables estimation of the proportion of crashes that would be avoided, or that would occur but with less serious outcomes, if ESC were fitted to vehicles.

Sferco, Page, Le Coz & Fay (2001) is an example of an evaluation of the effectiveness of ESC that employed a prospective methodology. This study made use of the European Accident Causation Survey (EACS), which contains in-depth data on more than 1,600 crashes occurring on European roads. The purpose of EACS is to provide better knowledge of the causes of crashes, which would allow greater opportunity to investigate active safety solutions such as ESC. Sferco, Page et al. (2001) identified the proportion of the in-depth crashes in the EACS dataset for which it was judged that the presence of ESC would have influence the outcome of the crash. Experts in crash reconstruction that were familiar with the ESC technology were asked to give their opinion on the likely influence of ESC on the outcomes of each of the loss-of-control crashes in the dataset.

A similar methodology was employed by Langwieder, Gwehenberger, Hummel & Bende (2003), who used three independent sources of crash data to identify what proportion of crashes ESC would have had a positive influence over if it were fitted. Three different data sources were used because no single database contained all the data necessary to complete the evaluation of ESC. This typifies one of the problems of prospective methodologies – few in-depth databases are able to provide the rich data from the pre-crash phase that the method requires. Knowledge of the way ESC works to stabilize vehicles in certain situations was used to identify critical crash types for which ESC is likely to assist the driver in maintaining control over their vehicle. These critical situations included crashes involving skidding and more specifically crashes on curved sections of road and crashes in which the driver attempted more than one steering correction during the pre-crash phase. Reviewing each data source, and making assumptions about driver behaviour to redress the limitations of the data, Langwieder, Gwenberger et al. (2003) were able to estimate what proportion of crashes ESC would have had a positive influence on.

The prospective methodology described by both Langwieder, Gwenberger et al. (2003) and Sferco, Page et al. (2001) has several limitations, each of which is acknowledged in the latter study. Firstly, the methodology relies on the accurate reconstruction of each crash as well as the accurate assessment of the likely effect of ESC by experts. Effectively employing a prospective methodology such as that used by Sferco, Page et al. (2001) is reliant on the quality of the in-depth crash data. For most in-depth crash databases, each case is investigated by one of a number of crash investigators. Differences in the way the crash investigators collect data can affect the way the data are later interpreted. When separate databases are merged to form a larger sample of in-depth data, as was the case with the EACS dataset used by Sferco, Page et al. (2001), the affect of the subjective nature of data collection is compounded.

As well as relying on the subjective interpretation of the crash and the hypothetical effect of ESC, Sferco, Page et al. (2001) concede that the methodology does not account for the effect of risk compensation, which involves crash risk increasing when the driver of a vehicle is aware their vehicle is equipped with a certain safety feature because they drive the car more aggressively. With this limitation in mind, Sferco, Page et al. (2001) suggest that their estimates of effectiveness, which are summarised in Table 1, be considered upper bounds of the true measures of effectiveness.

The methodology also assumes that the sample of in-depth crash data is representative of the wider crash population. If the in-depth sample is biased, each crash type must be weighted accordingly.

Another weakness of the methodology is that it does not provide a reliable means of estimating the effect of ESC on occupant injury risk. For example, from Table 1 it can be seen that Sferco, Page et al. (2001) used the opinions of experts to estimate that 42% of loss-of-control injury crashes would have been influenced by ESC. However, the methodology does not enable quantification of the degree that the crash outcomes would have been affected if ESC were fitted. The fact that Sferco, Page et al. (2001) were able to estimate that ESC fitment would have a positive influence on 67% of fatal out-of-control crashes does not mean that ESC fitment would prevent 67% fatalities caused by loss-of control crashes. In fact it is not possible to estimate the number of fatalities prevented if the degree of the influence of ESC in each crash is unknown. For each loss-of-control case, the experts that were surveyed by Sferco, Page et al. (2001) did have the option to indicate that ESC fitment would result in the crash definitely being avoided. However, this definitive option was rarely chosen when compared to the number of times the experts stated that ESC would be likely to have had an influence on the crash outcome. Their reluctance to choose the more definitive estimation of the effect of ESC shows the difficulty in quantifying the influence that ESC would likely have in each crash. Judging that ESC would have an influence in a particular crash is one thing, but estimating the amount that ESC would reduce the risk of occupant injury is much more difficult.

Table 1:.Summary of Published Prospective Studies of ESC Effectiveness

Jurisdiction & Author	**Target Crash Type**	**Estimated Reduction**
Europe (Sferco et al, 2001)	All Injury Crashes All Fatal Crashes Loss of Control Injury Crashes Loss of Control Fatal Crashes	18% 34% 42% 67%
Germany (Langwieder et al, 2003)	Single Vehicle Skidding Crashes All Crashes	42-60% 20-25%

1.2.2 Retrospective Studies of ESC Effectiveness

In recent years, the proportion of new vehicles that have ESC available as an optional or standard feature has increased dramatically. This is true for European and US markets as well as for the Australian market although the level of market penetration varies between jurisdictions. For example, Page & Cuny (2006) estimated that nearly 30% of newly registered cars in France came equipped with ESC, while Kreiss, Schüler & Langwider (2005) estimate that 60% of recently registered German cars were fitted with ESC. The

Institute for Highway Safety (2006) reported that ESC was standard on 40% of passenger vehicle models in the US and available as an option on another 15% at the time of the study. In Australia, vehicle sales data collected by Polk Automotive Intelligence for VicRoads suggest ESC was standard on about 25% of new cars and optional on another 12% by the end of 2006. As there are more ESC-equipped vehicles on the road, more ESC-equipped vehicles are appearing in the mass databases of crashes occurring in different jurisdictions. If the vehicles that are equipped with ESC can be identified within these databases, their crash rates or crash profiles can be compared with those of vehicles that are not equipped with ESC. This enables the effectiveness of ESC to be estimated.

One of the challenges of using mass databases of crashed vehicles to evaluate the effectiveness of ESC is identifying the cars that are definitely equipped with ESC and those that are definitely not equipped with ESC. Most mass databases do not contain sufficient detail on vehicle features to determine whether ESC was fitted. Many only contain basic body style, make, model and year of manufacture information. Some also provide the Vehicle Information Number (VIN) and the registration identifier of each crashed vehicle while other mass crash data sources can be matched to registration data to gain more detailed information on the crashed vehicle.

One method that can be employed is to identify which models of vehicles have ESC fitted as standard and then compare the crash experience of these vehicles with models that did not have the technology available as either a standard feature, an optional extra or as a standard feature on a more highly specified variant of the same model. Vehicles belonging to models with an ambiguous ESC status would be excluded from the sample to be analysed. However, this means that if vehicles manufactured in the same year are compared against each other, the sample of ESC-fitted vehicles will all be different models to the sample of vehicles not fitted with ESC. The models identified as definitely having ESC may be driven in a different manner to the non-ESC models. This is especially true if the models with ESC as standard are more expensive vehicles or are designed for different purposes than models in the non-ESC sample. This may mean that the two different samples are exposed to different traffic environments and may be driven in different ways, thus biasing measures of the effectiveness of the technology. Another disadvantage of identifying vehicles fitted with ESC based solely on make and model variables is that until recently, the range of models that offered ESC as a standard feature was very limited. Therefore, there is a danger of proscribing the influence of other features common to all or a majority of the ESC models to the influence of ESC on crash outcomes.

Studies by Aga & Okada (2003), Page & Cuny (2006) and Farmer (2004, 2006) have tried to overcome this limitation by only comparing the crash experiences of different releases of the same model. Each of these studies compared the crash experiences of vehicles manufactured prior to the date that vehicles of a particular model had ESC fitted as a standard feature with those manufactured after that date. This study design has several limitations. Firstly, the vehicles of a particular model that were manufactured after the date in which ESC was introduced as a standard feature often differ from the earlier versions of the model in more ways than just the addition of ESC. For example, Page & Cuny (2006) compared the Renault Laguna 1, which was manufactured prior to 2001 with the Laguna 2, which was launched in January 2001. The older model did not have ESC available as standard or optional equipment, while the newer model had ESC fitted as standard. However, the Laguna 2 also introduced several other primary safety improvements, such as Emergency Brake Assist and a tyre pressure monitoring system. When ESC is added to the list of standard features for many models, it is not uncommon for other primary and secondary safety features to be added as standard or optional features as well. This will bias the sample of ESC-fitted vehicles, meaning that Page & Cuny's (2006) estimate that ESC reduces crash risk by 44% (see Table 2) is most likely an overestimate.

In his evaluations of the effectiveness of ESC in preventing crashes on US roads, Farmer (2004, 2006) was able to overcome this problem by limiting the analysis to models equipped with ESC that were identical in every way to the earlier release except for the addition of ESC. Farmer could restrict the analysis sample in this manner because the US mass crash databases contain a large number of cases. However employing the same technique in jurisdictions where there are less crashes (such as Australasia) means the power of subsequent analyses will be prohibitively small. In fact, even Farmer (2004) found that restricting the sample to be analysed in this way prevented testing the hypothesis that ESC reduced serious single vehicle crashes. Similarly, although Bahouth (2005) was able to estimate the ESC would prevent 52% of single vehicles crashes, restricting the ESC-fitted sample to only six models prohibited separate estimates for crashes of different severities. Restricting the sample of ESC-fitted vehicles in this manner also means that the sample of crashed vehicles used to evaluate ESC is even less representative of the population of vehicles fitted with ESC: for example Farmer (2004) conceded that the sample used in his evaluation was biased toward higher-performance vehicles. Therefore, Farmer's (2004) estimate that ESC reduces the risk of single vehicle crashes by 41% (see Table 2) may not apply to lower priced or lower performance cars.

If the mass crash database being used to evaluate ESC contains the VIN of the crashed vehicles, some of the disadvantages discussed above can be eliminated or their effect minimised. The VIN used for many models enables differentiation between vehicles of different levels of specification. This enables vehicles of the same model and year of manufacture to be categorised as either having ESC or not having ESC when ESC is only available as a standard feature on higher specification variants of particular models. This enables the analysis sample to be increased to include models that have ESC as standard on some variants but not on others. This increases the number of different types of models that can be included in the sample of vehicles to be analysed, thus meaning the estimates of effectiveness are based on data from a more representative sample of ESC fitted vehicles. It also means that vehicles in the non-ESC sample can be more effectively matched with vehicles in the ESC sample in case-control study designs. Including the same model in the case and control sample will also reduce, but not eliminate, the bias associated with more conservative drivers choosing models of vehicles equipped with ESC.

The main disadvantage of using the VIN to classify vehicles in a mass crash database as either ESC-equipped or without ESC is that the classification process is labour intensive, requiring detailed examination of the VIN of all the models in which ESC is potentially available. However this process can be made more efficient with the cooperation of vehicle manufactures or by using databases that provide information on the specifications of vehicles by VIN. The methodology section of this report explains how this process was used in the current study.

There are several ways of analysing the crash data once vehicles in the mass database have been classified either as ESC-equipped or not having ESC. One method is to compare crash rates of the two samples using exposure data. Ideally such exposure data would be the kilometres travelled by the two samples of vehicles during the period in which the crash data was collected. However, such data are rarely available. In fact, this literature review found no study that was able to successfully employ such a study design to evaluate ESC.

An alternative measure of exposure would be to compare the number of crashes per registered vehicle for the ESC-equipped sample and the sample of vehicles without ESC. This requires the availability of a registration data source that contains adequate data to enable vehicles to be classified according to whether they do or don't have ESC. However, even if such registration data are available, the data do not necessarily represent an accurate measure of exposure. The annual distances and the way that vehicles are driven vary between types of vehicles. This is because different types of people tend to buy different types of vehicles and different types of vehicles are driven for different purposes. If one type of vehicle is being driven further each year than another type, one would expect the probability that a vehicle belonging to the former type is involved in a crash in any one year to be higher than that for a vehicle of the latter type. If there is a difference between the two types of vehicles in the proportion that are fitted with ESC, using the number of registered vehicles as a measure of exposure will lead to a biased estimate of effectiveness. This problem was overcome by Farmer (2004, 2006) who restricted the case and control samples to vehicles that are likely to be driven in the same way irrespective of ESC status. However this approach creates the problems of representativeness and reduction in statistical power that has already been discussed.

An alternative method of estimating the effectiveness of ESC (or any primary safety feature) is to use an in-direct measure of exposure. Such a method was used by Evans (1998) to assess the effectiveness of antilock braking systems. The method requires the identification of a type of crash in which it can be assumed that ESC will not be influential. Multiplying the ratio of vehicles without ESC that were involved in crashes where ESC is not relevant to types of crashes that are hypothesised to be influenced by ESC by the observed number of ESC-fitted vehicles that were involved in crashes not influenced by ESC gives the expected number of vehicles fitted with ESC that were involved in crashes hypothesised to be affected by the technology. Statistical tests can be used to determine whether the observed number of ESC-fitted vehicles involved in crashes hypothesised to be influenced by the technology is significantly different to the expected number. This method of using an in-direct measure of exposure is commonly referred to as an "induced exposure method" and has been used by many studies that have evaluated ESC in international jurisdictions. For example, Lie, Tingvall, Krafft & Kullgren (2004, 2006) used induced exposure to measure the effectiveness of ESC in Sweden, Kreiss, Schüler & Langwieder (2005) used it in Germany, Page & Cuny (2006) used it for their French study and several studies have used it to evaluate ESC in the USA (including Bahouth, 2005; Dang, 2004; Green & Woodrooffe, 2006).

When using an induced exposure methodology, it is assumed that the crash type used as a measure of exposure is not affected by ESC. If this assumption is not valid, the estimates of effectiveness will be biased. Dang (2004) used counts of crashes involving multiple vehicles as a measure of exposure to derive her estimate that ESC would reduce the risk of single vehicle impacts by 35% for cars and 37% for 4WDs. However other studies have shown that ESC fitment does affect multiple vehicle crash risk. For example, Farmer (2006) estimated that ESC reduced the risk of involvement in a multiple vehicle impact by between 25% and 37%. The result of the latter study undermines the estimates presented by Dang (2004).

Several evaluations of ESC have used multiple vehicle crashes in which the front of one vehicle impacts the rear of another (i.e. rear impact crashes) as a measure of exposure. For example Green & Woodrooffe (2006) used the assumption that ESC does not affect involvement in rear-end impact crashes to derive their estimate of a 31% reduction in the risk of being involved in a single vehicle crash on a dry road for cars fitted with ESC.

Although Table 2 shows that studies by Bahouth (2005) and Farmer (2006) have estimated that ESC affects the risk of involvement in multiple vehicle crashes, the present literature review has not found any study that has shown that ESC has an effect on multiple vehicle crashes involving rear impacts.

Table 2 shows that some of the evaluations that employ the induced exposure method provide separate estimates of effectiveness for different types of crashes (e.g. Bahouth, 2005; Green & Woodrooffe, 2006), different types of vehicles (e.g. Dang, 2004; Green & Woodrooffe, 2006), different types of road environments (Lie, Tingvall et al., 2004; 2006) and crashes of different severities (Dang, 2004; Lie, Tingvall et al., 2004; 2006). It can be seen that estimates of effectiveness vary depending on the type of crash, the type of location, the type of vehicle and the severity of the crash. For example, some studies suggest ESC is more effective in preventing single vehicles crashes than multiple vehicle crashes (Bahouth, 2005), while Lie, Tingvall et al. (2004) suggest that ESC is particularly effective in preventing crashes on wet roads. Similarly, several studies suggest that ESC is more effective at preventing single vehicle crashes involving 4WDs than single vehicle crashes involving cars (Dang, 2004; Green & Woodrooffe, 2006).

Such evaluations are possible because mass crash databases often contain information on the road environment (including the condition of the road surface) at the location of the crash, a classification of the type of crash, a description of all the vehicles involved and the severity of the crash. However, the degree of detail of such data varies between databases. These evaluations can be more useful than evaluations that only provide an estimate of the effectiveness of ESC in preventing all crashes. This is because by providing separate levels of effectiveness for different scenarios, it is possible to understand how ESC is likely to affect an existing, localised crash problem. For example, if a particular jurisdiction has an over-representation of crashes involving 4WDs, studies that give separate estimates for 4WDs are likely to be particularly useful.

Furthermore, understanding that the effectiveness of ESC is dependent on a number of factors goes some way to explaining the variation in estimates of effectiveness in studies that employ the same methodology on data from different jurisdictions. Reviewing the estimated levels of effectiveness presented in Table 2, it can be seen that most studies show that ESC provides some benefit in reducing crashes. However the degree of this benefit varies between studies. For example, the German study by Becker (2003 cited in Thomas & Frampton, 2007) estimated that ESC would reduce the risk of crashes by 45%, while Lie, Tingvall et al. (2004) estimated a reduction of only 22%. Bahouth (2005) noted that such differences in findings may be due to differences between the “study vehicle populations” (p. 32).

As different jurisdictions have different vehicle populations, different road environments and driver behaviours, the overall measures of effectiveness of ESC are likely to differ between jurisdictions. Australia and New Zealand have different driving conditions to Sweden and a different mix of vehicles to the US. It is difficult to decide whether it is more appropriate to use estimates of effectiveness from European or US studies when trying to predict the benefits of ESC fitment for the Australian fleet. Furthermore, the ESC systems available on cars sold in the Australasian market may be different or calibrated differently to those in European or US markets. This highlights why it is important that estimates of the effectiveness of ESC in a particular jurisdiction are derived using crash data from that jurisdiction. O this basis it was considered timely to complete an evaluation of ESC using Australian and New Zealand crash data.

Table 2: Summary of Published Retrospective Studies of ESC Effectiveness

Jurisdiction, Author & Year	Target Crash Type	Estimated Reduction
Germany (Becker et al, 2003)	All Crashes	45%
Germany (Kreiss et al, 2005)	All ESC Sensitive Crashes Fatal ESC Sensitive Crashes	32.4% 55.5%
Japan (Aga & Okada, 2003)	Single Car Crashes Severe Single Car Crashes Head-On Crashes Severe Head-On Crashes	35% 50% 30% 40%
USA (Dang, 2004)	Single Vehicle Car Crashes Single Vehicle SUV Crashes Fatal Single Vehicle - Car Fatal Single Vehicle – SUV	35% 67% 30% 63%
France (Page & Cuny, 2006)	All Crashes	44% (not sig)
USA (Bahouth, 2005)	Multi Vehicle Frontal Crashes Single Vehicle Crashes	11.2% 52.6%
USA (Green & Woodrooffe, 2006)	Single car crashes (dry road) Single SUV Crashes (dry road) Rollover car crashes (dry road) Rollover SUV crashes (dry road) Run off road car Run off road SUV (middle aged car drivers & older SUV drivers benefited most)	30.5% 49.5% 39.7% 72.9% 54.5% 70.3%
Sweden (Lie et al, 2004)	All Crashes All crashes - wet road All crashes - snow & ice on road	22.1% 31.5% 38.2%
Sweden (Lie et al, 2006)	All injury crashes (not rear end) All serious and fatal crashes Fatal + Serious loss of control – wet road Fatal + Serious loss of control – ice or snow	16.7% 21.6% 56.2% 49.2%
USA (Farmer, 2004)	All single vehicle crashes Single vehicle fatal crashes	41% 56%
USA (Farmer, 2006)	All single vehicle – SUV All single vehicle – cars Fatal single vehicle – SUV Fatal single vehicle – car Multiple vehicle – SUV Multi vehicle – car	49% 33% 59% 53% 32%-37% 25%

1.3 STUDY AIMS

Overseas studies have clearly established the benefits of ESC systems in reducing crash risk, particularly for run off road and rollover crashes. However, any estimation of the effectiveness of vehicle related features will to a certain extent reflect the types of vehicles in the fleet and the general road and driving conditions to which they are exposed. Australia and New Zealand differ from Europe and the USA on these key measures in a number of important ways.

This study aimed to evaluate, as far as possible given the data available, the effectiveness of ESC systems in reducing crash risk and to establish whether the benefits of this feature estimated from overseas studies has translated to the Australian and New Zealand environments. In doing so, the study aimed to:

- Establish appropriate methodology for identifying ESC equipped vehicles in the Australian and New Zealand crashed vehicle fleets

- Examine the proportion of ESC equipped vehicles represented in the crash data

- Estimate the effectiveness of ESC in reducing crash risk in Australia and New Zealand both overall and for key crash types targeted by the technology

- Establish past and projected future ESC fitment rates and from these infer the potential future benefits of the technology.

2 DATA

The crash data used to assess the effectiveness of Electronic Stability Control were police-reported crash data from five Australian states and NZ which had been collected as part of the Monash University Accident Research Centre's (MUARC's) *Used Car Safety Ratings* project. Cameron, Mach & Neiger (1992) were the first to use police-reported crash data from NSW and Victoria to assess the crashworthiness of vehicles in the Australian fleet. Since then, MUARC have increased the number jurisdictions from where it sources police-reported crash data. The most recent crashworthiness report (Newstead, Watson & Cameron, 2006) used police-reported crash data from four Victorian states (Victoria, NSW, Queensland and Western Australia) as well as New Zealand. Data from each jurisdiction contain information on the Vehicle Identification Number (VIN) of crash-involved vehicles. This enables the make and model of each vehicle to be determined, allowing for the crashworthiness of different models to be estimated. For a detailed description of how vehicles in each police-reported crash database was classified according to make, model and year of manufacture, the reader is referred to Newstead, Watson & Cameron (2006). Most recently crash data from South Australia have been added to the pool of data available. The combined data on crashes occurring in each jurisdiction during the period 1987-2005 has been used in the present evaluation of ESC.

This study used police-reported crash data from the Used Car Safety Ratings project to assess the safety benefits of ESC because these crash data allow identification of different models of vehicles and, for many vehicles in the dataset, provide record of the VIN. These two pieces of information, along with the record of each vehicle's year of manufacture provide a means of determining whether each vehicle was fitted with Electronic Stability Control. Since ESC was first added to a passenger vehicle in 1995, only police-reported crash data from 1995-2005 were used in the present analysis.

Aggregating the crash data from NZ and the five Australian states resulted in 1,270,773 records of vehicles involved in crashes occurring during the period 1995-2005. However, the sample of crashed vehicles used to assess the safety benefits of ESC was further reduced by omitting cases in which the model of the vehicle could not be accurately determined.

The Used Car Safety Ratings project relies on a computer program that was initially developed by the NRMA that used the VIN and chassis number to identify the make, model and year of manufacture of each vehicle in a dataset. Pappas (1993) provides details of the VIN decoding process used in the initial computer program. Since 1993, MUARC has continued to update and improve the original program, so that when the program was recently applied to NSW crash data, the model could be identified for all but 4% of passenger vehicles manufactured from 1982 to 2004 (Newstead, Watson & Cameron, 2006). When a vehicle's model is identified by the program, it is given a *modelh* value that corresponds to the particular model of vehicle. This modelh codes will differentiate between different models of vehicles, but not between different trim levels of the same model. Vehicles for which the model cannot be identified are assigned a modelh code of "Z". These vehicles were excluded from the present analysis, leaving 1,034,171 vehicles still eligible for inclusion in the analysis. It is likely that many of the vehicles excluded because they had an invalid modelh code were not passenger cars, but rather heavy vehicles or motorbikes.

It is important to note that even if two cars have the same model name, they may not have the same model code. A new release of a particular model may be given a new modelh code, especially if it based on a new vehicle platform or deemed significantly different from the vehicles previously released. Furthermore, vehicles of the same modelh classification may have been manufactured in different years.

Using the Used Car Rating Safety Ratings program, once a vehicle was given a valid modelh code, it was classified into one of a thirteen of market groups, which are based on the Federal Chamber of Automotive Industries (FCAI) classification of vehicles for the purpose of reporting Australian new vehicle sales in their VFACTs publication. Each of these classifications are listed in the first column of Table 3. For a detailed description of each category, the reader is referred to Newstead, Watson & Cameron (2006). The market group of some vehicles could not be determined. These vehicles were classified as having "Unknown" market group.

Table 3: Re-classification of vehicle market groups for the purposes of the present evaluation of Electronic Stability Control

Market group Classification	Included in analysis	Broad Classification
Passenger Cars		
- Light	✗	
- Small	✓	Car
- Medium	✓	Car
- Large	✓	Car
- People Movers	✗	
- Sports	✓	Car
- Luxury	✓	Car
Four Wheel Drives		
- Compact	✗	
- Medium	✓	4WD
- Large	✓	4WD
Light Commercial Vehicles		
- Van	✗	
- Utility	✗	
Unknown	✗	

Vehicles belonging to some market groups were excluded in the present analysis. In particular, people movers, light vehicles, compact 4WDs and commercial vehicles were excluded. This was done because when crashed vehicles were classified according to whether they had ESC or not (see the following section), it was revealed that very few of these types of vehicles offered ESC as either a standard feature or an option. Including them in the analysis may have biased the sample as commercial vehicles have been shown to have a higher crash risk than other vehicles (Becker, Delaney & Newstead, 2007), while light vehicles have a higher risk of injury for their occupants when involved in crashes (Newstead, Watson & Cameron, 2006). When these vehicles were excluded, 626,692 crashed vehicles remained in the six-jurisdiction sample that would be used to assess the effectiveness of ESC.

The crashed vehicle sample was further restricted to cars manufactured more recently than 1997. The reason these vehicles were excluded was that very few vehicles manufactured prior to 1997 were equipped with ESC. Previous studies have shown that vehicle age has an effect on crash risk. As newer vehicles are more likely to be equipped with ESC than older vehicles, excluding older vehicles from the study eliminates a potential bias. Of the crashed vehicles not yet excluded from the sample to be analysed, 221,595 were manufactured more recently than 1997.

The next step in completing the evaluation involved classifying the vehicles in this sample according to their ESC status. The method used to classify these vehicles is described in the following section.

2.1 IDENTIFYING CRASHED VEHICLES WITH ESC

In order to assess the safety benefits of Electronic Stability Control, it was necessary to identify which of the crashed vehicles had ESC fitted at the time of the crash. This was achieved by reviewing the following sources of information on the specifications of vehicles sold in Australia in the period 1995-2005:

- The Redbook website (www.redbook.com.au) which provides detailed information on the specifications and VIN of most vehicles sold in Australia. Redbook provides information on both current and previous models.
- The Road Vehicle Certification System (RVCS) website (http://rvcs-prodweb.dot.gov.au), which provides access to data on the VIN of different variants of vehicles sold in Australia. This information allows the variants of different models to be identified from the VIN in many instances. The website also provides some information on how variants and trim levels of the same model differ with respect to standard and optional features available. Like Redbook, data on both former and current models is available.
- The Carsales website (www.carsales.com.au), which provides information on vehicle specifications of both current and older models. However, this website does not provide any information on the VIN of different models.
- The TAC Arrive Alive! Electronic Stability Control fact sheet, which provides a list of current models that provide ESC as either a standard feature or an optional extra.
- Vehicle manufactures' publicly-available list of specifications for current models and the various trim levels available to the consumer.

The modelh variable developed for the Used Car Safety Ratings project groups similar types of cars together. However, two vehicles with the same modelh code will not necessarily both have the same ESC status. As, each modelh codes span several years, if Electronic Stability Control was added to the list of standard features some time after the model's initial release, some vehicles should be coded as having the feature, while other should be coded as not having the feature. Furthermore, for some modelh classifications, ESC is only offered as an option or as a standard feature on higher (and more expensive) levels of trim.

Each of the previously listed vehicle specification information sources were used to determine which modelh codes represented vehicles with ESC and which represented vehicles without the safety feature. Where it was found that some vehicles of a particular modelh code did have ESC and others did not, the data sources listed above were used to determine ESC status based on VIN and year of manufacture values.

Reviewing these sources enabled vehicles to be classified into one of the following groups:

- Vehicle has ESC either as a standard feature for the model or as a standard feature for the level of trim or year of manufacture, which both can be identified via the VIN;
- Vehicle model does not have ESC as an option or as standard;
- Vehicle ESC status cannot be determined either because it is offered as an optional extra or as standard on some trim levels only and these vehicles cannot be identified from trim levels not offering ESC.

A computer program was then created that used the modelh value, the VIN and the year of manufacture of crashed vehicles to classify each of them into one of the above three categories. Table 4 shows how the 221,595 crashed vehicles are distributed with respect to the fitment of ESC after the program was applied. Results for each jurisdiction are shown separately. It can be seen that the program could not decode the VIN of 6,088 (2.7%) of the 221,595 vehicles, while the ESC status of a further 4,622 (2.1%) could not be determined, either because ESC was an optional extra or only available on a trim level that could not be identified from other trim levels.

Table 4: Distribution of Electronic Stability Control fitment by jurisdiction for vehicles manufactured more recently than 1997 that were crashed in the period 2001-2005 (excluding compact 4WDs, commercials, people movers and light vehicles)

Jurisdiction	VIN not recognised		Fitted		Not Fitted		Optional or Unknown	
	N	%	N	%	N	%	N	%
NSW	695	0.9%	3,352	4.4%	69,859	92.2%	1,880	2.5%
QLD	141	0.6%	519	2.3%	21,277	95.4%	370	1.7%
SA	326	0.8%	1,317	3.1%	39,852	94.1%	848	2.0%
VIC	166	1.0%	709	4.2%	15,557	92.3%	422	2.5%
WA	4,199	7.1%	1,556	2.6%	52,479	88.6%	985	1.7%
NZ	561	11.0%	246	4.8%	4,162	81.8%	117	2.3%
Total	6,088	2.7%	7,699	3.5%	203,186	91.7%	4,622	2.1%

Table 5 shows how the proportion of crashed vehicles that have ESC as standard is increasing for each model year. In 1998 approximately 1.2% of vehicles had ESC fitted, while in 2003 this had increased to nearly 6.6%. If light cars, Compact 4WDs and people movers are added to the sample, the proportion of crashed vehicles manufactured in 1998 with ESC as standard drops from 1.2% to 0.9%, while the proportion manufactured in 2003 with ESC as standard drops from 6.6% to 5.2%. Dang (2004) reported that 7.4% of light vehicles in the US fleet that were manufactured in 2003 were fitted with ESC. When one considers that the analogous Australian estimate of 5.2% does not include those vehicles in which ESC was an optional extra or vehicles in which ESC was only available on trim levels that could not be distinguished from trim levels not offering ESC, the rate of take up of ESC in light vehicles for Australia is probably not too far behind that of the US. However, fitment rates for both countries still lag behind countries such as Sweden, where the proportion of new cars sold that were equipped with ESC jumped from 15% in March 2003 to 69% in December 2004 (Farmer, 2006).

Table 5: Distribution of Electronic Stability Control fitment by year of manufacture for vehicles crashed in the period 2001-2005 (excluding compact 4WDs, commercials, people movers and light vehicles)

Year of Manufacture	VIN not recognised		Fitted		Not Fitted		Optional or Unknown	
	N	%	N	%	N	%	N	%
1998	642	1.5%	528	1.2%	42,535	97.3%	5	0.0%
1999	863	2.1%	850	2.1%	39,307	95.5%	157	0.4%
2000	948	2.2%	1,050	2.5%	40,334	94.6%	290	0.7%
2001	1,198	3.4%	1,270	3.6%	32,214	90.7%	826	2.3%
2002	878	3.4%	1,153	4.5%	22,593	88.4%	944	3.7%
2003	835	4.3%	1,282	6.6%	16,401	84.1%	984	5.0%
2004	468	4.4%	1,164	11.1%	8,032	76.3%	862	8.2%
2005	256	8.6%	402	13.5%	1,770	59.4%	554	18.6%
1998-2005	6,088	2.7%	7,699	3.5%	203,186	91.7%	4,622	2.1%

As the status of vehicles with respect to ESC fitment was unknown for the 6,088 vehicles where the VIN was not recognised and the 4,622 where ESC was either optional or only available on higher trim levels of models that could not be separated from trim levels without ESC, these vehicles were excluded from the sample to be analysed. A further 105 vehicles that crashed in NSW were excluded from the analysis as it was not possible to determine if these vehicles were involved in rear end collisions. As will be explained in the following section, the methodology used in this report to assess the effectiveness of ESC relies on the identification of vehicles involved in rear end collisions, as the risk of such collisions occurring is unlikely to be affected by ESC. Therefore, 210,820 vehicles remained in the sample that would be used to analyse the effectiveness of ESC.

Table A.1 in Appendix A shows the list of models included in this study that were fitted with ESC. Not all the vehicles in the Australian fleet with the same make, model and year of manufacture values as those listed in Table A.1 will definitely have Electronic Stability Control, as the safety feature may have only been available on some trim levels. For models in which ESC was standard on only some trim levels, if the ESC-fitted trim could be distinguished from the non-ESC trim, these vehicles were included in Table A.1. It can be seen from Table A.1 that for the present analysis, approximately 90 different types of vehicle models have been included in the sample of cars known to have Electronic Stability Control. This is the first evaluation of ESC to include such a broad range of models in its sample of ESC-fitted vehicles.

3 METHOD

In order to measure crash risk for vehicles equipped with ESC compared to those without the safety feature, it is necessary to compare the number of crashes occurring for each group against the exposure of each group. In their evaluation of ESC, Page & Cuny (2006) note that as the number of kilometres travelled is usually not available for large groups of vehicles, a surrogate is usually used to measure the true level of exposure to which different groups of vehicles are exposed. Farmer (2006) used the number of registration records of 25 models of vehicles for which an ESC-fitted and an ESC-not-fitted dichotomy could be identified. Estimating crash rates using registration data requires that:

1) registration data is available;
2) the registration data can be decoded so that ESC fitment can be determined.

NSW is the only Australian state for which registration data that allow classification by ESC status was available to the study. Therefore, if registration data were used as a measure of exposure when estimating the effectiveness of ESC in the local road environment, the sample of crashed vehicles to be analysed would be restricted to those involved in crashes occurring on NSW roads. This would reduce the number of vehicles with ESC in the sample from 7,699 to 3,352. Reducing the sample by more than 50% is not desirable as it would decrease the statistical power of the analyses. Furthermore, a sample only including NSW vehicles might be less representative of the Australian and New Zealand fleets than a sample that includes vehicles crashed in five states and New Zealand.

Lie, Tingvall et al. (2004) proposed an alternative methodology to assess the influence of ESC on crashes. This method can be used when it is not possible to estimate true exposure and is often referred to in the literature as "induced exposure". It was previously used by Evans (1998) to assess the effectiveness of anti-lock braking systems. Since Lie, Tingvall et al. (2004) used induced exposure to evaluate the effectiveness of ESC in Sweden, many other studies have used the same methodology in similar analyses of ESC (see for example Dang, 2004; Bahouth, 2005; Lie, Tingvall et al., 2006; Page & Cuny, 2006).

The present evaluation of the effect of ESC on crashes on Australian road also uses the induced exposure methodology. This methodology is explained in the following section.

3.1 STUDY DESIGN

The induced exposure methodology for approximating the true exposure of two groups of vehicles, one which is equipped with ESC and the other which isn't, relies on the identification of a crash type that is not affected by ESC fitment. The proportion of vehicles involved in crashes that are assumed not be influenced by ESC fitment can then be used to estimate the expected number of other types of crashes if the null hypothesis (that ESC has no effect on crash occurrence) were true. Any deviation from the expected number of crashes can be considered to be an effect of the fitment of ESC providing that the two groups of vehicles are the same except with respect to ESC fitment, nor do they differ with respect to the way they are driven. The methodology must control for any such confounding factors that are known to exist.

The following section relates to how a suitable crash type for use as a measure of induced exposure was defined in the present analysis. This is followed by a brief explanation of the Poisson regression analysis methodology which was used to test the significance of differences in crash distributions between the two samples of crashed vehicles. A brief explanation of how several confounding factors were controlled for is also provided.

3.2 CHOOSING A CRASH TYPE AS A SUITABLE MEASURE OF INDUCED EXPOSURE

In the evaluation of the effectiveness of ESC on US roads, Dang (2004) assumed that ESC has no effect on multi-vehicle crashes, so these were used to estimate the expected number of single vehicle crashes involving ESC-fitted cars if ESC did not have an influence on single vehicle crashes. Choosing such a broad definition of crash for the induced exposure method has its disadvantages. Firstly, it is possible that ESC does affect some types of multiple vehicle crashes. For instance, ESC may reduce the risk head on collision caused by a vehicle over-steering on a bend and heading into on-coming traffic. Secondly, Lie, Tingvall et al., 2006 noted that using such a broad crash type definition as the induced exposure measure limits the possibility of estimating the overall effect of ESP.

In their evaluations of the influence of ESC on crashes in Sweden, Lie, Tingvall et al. (2004, 2006) assumed that ESC would have no influence on rear end impacts on dry roads. Rear end impacts were limited to dry roads as low friction surfaces were considered a risk factor for crash involvement. Page & Cuny (2006) chose multiple vehicle crashes for which braking was not a factor in the crash as the measure of induced exposure, while Bahouth (2005) chose vehicles that were rear-ended by another vehicle. Thus, in the studies by Bahouth (2005) and Page & Cuny (2006), if a vehicle rear-ended another vehicle, the striking vehicle would not be included in the group of crashes used to estimate the exposure measure, while for Lie, Tingvall et al. (2004, 2006), the vehicle would be counted in the induced exposure group as no distinction is made between the struck and striking vehicle in rear impacts. Results from Tingvall, Krafft, Kullgren & Lie (2003) suggest that it is not necessary to differentiate between struck and striking vehicles when using rear end impacts as an induced exposure measure as the bullet to target distribution of cars with and without ESC was almost identical – that is 44% of ESC vehicles involved in rear impacts were the target vehicles, compared with 47% of non-ESC vehicles. Similar distributions (37% compared with 43%) were found using the data compiled for the present study (see the Section 3.4 for further details).

In the present study, vehicles involved in rear end impacts on all road surface conditions were used as the measure of induced exposure. Only 16% of vehicles analysed were involved in crashes on wet roads. Therefore, stratifying the analysis by the condition of the road surface was unlikely to lead to significant results for the effectiveness of ESC on wet roads and would decrease the power of the overall analysis. The crash type used to estimate induced exposure also included both the struck vehicle and the striking vehicle in rear end crashes. This is because for NSW crash data, it was not possible to determine the role of each vehicle in a multiple vehicle crash. Removing all NSW cases from the sample to be analysed would have reduced the sample of ESC-fitted vehicles by 43%.

3.3 ESTIMATING CRASH REDUCTION USING POISSON REGRESSION

Using rear end impacts as a measure of induced exposure, the odds ratio of a crash not being a rear end crash by ESC fitment can be expressed as

$$OR = \frac{A_{ESP} / R_{ESP}}{A_{nonESP} / R_{nonESP}} \qquad \text{(Equation 1)}$$

where R is the number of vehicles involved in rear end crashes, A is the number of other types of crashes and the subscripts indicate the ESC fitment status of the vehicle. From this, the effectiveness, or the percent reduction in non-rear end crashes due to the fitment of ESC, can be expressed as

$$E = (1 - OR) \times 100\,. \qquad \text{(Equation 2)}$$

Medical literature shows that the most appropriate way of analysing count data while controlling for the effect of non-treatment effects using controls is to use log-linear analysis with Poisson error structure (Breslow & Day, 1987). In the case of the analysis of casualty crash data, this will not result in an estimate of the relative risk of an outcome (such as the risk of contracting a disease) but rather the relative change in the treatment group compared to the control. In the present analysis, the control group can be thought of as rear end impact crashes, while the treatment group can be thought of as all other types of crashes. The crash counts of the control group are used to give crash counts of the treatment group that can be expected if ESC does not have an influence on crashes. The Poisson model estimates the extent to which the observed counts of vehicles fitted with ESC in the treatment group differs from the expected counts. The distribution assumptions about casualty crash frequency made in the use of this method are consistent with those proposed by Nicholson (1985, 1986).

Bruhning & Ernst (1985) demonstrated a technique of applying log-linear Poisson models so that the aggregate effect of a road safety feature (in the present case a vehicle feature) across subsets of treated sites can be estimated. This enables treatment and control pairs to be matched to each other based on shared characteristics that could otherwise confound the estimate of the effect of the feature being tested. It also enables the effect of the treatment on different types of crashes to be analysed separately. Assuming that L groups of treatment and control pairs are formed, a Poisson log-linear model can be used to estimate the effectiveness of a road safety feature either across all groups, across each group individually or across combinations of groups.

For the assessment of the effectiveness of ESC, applying the technique demonstrated by Bruhning & Ernst (1985) requires the crash data to be arranged as a series of L 2x2 contingency tables, as represented by Table 6.

Table 6: Contingency table format used in the present analysis

Vehicle/Crash Characteristic Group Number	Rear End Crash		Not a Rear End Crash	
	ESC fitted	ESC not fitted	ESC fitted	ESC not fitted
1	n_{111}	n_{112}	n_{121}	n_{122}
⋮	⋮	⋮	⋮	⋮
L	n_{L11}	n_{L12}	n_{L21}	n_{L22}

Once the crash data are arranged according to Table 6, a log-linear model with Poisson error structure is fitted to the data using a statistical software package such as SAS. This model is defined as

$$\ln(n_{ijk}) = \beta_0 + \beta_i + \beta_{ij} + \beta_{ik} + \beta_{ijk} + \varepsilon_{ijk} \qquad \text{(Equation 3)}$$

where the β values are the parameters of the model where the index i represents the group number, j represents whether the crash was a rear end crash, k denotes whether ESC was fitted and ε is a random error term. The percentage reduction in crashes of group i that can be attributable to ESC is equal to

$$\Delta_i = 100 \times (1 - \exp(\beta_{ijk})) . \qquad \text{(Equation 4)}$$

The statistical significance of Δ_i is equal to the statistical significance of β_{ijk} obtained from the fitted log-linear model, while confidence limits are computed using the estimated standard error of β_{ijk}.

To estimate the effect of ESC on all types of crashes (excluding rear end crashes), the data is fitted to the model defined as

$$\ln(n_{ijk}) = \beta_0 + \beta_i + \beta_{ij} + \beta_{ik} + \beta_{jk} + \varepsilon_{jk} \qquad \text{(Equation 5)}$$

and the average percentage reduction attributable to ESC across all is equal to

$$\Delta_i = 100 \times (1 - \exp(\beta_{jk})) . \qquad \text{(Equation 6)}$$

3.4 MATCHING CASE AND CONTROL GROUPS

Choosing which potential confounding variables to control for is not a simple task. Trying to control for too many confounders, or stratifying the data so that effectiveness estimates can be derived for many different types of crashes, may result in low statistical power and correspondingly large confidence intervals. This is due to low cell counts in the cells represented by Table 6. Since the standard error of the parameter estimates has an inverse relationship to the cell counts, having a low cell count in a few cells, can have what appears to be a disproportionate effect on the confidence intervals of the estimate.

The following sections describe the process used to decide what potential confounders to control for.

3.4.1 Vehicle Type

An important way vehicles fitted with ESC could differ from those without ESC is the general primary safety performance of the vehicle. If ESC is more likely to be fitted in large cars than small cars and the crash distribution for larger cars or the risks associated with larger cars are different to those of smaller cars, these differences will confound the estimated effectiveness of ESC. Some previous studies matched vehicle models that were identical in every way except for the fitment of ESC. However this often resulted in only a small number of models being eligible for inclusion in the analysis data set. For example Page & Cuny (2006) were limited to studying only two versions of the Renault Laguna: an earlier model that was not fitted with ESC and a later release that was fitted with ESC as standard. This limits the findings of the study as the level of effectiveness of ESC on the broader vehicle fleet may differ to the effectiveness when assessed using a single model, especially when one considers that different manufacturers have developed different ESC systems.

The present analysis has included a broad a range of vehicles when assessing the effectiveness of ESC. However some vehicle types have been excluded. As previously mentioned, market groups with low fitment rates were excluded. These included light cars, commercial vehicles, people movers and compact 4WDs. The remaining vehicles were then put into one of two broad categories:

1) 4WDs;
2) and cars.

Table 3 on page 11 shows how vehicles were categorised according to market group. Vehicles classified as 4WDs were put into different control groups to vehicles classified as cars. This enabled the Poisson model to control for the different crash risks and crash type distributions of 4WDs and cars.

3.4.2 Year of Manufacture

The present study also controlled for the year that the vehicle was manufactured. The reason for this is that this variable is likely to be highly correlated with ESC fitment. As shown in Table 5 on page 14, the proportion of new vehicles definitely fitted with ESC is increasing with each passing year.

Some studies, such as Bahouth (2005), also controlled for the age of the vehicle. Even though, in the present analysis, year of manufacture has been controlled for, it may still be necessary to control for vehicle age. This is because the crash data used in the present analysis represents vehicles crashed over a five year period (2001-2005). Older vehicles are on the road for longer so they are exposed to risk for a greater period. The data used in the present study were analysed to see if, when vehicles are grouped by year of manufacture and year of crash, there is a bias towards vehicles with ESC being more or less likely to be involved in rear end impacts. If such a bias existed, it would be necessary to control for year of crash (or vehicle age) as well as market group. This is because the bias will be reflected in the estimates of the effectiveness of ESC when measured using induced exposure. Table 7 shows that there is very little difference in the percentage of vehicles involved in rear end impacts for ESC-fitted vehicles and vehicles without ESC when the data set is stratified by year of crash and year of manufacture. In fact for all except five year of manufacture/year of crash pairs, the percent of ESC equipped vehicles involved in rear impacts is within 5% of the percent of vehicles without ESC.

Using the same data as that used to create Table 7, a logistic regression model of the likelihood that the crash is a rear end crash was created. ESC fitment and year of manufacture were included in the model. When year of crash was included in the model, the model parameters of the variables related to ESC and year of manufacture were almost the same as when the year of crash variable was not included in the model. This further suggests that controlling for year of manufacture adequately controls for any bias associated with vehicle age.

Table 7: Percentage of crashed vehicles involved in rear end impacts by year of manufacture, year of crash and ESC fitment

Year of Manufacture	Year of Crash									
	2001		2002		2003		2004		2005	
	ESC	No ESC	ESC	No ESC	ESC	No ESC	ESC	No ESC	ESC	No ESC
1998	39.67	38.77	31.19	38.59	37.50	38.20	34.91	37.99	44.79	38.00
1999	44.21	38.52	27.43	39.09	37.72	38.57	34.55	38.22	37.25	37.71
2000	37.50	37.92	35.27	39.12	37.05	39.85	36.23	38.77	38.46	38.75
2001	33.33	37.56	40.68	37.99	39.37	40.46	38.81	40.64	48.39	38.55
2002			36.51	37.55	38.70	40.27	36.21	40.60	34.71	39.82
2003					36.76	38.95	36.64	40.07	37.82	39.72
2004							40.00	39.49	40.05	40.27
2005									35.57	37.57
1998-2005	38.68	38.20	34.21	38.47	37.85	39.39	36.76	39.40	39.63	38.80

3.4.3 Jurisdiction

Bahouth (2005) created separate models for crash data sourced from different jurisdictions. Effectiveness across all jurisdictions was then estimated using a weighted average of estimate of effectiveness for each jurisdiction. The rationale for this approach was that different jurisdictions may have different inclusion criteria for their crash databases. Furthermore, different jurisdictions may define key variables differently. The present analysis sources crash data from five Australian states and New Zealand. It is true that the criteria for inclusion vary across these jurisdictions. Victorian and New Zealand crash databases only include police-reported crashes in which a road user was injured, while the minimum criteria for inclusion in NSW and Queensland police-reported crash datasets is that a vehicle was towed from the crash scene or somebody was injured. For South Australia and Western Australia, property damage only crashes are included in each data set provided property costs exceeded $1000, but this increased to $3000 for South Australia from 2003 onwards.

Instead of matching cases and controls based on jurisdiction, for the present analysis, it was decided that when assessing the effectiveness of ESC in preventing crashes of any severity (including property damage only crashes), Victorian and NZ data would be excluded from the sample. This is because, as far as crashes of all severities are concerned, both these data sets are incomplete. Excluding crash data from these two jurisdictions reduced the sample of crashed vehicles to be analysed from 210,820 to 190,146 crashed vehicles.

A separate analysis of the effectiveness of ESC in preventing injury crashes would also be carried out in the present evaluation. Since Victorian and New Zealand datasets include all police-reported injury crashes, data from all six jurisdictions could be used to estimate effectiveness in preventing injury crashes. In this report, a vehicle was said to be involved in an injury crash if the driver of that vehicle received an injury of any severity. This definition is in keeping with the definition used by Newstead, Watson & Cameron (2006) in their *Used Car Safety Ratings*. Newstead, Watson & Cameron (2006) used this definition of an injury crash because NSW crash data only enabled the injury status of drivers to be deduced. Using this definition is also of benefit to the present study in that it eliminates any bias associated with some types of vehicles having different occupancy rates.

When the crash data from the six jurisdictions were merged, care was taken to ensure that the definitions for key variables (such as crash type, market group and year of manufacture) and potential confounders (such as driver age, driver gender and road condition) were consistent across jurisdictions.

3.4.4 Driver/Vehicle Use Characteristics

Cars fitted with ESC may differ from cars without ESC in the way they are driven. The case of anti-lock braking systems (ABS) provides a recent example of how the effectiveness of a safety feature can be undermined by differences in the way vehicles with the feature installed are driven when compared with those without the safety feature. In their of review of the literature regarding ABS, Burton, Delaney, Newstead, Logan & Fildes (2004) found that there was a discrepancy in the benefits that were expected from ABS and the effectiveness exhibited in terms of reducing the number of real world crashes. When evaluating the effectiveness of ABS in preventing real world crashes, the typical finding was that the net effect was close to zero. The reason for this is that the crash distributions for vehicles fitted with ABS was different to that of vehicles not fitted with ABS. Vehicles fitted with ABS were involved in more single vehicle road departure crashes but less multiple vehicle crashes and less fatal pedestrian crashes (Burton, Delaney et al., 2004).

There are several theories why the crash distribution of the ABS fleet is different to that of the non-ABS fleet. One possibility is that ABS is associated with a change in driver behaviour and that this change increases crash risk. Evans (1998) noted that drivers never drive more slowly when their vehicles have ABS and that in some circumstances, some drivers drive a little faster because their vehicles have ABS. In their review of the literature regarding ABS, Burton, Delaney et al. (2004) noted that consensus had yet to be established regarding whether the increased single vehicle crash risk associated with ABS-fitted vehicles was due to ABS allowing drivers to execute dangerous crash avoidance responses in emergency braking situations. Such responses include excessive steering movements that may lead to road departures. For vehicles not fitted with ABS, in some situations, such steering movements would not result in the vehicle departing from its course because the car’s tyres have less traction. The same review also noted that a possible reason for the increased risk of ABS-fitted vehicles in some types of crashes may be due to incorrect operation and a lack of understanding of how ABS operates.

The example of ABS shows that the presence of a safety feature can change the crash distribution exhibited by a group of vehicles. This could be due to the effects of the feature itself or changes in the way the driver operates the vehicle when the feature is present. It could also be due to a different population of drivers being more likely to drive vehicles with the feature. In the present analysis, it has been assumed that ESC neither increases nor decreases the risk associated with rear end impacts. If the presence of ESC is shown to increase the risk of being involved in a rear impact, the estimated benefits of ESC in other types of crashes will be underestimated. Conversely, if ESC decreases the risk of being involved in a rear impact, the estimated influence of ESC in other types of crashes will be over estimated. If either of these scenarios were shown to occur, it will be necessary to control the factor that accounts for the change in relative risk. For example if it is shown that drivers of cars fitted with ESC drive faster than non-ESC drivers and that this causes them to be involved in more rear end crashes, it would be necessary to control for speed in the analysis of ESC. Similarly, it is shown that drivers of ESC vehicles are on average older than drivers of cars not fitted with ESC and that this causes them to be involved in less (or more) rear end crashes, it would be necessary to control for age.

In the present analysis, the data available did not allow confounders related to driver behaviour to be controlled. Only the year of manufacture of the vehicle and the type of vehicle (4WD or car) are controlled for. There weren't enough data to allow more potential factors to be included in the model. In the Results section of this report, the effects of some potential confounders are tested and the Discussion addresses the likely influence that their omission will have on the reported effective estimates.

3.5 OUTCOMES

The Poisson model has been used to derive the estimated increased or decreased crash risk of a vehicle fitted with ESC being involved in the following types of crashes:

- Police-reported crashes of all severities (i.e. including property damage only crashes); and
- Police-reported crashes in which the driver of the vehicle is injured (minor, serious or fatal).

These two estimates of effectiveness have been derived for all types of vehicles as well as for 4WDs and cars separately, where "4WDs" and "cars" are defined using Table 3.

Effectiveness in preventing single vehicle and multi-vehicle crashes has also been analysed separately for all vehicles as well as for 4WDs and cars separately. These analyses have been undertaken for both police reported crashes of all severities as well as police reported crashes in which the driver of the vehicle was injured.

Each point estimate of effectiveness is presented along with 95% confidence intervals.

4 RESULTS

As previously explained, separate Poisson models were used to estimate the effectiveness of ESC in preventing a vehicle being involved in police reported crashes of all severities (including property damage only crashes) as well as crashes in which the driver of the vehicle is injured. Furthermore, for each of these two criteria for inclusion in the analysis, models that gave separate estimates of effectiveness for single vehicle crashes and multiple vehicle crashes were also presented.

Each model controlled for the effects of year of manufacture and market group, where market group was defined using a broad dichotomy (4WDs or cars). The induced exposure method was employed, with rear end impacts providing the necessary measure of exposure as they were adjudged not to be affected by the presence of absence of ESC.

The following sections describe the outcomes from each analysis model and how they can be interpreted.

4.1 OVERALL EFFECTIVENESS

The results derived in this section give the estimated effectiveness of ESC in terms of reducing the risk of involvement in non-rear end impact crashes. The analysis does not represent the effectiveness in preventing all types of crashes (i.e. including rear impact crashes) as rear impact crashes were used as a surrogate exposure measure as they were assumed not to be affected by the presence of ESC. Table 8 presents the results for all types of police reported crashes (including property damage only crashes) as well as crashes in which the driver of the vehicle was injured.

As mentioned in the Section 3.4.3, when police reported crashes of all severities were considered, Victorian and New Zealand data were excluded as these data sets do not contain information on property damage only crashes.

Table 8 presents unadjusted and adjusted measures of effectiveness for each crash type. Unadjusted effectiveness is derived by first calculating the odds ratio of being involved in a non-rear impact crash for vehicles fitted with ESC compared to vehicles without ESC. This odds ratio is calculated using Equation 1 from Section 3.3. The odds ratio is then applied to Equation 2 to give the unadjusted measure of effectiveness. The adjusted measure of effectiveness is derived using the Poisson model which uses rear impact crashes as a measure of induced exposure while matching vehicles fitted with ESC and vehicles not fitted with ESC according to market group and year of manufacture. This model controls for bias in the unadjusted estimate of effectiveness stemming from uneven distributions of year of manufacture and market group in the sample of ESC-fitted vehicles when compared to vehicles not fitted with ESC.

Table 8: Estimated effectiveness of Electronic Stability Control in reducing the risk of a non-rear end crash

Type of Crash	Unadjusted % Crash Reduction	Adjusted % Crash Reduction	Statistical Significance	Lower 95% Confidence Limit	Upper 95% Confidence Limit
All Crashes	-5.18	-7.07	0.0086	-12.67	-1.76
Driver Injury Crashes	10.73	9.84	0.1027	-2.10	13.83

It can be seen from that unadjusted effectiveness of ESC in reducing the risk of all crashes was equal to -5.2. This means that vehicles equipped with ESC were approximately 5% more at risk of being involved in a crash of any severity. When differences in the distributions of year of manufacture and market group are adjusted for using Poisson regression, the effectiveness of ESC in reducing the risk of non-rear end crashes is equal to -7.1, ranging from -12.7 to -1.8 with 95% confidence. Therefore, the model suggests that the presence of ESC significantly increases the risk of involvement in a non-rear end police-reported crash of any severity.

When the crash sample is restricted to crashes resulting in the driver of the vehicle being injured, it is found that the unadjusted effectiveness of ESC is equal to 10.7, while the adjusted estimate of effectiveness is 9.8. Therefore, for this sample of more serious crashes, ESC is shown to be effective in reducing risk by 9.8%, however the estimate of effectiveness is of marginal statistical significant (ranging from -2.1 to 13.8 with 95% confidence).

4.1.1 Cars only

As vehicles fitted with ESC and those without ESC have been matched with respect to year of manufacture and broad market group, the coefficients of the Poisson model can be adjusted to give separate estimates of effectiveness for 4WDs and cars. Table 9 gives the adjusted estimates of effectiveness for ESC fitted to cars (i.e. excluding 4WDs) along with the unadjusted measures of effectiveness.

Table 9: Estimated effectiveness of Electronic Stability Control in reducing the risk of cars being involved in a non-rear end crash

Type of Crash	Unadjusted % Crash Reduction	Adjusted % Crash Reduction	Statistical Significance	Lower 95% Confidence Limit	Upper 95% Confidence Limit
All Crashes	-7.05	-8.37	0.0036	-14.40	-2.65
Driver Injury Crashes	10.17	8.63	0.1705	-3.96	19.68

The unadjusted and adjusted levels of effectiveness are very similar to those presented in Table 8 when both cars and 4WDs were evaluated. This is true when property damage only crashes are included in the sample being analysed and when the sample is restricted to vehicles in which the driver was injured. The reason that the results of Table 9 are so similar to that of Table 8 is that only 6% of the vehicles included in the analysis sample were 4WDs.

4.1.2 4WDs only

The models used to estimate the effectiveness of ESC in reducing the risk of cars being involved in crashes also returned estimates of the effectiveness of ESC in preventing 4WDs being involved in crashes. Table 10 shows that the unadjusted measure of effectiveness of ESC suggested that it was effective in reducing injury risk for drivers of 4WDs by 35.4%. However, after adjusting for market group and year of manufacture, this was reduced to 24.5%. This estimate of effectiveness was not significant, ranging from -20.4% to 52.7% with 95% confidence.

Table 10: Estimated effectiveness of Electronic Stability Control in reducing the risk of 4WDs being involved in a non-rear end crash

Type of Crash	Unadjusted % Crash Reduction	Adjusted % Crash Reduction	Statistical Significance	Lower 95% Confidence Limit	Upper 95% Confidence Limit
All Crashes	6.77	2.58	0.7351	-13.31	16.23
Driver Injury Crashes	35.41	24.51	0.2376	-20.38	52.66

Similarly, when the criteria for inclusion was broadened to include police reported property damage only crashes, the unadjusted level of effectiveness dropped from 6.8 to 2.6 when confounders were adjusted for. Again, this reduction was not significant (ranging from -13.3% to 16.2% with 95% confidence). The small number of 4WDs included in the analysis sample contribute to the wide confidence intervals on the adjusted estimates of effectiveness for 4WDs.

4.2 EFFECTIVENESS IN REDUCING SINGLE VEHICLE CRASHES

Section 4.1 gave estimates of the effectiveness of ESC in reducing the risk of a vehicle being involved in either multiple vehicle crashes or single vehicle crashes. In this section, the sample of crashed vehicles used to evaluate the effectiveness of ESC only includes those involved in single vehicle crashes. Therefore, this section provides details of the effectiveness of ESC in reducing the risk of a vehicle being involved in a single vehicle crash.

Of the vehicles included in the sample analysed in this evaluation, 11% were involved in single vehicle crashes, which translates to 19% of crashes in the dataset being single vehicle crashes. Table 11 shows that ESC was effective in reducing the risk of single vehicle crashes of all severities by 28.7%. This estimate was highly significant, with the estimate of effectiveness ranging from 21.2% to 35.4% with 95% certainty. When the sample of vehicles involved in single vehicle crashes was restricted to those in which the driver was injured, it was found that ESC was effective in reducing the risk of crashes by 32.4%, ranging from 16.9% to 44.9% with 95% certainty.

Table 11: Estimated effectiveness of Electronic Stability Control in reducing the risk of a vehicle being involved in a single vehicle crash

Type of Crash	Unadjusted % Crash Reduction	Adjusted % Crash Reduction	Statistical Significance	Lower 95% Confidence Limit	Upper 95% Confidence Limit
All Crashes	27.65	28.67	<.0001	21.20	35.44
Driver Injury Crashes	30.39	32.36	0.0002	16.90	44.94

4.2.1 Cars only

Table 12 shows that when the sample of single vehicle crashes was restricted to those involving cars only (i.e. excluding 4WDs), it was found that ESC was effective in reducing the risk of involvement in single vehicle crashes by 24.1%, ranging from 15.7% to 31.7% with 95% certainty. For single vehicle crashes in which the driver of the car was injured, ESC reduced risk by 26.8%, ranging from 9.4% to 40.8% with 95% certainty.

Table 12: Estimated effectiveness of Electronic Stability Control in reducing the risk of a car being involved in a single vehicle crash

Type of Crash	Unadjusted % Crash Reduction	Adjusted % Crash Reduction	Statistical Significance	Lower 95% Confidence Limit	Upper 95% Confidence Limit
All Crashes	24.60	24.10	<.0001	15.68	31.67
Driver Injury Crashes	28.48	26.77	0.0041	9.39	40.83

4.2.2 4WDs only

For single vehicle crashes involving 4WDs, ESC was estimated to reduce the risk of crashes of all severities by 54.5%, ranging from 38.5% to 66.4% with 95% certainty. As shown in Table 13, when single vehicle crashes involving 4WDs were restricted to crashes in which the driver was injured, the estimated effectiveness increased to 67.8%, ranging from 35.1% to 84.0% with 95% certainty.

A previous evaluation by Farmer (2006) showed that ESC reduced single vehicle crashes involving 4WDs by 56%. This evaluation of US crash data also estimated that ESC reduced the risk of rollover crashes in which an occupant of a 4WD was injured by 78% (ranging from 62% to 88% with 95% certainty). It would be interesting to study how much of the observed 68% reduction in risk of single vehicle crashes in which the driver of a 4WD was injured is due to ESC reducing the risk of rollover events. This issue, and other ways that the present analyses could be developed, are addressed in Section 9 of this report.

Table 13: Estimated effectiveness of Electronic Stability Control in reducing the risk of a 4WD being involved in a single vehicle crash

Type of Crash	Unadjusted % Crash Reduction	Adjusted % Crash Reduction	Statistical Significance	Lower 95% Confidence Limit	Upper 95% Confidence Limit
All Crashes	51.32	54.54	<.0001	38.45	66.43
Driver Injury Crashes	66.33	67.81	0.0015	35.12	84.03

4.3 EFFECTIVENESS IN REDUCING MULTIPLE VEHICLE CRASHES

In this section, the sample of crashed vehicles is restricted to those involved in multiple vehicle crashes. Table 14 shows that ESC fitment did not reduce the risk of a vehicle being involved in these types of crashes. When crashes of all severities were considered, the adjusted measure of effectiveness revealed that ESC increased the risk of involvement in a multiple vehicle crash by 14.8%, ranging from 9.0% to 21.0% with 95% certainty. However, when the sample of vehicles involved in multiple vehicle crashes was restricted to vehicles in which the driver was injured, ESC was shown to have no effect on crash risk (the Poisson model showed that ESC reduced risk by 1.8%, however this estimate ranged from -12.0% to 13.8% with 95% certainty).

Table 14: Estimated effectiveness of Electronic Stability Control in reducing the risk of a vehicle being involved in a multiple vehicle crash

Type of Crash	Unadjusted % Crash Reduction	Adjusted % Crash Reduction	Statistical Significance	Lower 95% Confidence Limit	Upper 95% Confidence Limit
All Crashes	-11.94	-14.80	<.0001	-20.96	-8.95
Driver Injury Crashes	4.05	1.77	0.7885	-11.96	13.83

Other studies have also shown that ESC has no real effect on multiple vehicle crashes. For example, Farmer (2006) found that the small (1%) increase in risk associated ESC was not significant.

4.3.1 Cars only

When the sample of vehicles involved in multiple vehicle crashes was restricted to cars, Table 15 shows that the results are not very different to those involving all types of vehicles (compare with Table 14). ESC was shown to increase the risk of multiple vehicle crashes for cars when property damage only crashes were included in the sample analysed, however when only cars in which the driver was injured were considered, ESC was estimated to have no significant effect on multiple vehicle crash involvement.

Table 15: Estimated effectiveness of Electronic Stability Control in reducing the risk of a car being involved in a multiple vehicle crash

Type of Crash	Unadjusted % Crash Reduction	Adjusted % Crash Reduction	Statistical Significance	Lower 95% Confidence Limit	Upper 95% Confidence Limit
All Crashes	-13.46	-15.02	<.0001	-21.58	-8.81
Driver Injury Crashes	4.21	2.84	0.6767	-11.26	15.16

4.3.2 4WDs only

When vehicles involved in multiple vehicle crashes were restricted to 4WDs, the Poisson model showed that ESC increased risk of involvement in a crash of any severity by 13.1%, ranging from 3.3% to 32.2% with 95% certainty. Table 16 shows that when the sample of 4WDs involved in multiple vehicle crashes was restricted to those in which the driver was injured, the adjusted risk associated with ESC was 14.1%, however the confidence limits associated with this estimate were very wide.

Table 16: Estimated effectiveness of Electronic Stability Control in reducing the risk of a 4WD being involved in a multiple vehicle crash

Type of Crash	Unadjusted % Crash Reduction	Adjusted % Crash Reduction	Statistical Significance	Lower 95% Confidence Limit	Upper 95% Confidence Limit
All Crashes	-4.92	-13.08	0.1233	-32.22	3.28
Driver Injury Crashes	13.15	-14.10	0.608	-88.85	31.06

The reader will note that the unadjusted estimate of effectiveness for 4WDs involved in multiple impacts where the driver of the 4WD is injured was a reduction in risk of 13.2%. However, when the Poisson model was applied to adjust for market group and year of manufacture, it was estimated that ESC increased risk by 14.1%, although this estimate was not significant. It is interesting that the adjusted estimate of effectiveness was different from the unadjusted estimate. However, the unadjusted estimate is still within the 95% confidence intervals of the unadjusted estimate of effectiveness. A reason for why the adjusted confidence limits are so wide is that when the sample of 4WDs involved in multiple impacts was reduced to those in which the driver was injured, the number of vehicles in the analysis was reduced by a factor of 10 (from 11,080 4WDs to 1,039).

4.4 EFFECT OF OTHER CONFOUNDERS

The models presented in the previous section control for the year of manufacture as well as the market group of vehicles. As mentioned in the Method section of this report, it is possible that the relationship between crash involvement (or type of crash) and ESC may be confounded by additional factors. For example, different types of drivers may be more likely to drive ESC-equipped vehicles, or ESC may affect the way vehicles are driven, thus changing the risk associated with different types of crashes. If the influence of these confounders is imbalanced for rear end impacts when compared with other types of crashes, the estimates of effectiveness presented in the previous section will either be exaggerated or underestimated.

Logistic regression was used to test several potential confounding factors. Firstly the age and sex of the driver were tested. The condition of the road surface (i.e. whether it was wet or dry) was also tested as a potential confounder. Logistic regression models measuring the odds that a crash is a rear end crash were created for each of these variables. Factors already controlled for in the Poisson model, i.e. year of manufacture, market group and ESC fitment were included in the model. Then each potential confounding factor was forced into the model. It was found that for all three potential confounders (driver age, driver sex and road condition), the parameters associated with each of these variables were significant when separately added to the logistic regression model. This suggests that controlling for any or all of these three variables in the Poisson model may modify the estimate of the risk associated with ESC. At present, there is insufficient data to allow for the control of each of these parameters. The implications of not controlling for these factors are addressed in the Discussion section.

5 IMPLICATIONS OF THE RESULTS BY JURISDICTION

The results presented in the previous section demonstrate that the fitment of ESC to the Australian and NZ vehicle fleet is associated with a reduction in the risk of single vehicle crashes and that the technology has been particularly effective in reducing the risk of single vehicle crashes involving 4WDs. This means that ESC will be of particular benefit to jurisdictions with a single vehicle crash problem and, more specifically, a single vehicle crash problem involving 4WDs.

Table 17: Distributions of post-1997 vehicles involved in crashes in which the driver was injured that occurred during 2001-2005 by crash type, broad vehicle category and jurisdiction

Jurisdiction	Vehicle Type	Multiple Vehicle	Single Vehicle	All Crashes
NSW	4WD	709 (4.6%)	214 (1.4%)	923 (5.9%)
	Car	12,375 (79.6%)	2,242 (14.4%)	14,617 (94.1%)
	All Vehicles	13,084 (84.2%)	2,456 (15.8%)	15,540 (100%)
VIC	4WD	576 (7.9%)	71 (1%)	647 (8.9%)
	Car	6,087 (83.3%)	576 (7.9%)	6,663 (91.1%)
	All Vehicles	6,663 (91.1%)	647 (8.9%)	7,310 (100%)
QLD	4WD	343 (4.2%)	163 (2%)	506 (6.2%)
	Car	6,296 (77.4%)	1,334 (16.4%)	7,630 (93.8%)
	All Vehicles	6,639 (81.6%)	1,497 (18.4%)	8,136 (100%)
WA	4WD	965 (8.8%)	296 (2.7%)	1,261 (11.5%)
	Car	8,412 (76.9%)	1,264 (11.6%)	9,676 (88.5%)
	All Vehicles	9,377 (85.7%)	1,560 (14.3%)	10,937 (100%)
NZ	4WD	179 (6.1%)	112 (3.8%)	291 (10%)
	Car	1,944 (66.6%)	685 (23.5%)	2,629 (90%)
	All Vehicles	2,123 (72.7%)	797 (27.3%)	2,920 (100%)
SA	4WD	313 (6.1%)	137 (2.7%)	450 (8.7%)
	Car	3,924 (76.1%)	781 (15.2%)	4,705 (91.3%)
	All Vehicles	4,237 (82.2%)	918 (17.8%)	5,155 (100%)
All	4WD	3,085 (6.2%)	993 (2%)	4,078 (8.2%)
	Car	39,038 (78.1%)	6,882 (13.8%)	45,920 (91.8%)
	All Vehicles	42,123 (84.2%)	7,875 (15.8%)	49,998 (100%)

Although Light cars and compact 4WDs were not included in the dataset used to derive the effectiveness estimates in the Results section, these categories were each included in the dataset used to create this table to give a more accurate representation of the 4WD/Car distribution within each jurisdiction's fleet

Based on these figures, different jurisdictions will derive different expectations of the benefits of ESC depending on their mix of single and multiple vehicle crashes and on the involvement of 4WDs in single vehicle crashes. Table 17 shows the distribution of drivers of vehicles manufactured after 1997 who were injured during the period 2001-2005 by vehicle type and crash type (single or multiple vehicle crashes). Unfortunately, with the data available, it was not possible to estimate the effectiveness of ESC in preventing serious injury crashes, nor was it possible to derive the distributions of serious injury crashes by crash type and vehicle type for each jurisdiction. Therefore, there is no certainty that the estimates of effectiveness in reducing driver injury crashes and the distributions by crash type and vehicle type for driver injury crashes reflect the analogous estimates of effectiveness and distributions when restricted to crashes in which the driver was seriously injured. However based on the results for driver injury crashes, it has been assumed in the following that ESC significantly reduces the risk of single vehicle crashes in which the driver was seriously injured and is particularly effective in reducing the risk of such crashes for 4WDs.

Table 17 shows that all six jurisdictions have a single vehicle crash problem, so the benefits of ESC that were demonstrated in this report are relevant to each jurisdiction. However, the proportion of injured drivers that were injured in single vehicle crashes varies between nine and 27% across jurisdictions. For New Zealand 27% of drivers were injured in single vehicle crashes, compared with 16% of New South Wales drivers, 18% of Queensland and South Australian drivers and 14% of Western Australian drivers. Of the drivers injured in the same period in Victoria, only 9% were injured in single vehicle crashes. Thus, the benefits (in terms of reducing the number of serious injuries) derived from increased fitment of ESC in new cars can be expected to be greater for New Zealand than jurisdictions such as Victoria. This means that although ESC fitment will provide benefits to Victorian road users, the technology addresses a type of crash which is particularly relevant to the New Zealand road safety situation.

Results from this study also showed that ESC was particularly effective in reducing single vehicle crashes involving 4WDs. Therefore, the technology would be particularly beneficial in jurisdictions were there is a high proportion of single vehicle crashes involving 4WDs. Table 17 shows that the proportion of driver injury crashes that were single vehicle crashes involving 4WDs ranged between 1 and 4 percent across the six jurisdictions. Nearly four percent of New Zealand crashes in which a driver was injured were single vehicle 4WD crashes, while for South Australia and Western Australia, the figure is just less than three percent. Victoria was the jurisdiction with the lowest proportion of driver injury crashes that were single vehicle crashes involving a 4WD (one percent).

Table 17 also shows that Western Australia was the jurisdiction with the highest number of drivers of 4WDs who were injured in single vehicle crashes in the period 2001-2005 (296 injured drivers, compared with 214 for NSW). This is perhaps surprising given the fact that NSW's population is over three times greater than that for Western Australia (ATSB, 2003). Assuming that each jurisdiction's distribution of injured drivers accurately reflects the distribution for seriously injured drivers, the long term benefits of ESC fitment in new 4WDs would be expected to be greater for jurisdictions such as Western Australia. This is because Western Australia appears to have a high absolute number of single vehicle crashes involving 4WDs when compared to other jurisdictions.

6 HISTORICAL AND PROJECTED ESC FITMENT RATES IN AUSTRALIA

Figure 1 shows the percentage of new cars sold in Australia between 2000 and November 2006 that have ESC as standard. This graph was derived from sales monitoring data collected by Polk Automotive Intelligence for VicRoads. The graph shows that in 2000, the fitment rate was very low; in fact it was close to zero percent. However, over the next three years, it gradually increased to five percent, and in the year from May 2003 to May 2004, the estimated rate doubled to ten percent. Since then, the percentage of new vehicles fitted with ESC as standard has continued to increase, but at different rates. Recently, the fitment rate has climbed from 15% in May 2006 to 25% in January 2007.

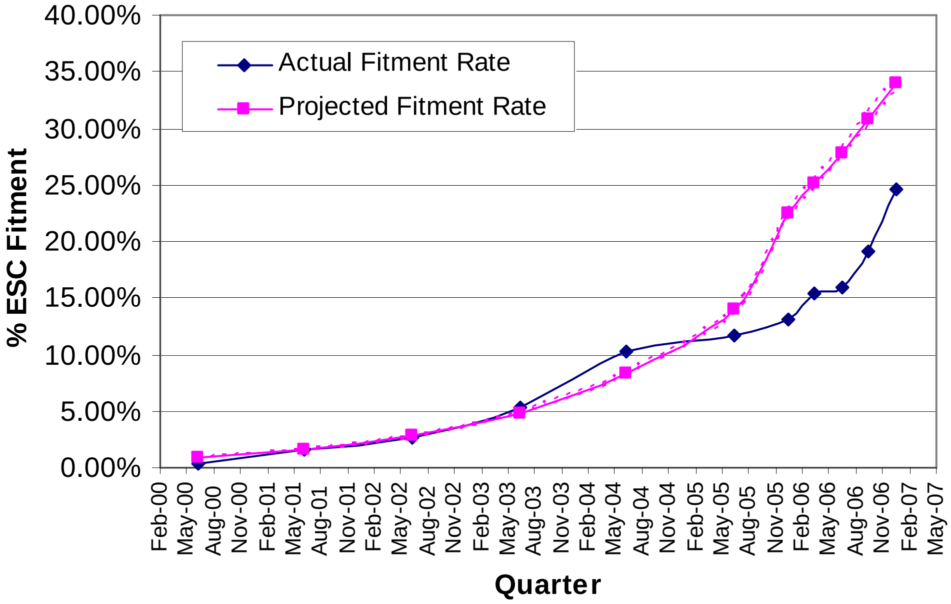

Figure 1: Percentage of new cars sold in Australia that have ESC fitted as standard (Actual fitment rates from Polk sales monitoring data)

Using the data collected by Polk for the period 2000-2005, a logistic regression model was fitted to the data from which to project ESC fitment rates beyond 2005. This was done at the request of VicRoads, who were interested in knowing whether the actual rate of fitment of ESC in the period after 2005 surpassed the rate that would be expected based on the take up of the technology prior to 2006. Data for new vehicles in the period 2000-2005 was used to create the predictive model as 2005 sales data was the most recently available data at the time the model was constructed. It was also the period before a major public education campaign on the benefits of ESC was launched. If the model was constructed using sales data up to 2007, the predicted fitment rates would differ to those shown in Figure 1. However Figure 1 gives a good indication of how ESC fitment rates for new cars in Australia have increased rapidly after only modest gains in the period from mid 2004 to early 2006. It can be seen that based on 2000-2005 data, modest gains during this period have resulted in present fitment rates being less than expected based on the 2000-2005 data. The expected rate of fitment at the start of 2007 was 35%, compared to the actual rate of 25%.

Making various assumptions about fitment rates beyond 2007, the number of new vehicles sold in the future and projecting the number of single vehicle crashes that we can expect to occur in the future, it is possible to make a rough estimate of the number of serious single vehicle crashes that ESC will prevent in the future.

Firstly, it was necessary to project the rate of fitment of ESC to new vehicles in the future. It can be seen from Figure 1 that since May 2004, the fitment rate has increase from 10% to 12% in May 2005 and then to 16% in May 2006 and to 25% in 2007. Therefore, for the last three years, the rate of fitment has increased by 2% and then 4% and then 9% annually. It is reasonable to assume that the rate of fitment will continue to increase in this fashion. Therefore, in this section, it is assumed that for the years 2008 and 2009, the rate of fitment to new vehicles increases by 18% and then 36% respectively. Therefore, as shown in the second column of Table 18, by 2010, 100% of new vehicles are assumed to be fitted with ESC, while in 2008 approximately 42% of new vehicles will be fitted with ESC and in 2009, 76% of new vehicles will be fitted with ESC. For simplicity, the fitment rate for 4WDs is assumed to be equal for both 4WDs and cars, even though Appendix B shows that the present fitment rate for medium-sized 4WDs are higher than that for other market groups. This assumption is not likely to have a great influence on the projected total reduction in serious single vehicle crashes as the medium 4WDs only make up a fraction of the vehicle population when compared with passenger cars. It is difficult to know whether these projections of ESC fitment accurately estimate actual future fitment rates. A 100% fitment rate for new vehicles by 2010 may seem optimistic, however a recent media release (Fedral Chamber of Automotive Industries, 2007) states that the fitment rate has increased by 15% (from 20% to 35%) in just twelve months, which suggests such a scenario is perhaps not unreasonable.

From the analysis on this study, it was estimated that ESC reduces the risk of a serious single vehicle crash involving a car by 27% and a single vehicle crash involving a 4WD by 68%. As noted, it was not possible to estimate the risk reduction associated with serious single vehicle crashes. However the true serious injury risk reductions for cars and 4WD are likely to be greater than the injury risk reductions quoted above. This is because previous international studies have shown that ESC is more effective in preventing more serious crashes (see Table 2 of this report). Never-the-less, this report will adopt the conservative figure of 27% reduction in serious single car crashes and 68% reduction in serious single 4WD reductions. This scenario where ESC is assumed to be effective in preventing serious single vehicle crashes will be compared against the scenario in which ESC has no effect on the risk of serious single vehicle crashes because it was not fitted. This allowed estimation of the number of serious crashes prevented due to the introduction of ESC.

In order to make this comparison, it is also necessary to estimate the number of new vehicles (i.e. passenger cars and 4WDs) sold each year. The Australian Bureau of Statistics (2007) provides this data for each year in the period 2000 to 2007 in their Sales of New Motor Vehicles publication. The aggregate number of new 4WDs and passenger cars sold each year in the period 2000-2006 is shown in the third column of Table 18. From 2007 onwards, the annual volume of new vehicle sales is assumed to be equal to that seen in 2006. Although it is true that annual sales are growing slowly with each passing year, such an assumption will not greatly affect the comparison of the two scenarios being considered.

Multiplying the fitment rates in the second column of Table 18 by the number of new vehicles for each year gives the number of new vehicles in each year that are fitted with ESC (see the fourth column). The fifth column gives the number of vehicles manufactured after 1999 that are in the fleet for each year in the period 2000-2014. The sixth column gives the number of these vehicles that are fitted with ESC.

The scrappage rate for the vehicles in this table is assumed to be zero. This is because, for vehicles aged less than five years, the scrappage rate for vehicles aged less than ten years is less than 5% (Newstead, Scully & Becker, 2007), and most of the vehicles that are scrapped are scrapped due to involvement in a crash. However, as the rate of increase of scrappage accelerates for vehicles aged more than ten years, the comparison of the two scenarios is not extended beyond 2014.

The seventh column of Table 18 gives the percentage of post-1999 vehicles in the Australian fleet that were fitted with ESC for each year in the period 2000-2014. It can be seen that by 2014, only 47% of the post-1999 fleet have ESC, even though all new vehicles from 2010 onwards have ESC fitted as standard. This shows the importance of a technology being introduced to the new vehicle fleet quickly once it's benefits have been demonstrated. The quicker the technology is fitted to all new cars, the sooner the majority of cars in the fleet will be benefiting from the increased safety offered by the feature.

The eight and ninth columns of Table 18 give the estimated number of serious single vehicle crashes involving post-1999 vehicles that would occur under each of the two scenarios. These estimates were derived using several assumptions. Firstly it was assumed that the risk of a vehicle becoming involved in a crash of any severity in any year is equal to 1.5%. This estimate of crash risk was taken from Scully, Newstead and Becker (2007) who used NSW crash and registration data to show that crash risk remains fairly constant over a vehicle's life. It was also assumed that if a vehicle is involved in a crash of any severity, the risk that it is a serious crash is about 2.25%. This is the serious injury risk associated with vehicles manufactured in 2004 as reported in the 2006 instalment of the Used Car Safety Ratings (Newstead, Watson & Cameron, 2006). Although Newstead, Cameron & Watson (2006) demonstrated that risk of serious injury for occupants of passenger vehicles is declining, the value of 2.25 was assumed as it is the best estimate of serious injury risk currently available. It was also assumed that 20% of vehicles involved in serious crashes (i.e. ones in which a road user was seriously injured) were involved in single vehicle crashes. This estimate is in line with the distributions of driver injury crashes shown in Table 17.

It can be seen that as the ESC fitment rate in 2000 was close to zero, for both scenarios, 37 serious single vehicle crashes involving new vehicles were estimate to occur. The tenth column shows that with each passing year, the gap between the estimated numbers of serious single vehicle crashes involving post-1999 vehicles under the two scenarios begins to widen with each passing year. In 2014, using the measures of effectiveness from Tables 12 and 13, 516 serious single vehicle crashes involving post-1999 vehicles are predicted, compared with 628 if ESC were not effective or were not available on any vehicles. This is a saving of 113 serious single vehicle crashes in 2014. The final column of Table 18 shows that if the ESC fitment rates shown in the second column were adopted in Australia, 480 serious single vehicle crashes would be prevented over the 15 year period from 2000-2014.

Table 18: Projected number of serious single vehicle crashes (SVC) involving post-1999 manufactured vehicles that would be prevented in the period 2000-2014 if the rate of increase in ESC fitment in new vehicles doubles until 2010 (Australia only)

Year	ESC fitment rate	New vehicles		Post-1999 vehicles		Proportion of post-1999 vehicles with ESC	Expected number of post-1999 vehicles involved in serious SVC		Serious SVC prevented per year	Serious SVC prevented (cumulative)
		Total	With ESC	Total	With ESC		Scenario 1: ESC not fitted	Scenario 2: 29% (cars) and 66% (4WDs) reduction in serious SVC		
2000	0.3%	545,830	1,561	545,830	1,561	0%	37	37	0	0
2001	1.6%	560,938	8,729	1,106,768	10,291	1%	75	74	0	0
2002	2.7%	587,146	15,762	1,693,914	26,053	2%	114	114	1	1
2003	5.3%	604,050	32,248	2,297,964	58,301	3%	155	154	1	2
2004	10.2%	630,939	64,397	2,928,903	122,698	4%	198	195	3	5
2005	11.7%	642,526	75,390	3,571,429	198,088	6%	241	236	5	11
2006	16.0%	637,461	101,866	4,208,890	299,954	7%	284	276	8	18
2007	24.6%	637,461	156,815	4,846,351	456,770	9%	327	315	12	30
2008	41.8%	637,461	266,714	5,483,812	723,483	13%	370	352	19	48
2009	76.3%	637,461	486,510	6,121,273	1,209,994	20%	413	382	31	79
2010	100.0%	637,461	637,461	6,758,734	1,847,455	27%	456	409	47	127
2011	100.0%	637,461	637,461	7,396,195	2,484,916	34%	499	436	64	191
2012	100.0%	637,461	637,461	8,033,656	3,122,377	39%	542	462	80	271
2013	100.0%	637,461	637,461	8,671,117	3,759,838	43%	585	489	96	367
2014	100.0%	637,461	637,461	9,308,578	4,397,299	47%	628	516	113	480

When interpreting the results of Table 18, the considerable list of assumptions used to derive these estimates should be noted. Not least of these assumptions is the level of market penetration assumed for ESC during the period to 2010. Appendix B of this report shows the current take up of ESC for each market group. It can be seen that since 2000, the rate of fitment of ESC has varied greatly between market groups. For example, the take up has been modest for small and light cars when compared with fitment rates for large, sports and luxury/prestige cars as well as medium and luxury 4WDs. The level of penetration of the technology into the small and light car market may determine whether the ESC fitment rate for the fleet as a whole follow that predicted in Table 18.

It should also be noted that as different market groups have different crashworthiness ratings (see Newstead, Watson & Cameron, 2006), increases in the rate of fitment in some market groups may translate to different levels of savings (in terms of serious crashes prevented) than increases in the rate of fitment of the same magnitude in another market group. For example, the risk of serious injury given involvement in a crash is much greater for light cars than other market groups. Installing ESC on all light vehicles may then have a greater affect on the burden of serious injury than if ESC was standard on all vehicles belonging to a more crashworthy market group. Of course, if most serious crashes involving light vehicles are multiple vehicle crashes, ESC will have a reduced impact based on the results of this study. This shows that the benefits associated with ESC within market categories are dependent not only on present fitment rates, but also the crashworthiness of the vehicles in the market group, the crash profile of serious crashes involving vehicles in that market group along with assumed overall crash rates and vehicle exposure.

7 DISCUSSION

Several overseas studies have established that ESC fitment to vehicles is associated with a reduction in the risk of certain types of crashes. However, the Australian and New Zealand vehicle fleet differs from that of Europe, the USA and Japan. Furthermore, general road and driving conditions in Australasian jurisdictions are different to those in other countries. As measures of effectiveness are likely to be influenced by these factors, it is important to determine whether previously reported measures of effectiveness for ESC translate to the Australian and New Zealand environments. This study is the first to provide estimates of the effectiveness of ESC in preventing crashes from occurring on Australian and New Zealand roads. The study was able to provide estimates relevant to the local driving environment by using crash data from five Australian states and New Zealand.

The methodology section of this report defines a procedure that can be used to identify vehicles equipped with ESC from records of Australian and New Zealand crashed fleets. This procedure can be employed in future evaluations of the effectiveness of ESC in Australasian jurisdictions.

The results of this study show that the fitment of ESC to vehicles in the Australian and New Zealand fleets was associated with a significant reduction in the risk of single vehicle crashes. Table 11 shows that ESC was effective in reducing the risk of single vehicle crashes of all severities by 29% ($p<0.0001$) and single vehicle crashes in which the driver was injured by 32% ($p=0.0002$). That ESC was most effective in reducing single vehicle crashes shows that the estimates of effectiveness derived using data from Australia and New Zealand are in line with results from international studies (Bahouth, 2005; Farmer, 2006).

Tables 12 and 13 show that ESC was more effective at preventing single vehicle crashes for 4WDs than for passenger cars, with ESC reducing the risk of single vehicle crashes of all severities by 55% ($p<0.0001$) for 4WDs compared with 24% ($p<0.001$) for passenger cars. Several international studies also found that for crash types in which ESC was effective in reducing risk for cars, the technology was even more effective in reducing crash risk for 4WDs (Dang, 2004; Farmer, 2006; Green & Woodrooffe, 2006). One reason why ESC is more effective in preventing single vehicle crashes when installed on 4WDs is that 4WDs are at greater risk of being involved in rollover crashes than passenger cars (Keall & Newstead, 2007). Green & Woodrooffe (2006) showed that in the USA, ESC is particularly effective in preventing rollover crashes.

There also appeared to be a trend for ESC to be more effective in preventing single vehicle crashes in which the driver was injured when compared to single vehicle crashes of all severities. This finding is also supported by the numerous international evaluations (Aga & Okada, 2003; Farmer, 2004; 2006; Kreiss, Schüler & Langwieder, 2005; Lie, Tingvall et al., 2006). For example, for single vehicle crashes involving 4WDs, ESC reduced the risk of driver injury crashes by 68% compared with 55% when all crash severities were considered. However, these differences were not significant. For single vehicle crashes involving passenger cars, there was only a small disparity between the estimates of effectiveness for single vehicle crashes of all severities and crashes in which a driver was injured (see Table 12). There is a need for future studies of ESC effectiveness in Australasia to give separate estimates of effectiveness for serious injury crashes. With the data available for this study, such analysis was not possible.

In contrast to these results, Tables 14, 15 and 16 were not able to establish the effectiveness of ESC in reducing the risk of multiple vehicle crashes. Although ESC was estimated to actually increase the risk of multiple vehicle crashes of all severities by 15% ($p<0.0001$) there are some concerns about the validity of this result due to potential biases in the analysis. Furthermore, when the sample of vehicles involved in multiple vehicle crashes were restricted to those in which the driver was injured, ESC appeared not to affect crash risk (the estimated risk reduction was 2%, $p=0.789$) which appears to be inconsistent with the result for all crash severity levels.

As noted, the estimated increased risk associated with multiple vehicle crashes was somewhat surprising and there are a number of reasons why this result should be viewed with some care at this preliminary stage of analysis. Based on previous evaluations, it would not be surprising to find that ESC had no effect on multiple vehicle crashes, but an increase the risk of multiple vehicle crashes was not expected. There are several reasons why ESC could be associated with an estimated increased risk of multiple vehicle crashes. Firstly, it is possible that the intervention of the technology in the pre-crash phase of an on-road scenario in which a multiple vehicle crash could occur actually increases the risk of the crash occurring. In some instances, avoiding a single vehicle crash through intervention of the ESC technology could conceivably results in a multi-vehicle crash instead. Alternatively, the increased multiple vehicle crash risk could be because drivers change the way they drive when they know that their vehicle is fitted with ESC and that this change in driving style increases their risk of involvement in multiple vehicle crashes. A third possible reason why ESC might have shown to be associated with increased risk of multiple vehicle crashes is that the sample of vehicles fitted with ESC was biased in such a way that multiple vehicle crashes involving at least one vehicle fitted with ESC were more likely to be reported to police than multiple vehicle crashes involving only vehicles not fitted with ESC.

The fact ESC was estimated to significantly increase the risk of multiple vehicle crashes of all severities but had no effect when multiple vehicle crashes were restricted to driver injury crashes indicates that the increased risk associated with ESC for multiple vehicle crashes is unlikely to be due to the intervention of the technology itself. ESC systems are designed to intervene when they sense the vehicle is not travelling in the direction that the steering wheel position indicates that it should be travelling. This is more likely to happen during the pre-crash phase of higher-speed multiple vehicle crashes than low-speed multiple vehicle crashes. Since driver injury is more likely to occur in high-speed crashes, if the intervention of ESC systems was causing increased multiple vehicle crash risk, it would be expected that this increased risk would be evident when multiple vehicle crashes were restricted to crashes in which a driver was injured. The fact that ESC has a no effect on this group of crashes suggests it is unlikely that the intervention of the technology increases multiple vehicle crash risk.

Similarly, if the presence of ESC in a vehicle was causing drivers to change the way they drove their vehicle, which in turn caused an increase in the risk of them being involved in a multiple vehicle crash, it would be expected that this would also increase the risk of multiple vehicle crashes in which a driver was injured. Therefore, while there is a possibility that the knowledge that ESC is fitted to a vehicle may cause a driver to change her or his driving style, this is unlikely to be the reason ESC increased risk of multiple vehicle crashes. However, the effect of ESC on driver behaviour is an area that should be studied in future evaluations. This issue is discussed in greater detail in Section 7.1.

The most likely reason for why ESC was estimated to increase involvement in multiple vehicle crashes of all severities is that the sample of ESC-fitted vehicles analysed in this report is biased towards more expensive vehicles since these are the vehicles that first became available with the technology. When such vehicles are involved in a minor collision, there is a greater chance that the crashes will be recorded on police accident databases. This is especially true for jurisdictions such as New South Wales, South Australia and Western Australia where one of the criteria for reporting of a crash in which nobody was injured is that the property damage caused by the crash exceeded a certain threshold value. The over-reporting of property damage only crashes in which one of the vehicles was fitted with ESC would explain why ESC was associated with an increase in the risk of multiple vehicle crashes of all severities, while having no effect when restricted to multiple vehicle crashes in which a driver was injured. Furthermore, this bias is unlikely to affect single vehicle crashes which are known to have a higher average damage level and hence a more consistent basis for reporting.

Reporting bias related to vehicle value in property damage only crashes is considered to present a serious threat to the validity of estimates of the effect of ESC on multiple-vehicle crashes of all severity levels. Based on this, these particular estimates should not be considered indicative of the true effectiveness ESC in multi-vehicle crashes where property damage crashes are included. At best then, the remaining results suggest that ESC has little effect in reducing multi-vehicle crashes in Australia and New Zealand although further investigation of the multi-vehicle crash effects of the technology is recommended when vehicles across a wider price range and fitted with ESC are available for analysis.

Crash reporting biases related to vehicle price affecting the multi-vehicle crash estimates of ESC effectiveness are also likely to affect the overall estimates of ESC effects across all crash types which includes multi-vehicle crashes. Table 8 shows that ESC actually increased overall crash risk by 7% (p=0.009) when considering all crash types. However, when the sample was restricted to crashes in which a driver was injured, ESC was shown to be effective in reducing the risk by 10%, although this estimate was only marginally statistically significant (p=0.103). Since a significant proportion of the total crash population is made up of multi-vehicle crashes, the estimates of ESC effectiveness on all crash types will be subject to the same reporting biases noted in interpreting the multi-vehicle crash effects above. An extension of this study at a later date when additional crash data and a wider range of vehicle types with ESC fitted are available is warranted to better establish the overall effectiveness of ESC on all crash types.

In Section 6, estimates of effectiveness for reducing single vehicle crashes were used to predict the number of serious crashes that would be prevented if ESC fitment rates in Australia steadily increased from their current levels so that all new vehicles sold in 2010 would be fitted with ESC. It was found that by 2014, if the rate of fitment in new vehicles increased from 25% in 2007 to 100% in 2010, an estimated 480 serious single vehicle crashes would be prevented across Australia. Proportionately smaller absolute reductions would be expected or New Zealand based on their smaller fleet size but noting the expected greater overall effects of the technology because of the higher single vehicle crash rate in New Zealand and the higher proportion of 4WDs involved in these single vehicle crashes.

7.1 EXCLUSION OF OTHER POTENTIAL CONFOUNDERS

Before concluding, it is important to articulate some limitations of the methodology that was employed to complete this evaluation.

The analysis undertaken in this study does not adjust for confounders related to differences in how ESC vehicles are driven when compared to vehicles not fitted with ESC. Previous studies have been restricted to only adjusting for a small number of confounders because of limitations of the data available. However some studies did attempt to adjust for differences in the way ESC equipped vehicles were driven. Such studies adjusted their analysis using confounders such as driver age, driver sex, road conditions and whether the crash occurred at high speed.

Furthermore, Section 4.4 of this report showed that while the risk of involvement in a rear end impact may not be influenced by ESC fitment status, it may be influenced by the age and sex of the driver as well as the condition of the road surface. As each of these confounders may be correlated with ESC status, not controlling for them may result in a biased exposure measure.

Table 19 helps determine whether these confounders have biased the results presented in the present report. This table shows the distribution of vehicles involved in rear end impacts by ESC fitment status and the role of the vehicle in the crash (i.e. whether the vehicle was the striking vehicle or the target vehicle). These data are the same as the data used in the analyses presented in the Results section, except cases in which it was unknown whether the vehicle was the striking or struck vehicle in the rear end impact were excluded. This meant that all vehicles from NSW were excluded.

If there were differences in the way vehicles fitted with ESC were driven compared to the way vehicles not fitted with ESC were driven, and that these differences affected the assumption that ESC has no influence on rear end crashes, we would expect that the odds of a vehicle being rear-ended given involvement in a rear impact collision would differ for ESC-fitted vehicles and vehicles without ESC.

Table 19: Distribution of vehicles involved in rear end impacts by the role of the vehicle in the impact and whether the vehicle was fitted with ESC (NSW cases and cases where the role was unknown have been excluded)

Type of Rear End Impact	Electronic Stability Control in Vehicle		Total
	No	Yes	
Rear ended by another vehicle	30,104 (57.4%)	1,036 (62.6%)	31,140 (57.6)
Rear ended another vehicle	22,334 (42.6%)	618 (37.4%)	22,952 (42.4%)
All rear end impacts	52,438 (100%)	1,654 (100%)	54,092 (100%)

Table 19 shows that 63% of vehicles with ESC were rear ended in a rear end crash, compared 57% of vehicles without ESC. Thus, there isn't a great deal of difference in the distribution of the vehicle's role for vehicles fitted with ESC and those not fitted with ESC. This suggests that ESC only has a small effect on the way vehicles are driven. Since this report showed that the benefits of ESC fitment for preventing single vehicle crashes were very high (i.e. approximately 30% risk reduction for all vehicles and about 60% for 4WDs), it is unlikely that this relatively small difference will change the general pattern of conclusions regarding the effectiveness of ESC in preventing single vehicle crashes in particular.

8 CONCLUSIONS

This study aimed to evaluate the effectiveness of ESC systems in reducing crash risk and to establish whether estimates of effectiveness published in overseas studies translated to Australian and New Zealand environments. The study devised a methodology to identify which vehicles in crash data from five Australian states and New Zealand definitely had ESC fitted. This identification process enabled the crash profile of ESC-fitted vehicles to be compared with vehicles not fitted with ESC. Rear end impacts were used as an induced exposure measure to determine whether ESC-fitted vehicles were at greater or less risk of involvement in different types of crashes than vehicles not fitted with ESC.

It was found that ESC was effective in reducing the risk of single vehicle crashes and particularly effective in reducing the risk of single vehicle crashes when fitted to 4WDs. Specifically, ESC reduced the risk of involvement in single vehicle crashes of all severities by 24% for cars and 55% for 4WDs. Evidence was also presented that suggested that ESC was more effective in preventing crashes that resulted in driver injury than in preventing less serious crashes. However, the data available did not enable estimation of the effectiveness of ESC in preventing crashes resulting in serious injury. The effect of ESC on multiple vehicle crashes in Australia and New Zealand was not clear from this preliminary analysis.

Using the estimates of the reduction in risk of involvement in single vehicle crashes in combination with past and projected future ESC fitment rates, the future benefits of the technology were predicted for the Australian fleet. It was estimated that by 2015, over 450 serious crashes would have been be prevented if current fitment rates were increased so that by 2010 all new vehicles have ESC fitted as standard.

Further analysis of ESC effectiveness in Australasia is recommended in the future to establish whether the effectiveness estimates obtained here remain and to more closely examine differential effects of the technology by crash and vehicle type.

9 RECOMMENDATIONS FOR FURTHER RESEARCH

Evaluation studies that use crash data to evaluate a safety feature rely on there being a sufficient amount of suitable data available. The present study attempted to maximise the datasets used for analysis by including as many ESC-equipped vehicles in the analysis dataset as possible. This involved a labour-intensive process of examining the Vehicle Identification Numbers (VIN) of crashed vehicles in the crash data files and comparing them to VIN in data sources that described the specifications available on different models of vehicles (see Section 2.1 for details of this process). The sample of crashed vehicles fitted with ESC will increase as new crash data becomes available each year. Using this additional data in a follow-up study should increase the accuracy of reported measures of effectiveness.

Furthermore, a follow-up study will help determine whether the effectiveness of ESC in reducing single vehicle crashes is susceptible to a learning effect. Lie, Tingvall et al. (2006) noted that it is possible that over a period of time, drivers of ESC-equipped vehicles may adapt their driving behaviour.

Although this report has already identified vehicles manufactured prior to 2006 that definitely have ESC fitted, future evaluations will benefit greatly if data on the safety features of newly registered vehicles becomes more readily available. This would best be achieved by vehicle manufactures directly encoding the presence of safety features such as ESC into the VIN of vehicles they produce and making these codes publicly available.

With the additional data available, future evaluations of ESC could adjust for additional potential confounders. This would eliminate any remaining doubt that the sample being analysed is unbiased.

The present evaluation only provided estimates of effectiveness for broad categories of crashes, i.e. single vehicle crashes and multiple vehicle crashes. With the additional data available, future evaluations should have the power to enable estimates of effectiveness to be derived for finer classifications of crashes. For example some international studies have shown that ESC is more effective at preventing rollover crashes than other types of single vehicle crashes (Farmer, 2006; Green & Woodrooffe, 2006). Estimates of effectiveness for a greater range of crash types will enable individual jurisdictions to estimate the benefits of ESC relevant to their particular crash problems. Similarly, it would be useful if future evaluations gave separate estimates for different road conditions, as Swedish studies have shown that measures of effectiveness are dependent on road conditions (Lie, Tingvall et al., 2004; 2006) and for more specific classifications of vehicles that the car versus 4WD dichotomy considered here.

A limitation of the present study is that with the data available, it was not possible to evaluate ESC with respect to its effectiveness in preventing crashes that result in serious injury. If this data limitation could be overcome, such measures of effectiveness would be very valuable in realising the true benefits of the technology in terms of lives saved and serious injuries prevented.

Finally, with the availability of more data, it is possible that future evaluations could compare the effectiveness of ESC by vehicle make. Different manufacturers use different ESC systems and also calibrate their systems differently. If an evaluation could determine what system and calibration are most effective in Australian and New Zealand environments, the most effective system could be made available on all new models. This would increase the overall effectiveness of the technology.

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APPENDIX A – VEHICLES FITTED WITH ESC

Table A.1: A list of the market group, make, model, year of manufacture values of the 7,698 vehicles identified as having Electronic Stability Control in the analysis sample used in this report

Market Group	Make	Model	Year of Manufacture	Number of Vehicles
4WD- Medium to Large	BMW	X5	2000-2005	190
	Holden	Adventra	2003-2005	18
	Honda	MDX	2003-2005	35
	Jeep	Grand Cherokee WH	2005	3
	Lexus	RX330	2002-2005	89
	Mercedes-Benz	M-Class W163	1998-2005	331
	Mitsubishi	Pajero NM / NP	2003-2005	104
	Nissan	Murano	2005	5
	Porsche	Cayenne	2003-2005	9
	Rover	Range Rover	2002-2005	28
	Toyota	Lancruiser	2000	18
		Landcruiser Prado	2003-2005	124
	Volkswagen	Touareg	2003-2005	22
	Volvo	XC 90	2002-2005	38
Large	Audi	A8	2001	1
	BMW	6 Series E63	2004	1
		7 Series 1995-2001	1998-2000	6
		7 Series 2002-2007	2002-2004	24
	Holden	Commodore VY	2004-2005	254
		Statesman/Caprice WK/WL	2002-2005	18
	Hyundai	Sonata NF	1999-2005	6
	Jaguar	S-Type	2001-2004	23
		XJ	1998	1

		XJR	1998	1
		XK8	2000-2003	2
	Mercedes-Benz	CL500/600 W215	2004	1
		CLS W219	2005	3
		S-Class W129	2000-2001	2
		S-Class R230	2001-2005	5
		S-Class W220	1999-2004	59
		SLK R171	2004-2005	5
	Nissan	Maxima	2003-2005	92
	Peugeot	607	2003	1
	Toyota	Lexus ES300 II	2001-2005	20
		Lexus GS300/430/450h	2005	2
		Lexus LS430	2000-2003	11
		Lexus SC430	2001-2002	5
	Volvo	850/S70/V70/C70	1999-2002	16
		S80	1999-2004	33
Luxury/Prestige	Alfa Romeo	147	2001-2004	54
		156	2003	10
	Audi	A4	1999-2004	114
		A4 B6	1999	45
		A4/S4 Cabriolet	2003-2004	6
		A8	2002-2003	2
	BMW	1 Series E87	2003-2004	2
		3 Series 1992-1998	1998	192
		3 Series 1999-2007	1999-2004	1,116
		5 Series 1996-2007	1998-2003	190
		5-Series E60	2001-2004	9
		6 Series E63	2004	1
		7 Series 1995-2001	1999-2001	4
		7 Series 2002-2007	2002-2004	14

		8 Series	1998	1
		Z3	1998-2000	14
	Citroen	C5	2002-2003	7
	Holden	Statesman/Caprice WK/WL	2004	1
	Honda	Accord Euro	1999-2004	86
	Jaguar	S-Type	2002-2003	16
	Mercedes-Benz	A-Class W168	1998-2003	116
		C-Class W202	1998-2000	4
		C-Class W203	2000-2003	63
		CL500/600 W215	2000-2001	4
		CLK C209	2002-2004	28
		CLK W208	1998-2002	114
		E-Class W210	2000-2002	82
		E-Class W211	1998-2004	49
		S-Class W129	1999-2001	3
		S-Class R230	2001-2004	9
		S-Class W220	1999-2004	46
	Nissan	Maxima	2001-2004	30
	Peugeot	607	2001-2003	5
	Saab	9-3 II	2002-2003	13
	Toyota	Lexus ES300 II	2001-2003	18
		Lexus IS200	2001-2003	15
		Lexus LS430	2000-2003	15
	Volkswagen	Passat 1998-2007	2002-2004	35
	Volvo	850/S70/V70/C70	1999-2003	12
		S40/V50	2004	2
		S60	2000-2003	44
		S80	1998-2003	17
		V40/S40	2000-2002	11
		XC 90	2003-2004	10

Medium	Alfa Romeo	147	2001-2002	5
		156	2003	4
		147	2001-2005	68
		156	2003	11
	Audi	A6/S6/Allroad	2001-2004	6
		A6/S6/Allroad 2005-2007	2005	1
		TT	2000-2005	41
	BMW	3 Series 1992-1998	1998	157
		3 Series 1999-2007	1999-2004	1,052
		3 Series E90	1998-2005	9
		5 Series 1996-2007	1998-2003	140
		5 Series E60	2003-2005	30
		Z3	1998-2002	30
		Z4	2003-2005	10
	Chrysler	Crossfire	2004-2005	6
	Citroen	C5	2003	1
	Honda	Accord Euro	2002-2005	286
	Mazda	RX8	2003-2005	57
	Mercedes-Benz	B-Class W245	2005	1
		C-Class W202	1998-1999	4
		C-Class W203	1999-2005	385
		CLK C209	2002-2005	59
		CLK W208	1998-2002	81
		E-Class W210	2000-2002	65
		E-Class W211	2002-2005	80
		SLK W170	1999-2002	8
	Nissan	350Z	2003-2004	7
	Peugeot	407	2004-2005	7
	Renault	Laguna	2005	1
	Saab	9-3 II	2002-2005	22

	Subaru	Liberty	2000-2003	103
		Liberty/Outback	2004-2005	9
	Toyota	Lexus IS200	2001-2003	14
	Volkswagen	Passat 1998-2007	2002-2005	33
	Volvo	S60	2000-2004	44
Small	Audi	A4	1999-2003	59
		A4 B6	1999-2005	149
		A4/S4 Cabriolet	2002-2004	11
	BMW	1 Series E87	2004-2005	18
	Citroen	C4	2005	1
		Xsara	2003-2004	2
	Ford	Focus LS	2004	1
	Holden	Astra TS	2003-2004	73
	Mercedes-Benz	A-Class W168	1998-2004	147
		A-Class W169	2005	5
	Mitsubishi	Lancer CH	2004	1
	Peugeot	307	2002-2005	22
	Renault	Megane II	2005	1
	Toyota	Mr2 Zzw30R	2003-2004	6
	Volvo	S40/V50	2003-2005	18
		V40/S40	2000-2002	6
Sports	Audi	TT	2000-2002	21
	BMW	Z3	1998-2002	17
		Z4	2003-2004	9
	Mazda	RX8	2003-2004	18
	Mercedes-Benz	SLK W170	2000-2003	18
	Nissan	350Z	2003-2004	7
	Smart	Roadster	2003-2004	3
	Toyota	Lexus SC430	2001-2003	11
		MR2 ZZW30R	2003-2004	2

APPENDIX B – PROJECTED AND ACTUAL ESC FITMENT RATES IN AUSTRALIA BY VEHICLE MARKET GROUP

Figure B1: *Projected and Actual Rates of ESC Fitment to New Vehicles in Australia: Light Cars*

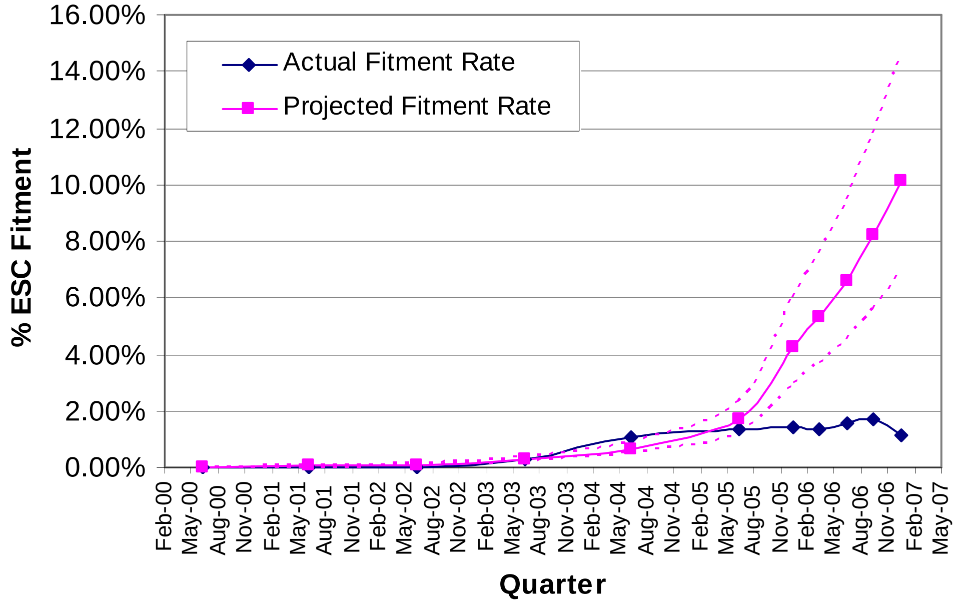

Figure B2: *Projected and Actual Rates of ESC Fitment to New Vehicles in Australia: Small Cars*

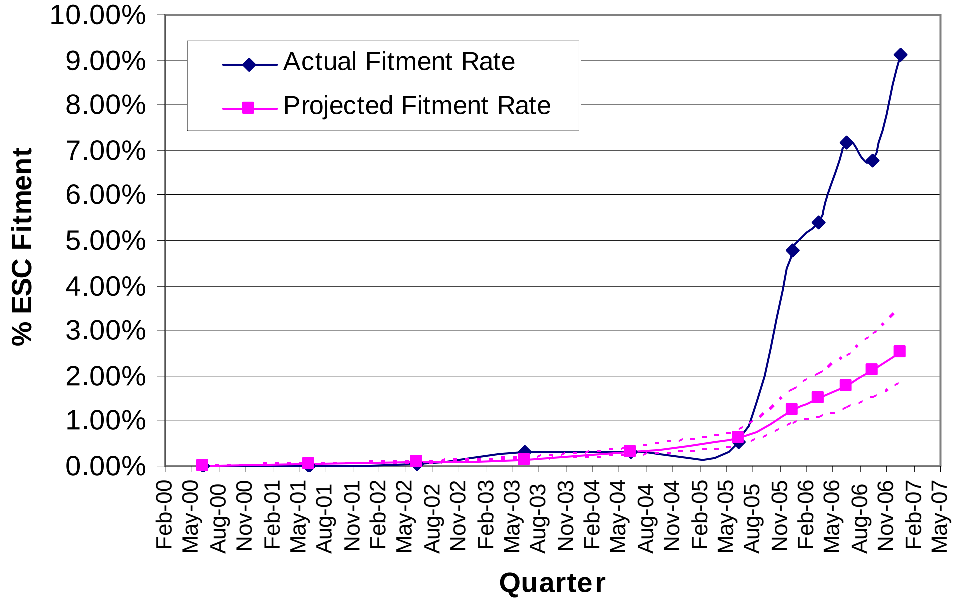

Figure B3: *Projected and Actual Rates of ESC Fitment to New Vehicles in Australia: Medium Cars*

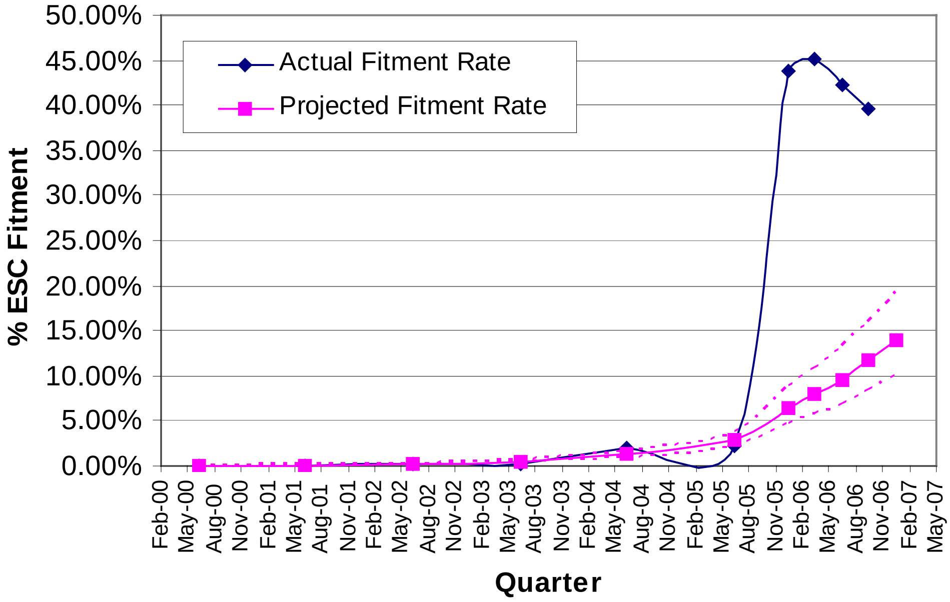

Figure B4: *Projected and Actual Rates of ESC Fitment to New Vehicles in Australia: Large Cars*

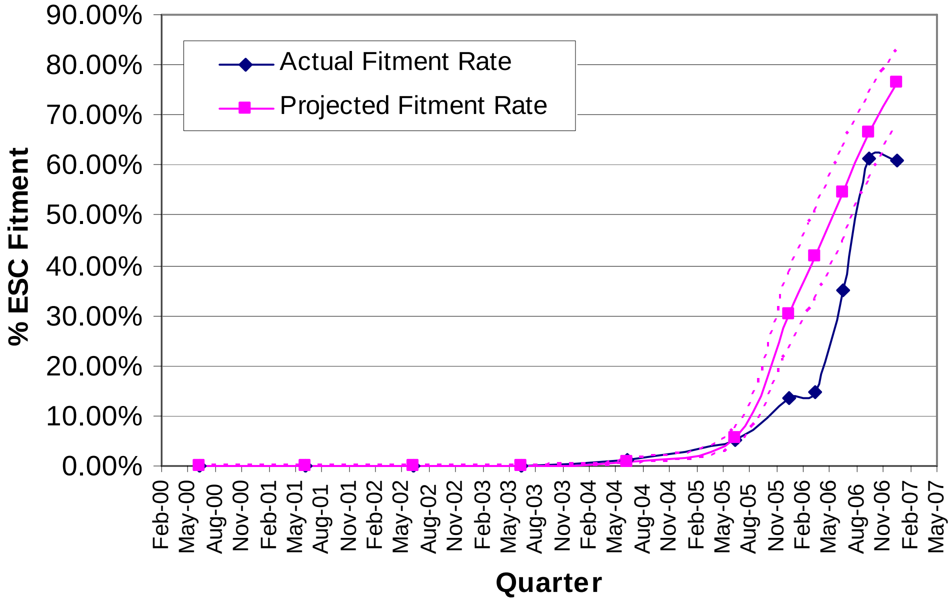

Figure B5: *Projected and Actual Rates of ESC Fitment to New Vehicles in Australia: People Movers*

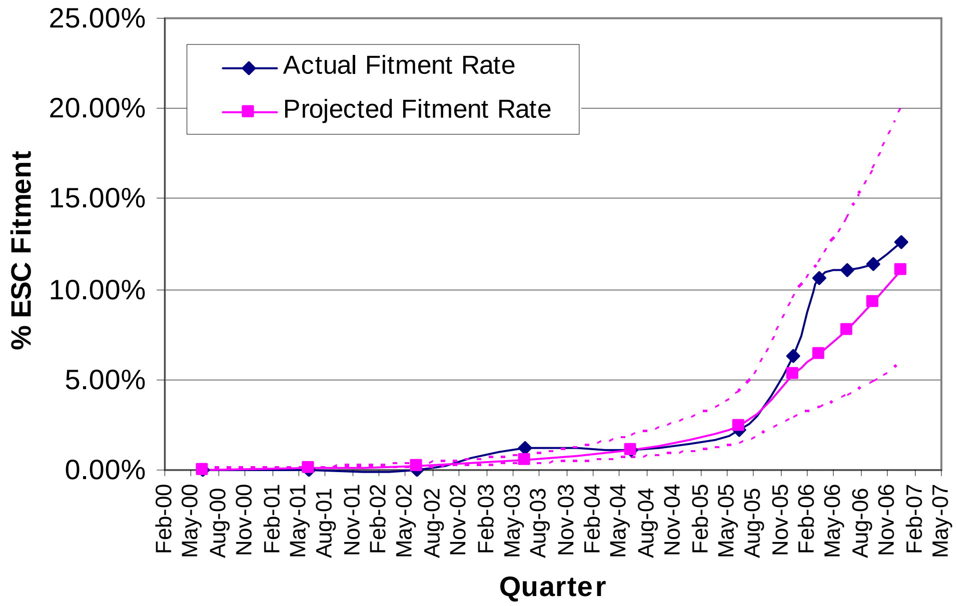

Figure B6: *Projected and Actual Rates of ESC Fitment to New Vehicles in Australia: Sports Cars*

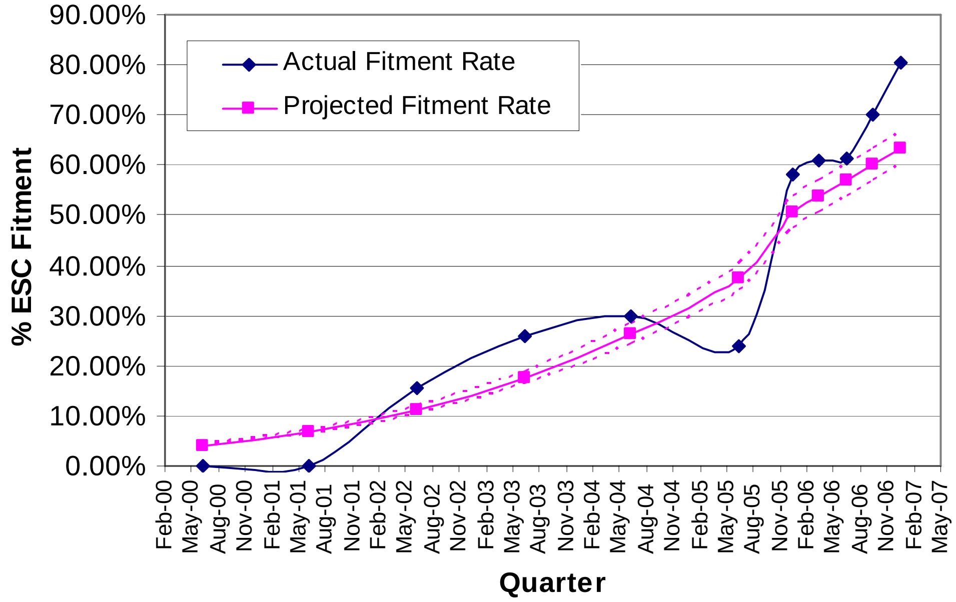

Figure B7: *Projected and Actual Rates of ESC Fitment to New Vehicles in Australia: Prestige Cars*

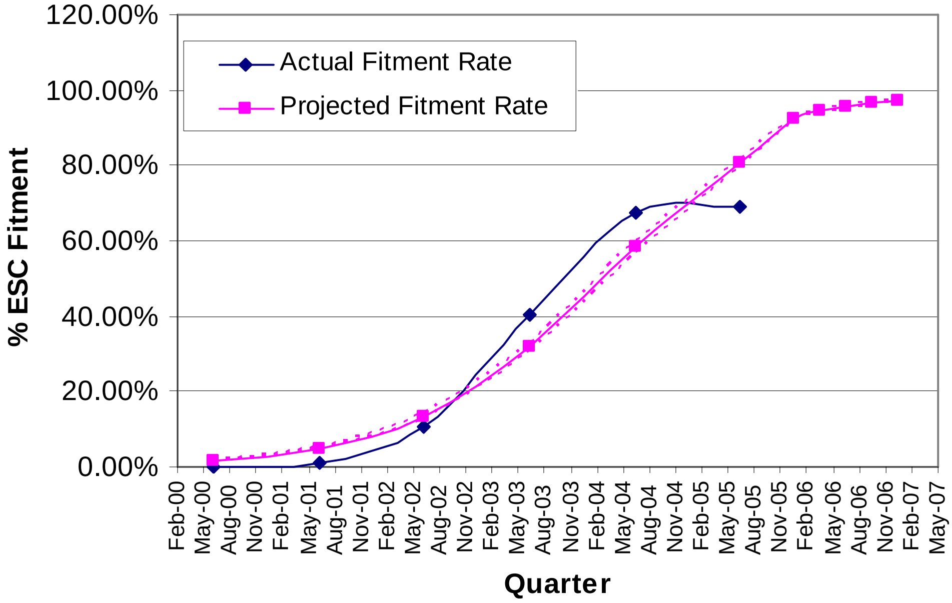

Figure B8: *Projected and Actual Rates of ESC Fitment to New Vehicles in Australia: Luxury Cars*

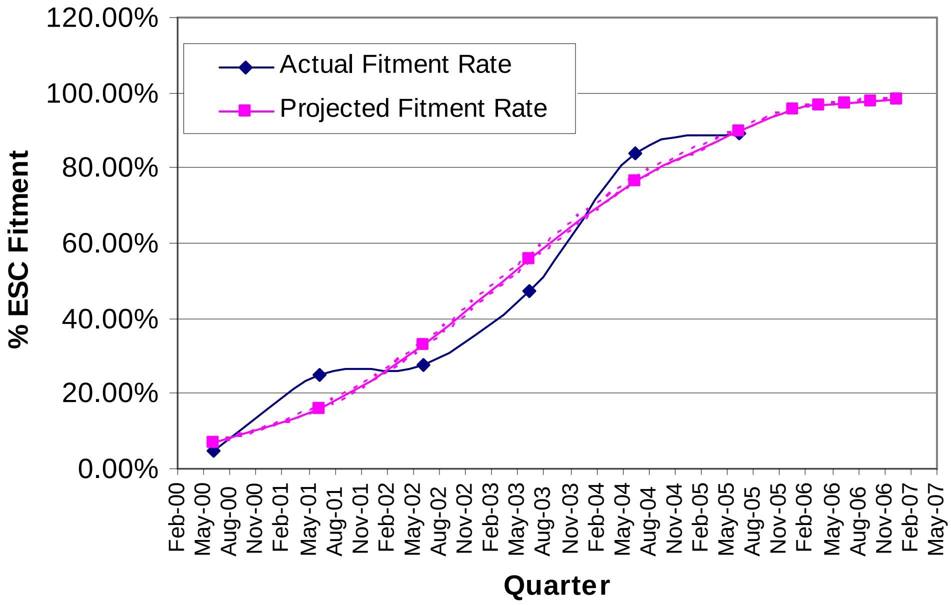

Figure B9: *Projected and Actual Rates of ESC Fitment to New Vehicles in Australia: Compact 4WDs*

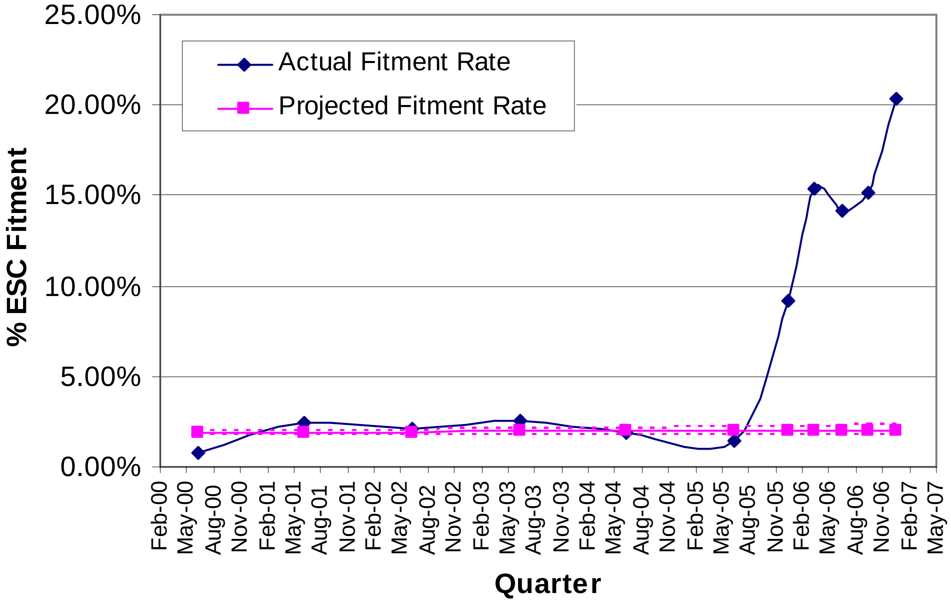

Figure B10: *Projected and Actual Rates of ESC Fitment to New Vehicles in Australia: Medium 4WDs*

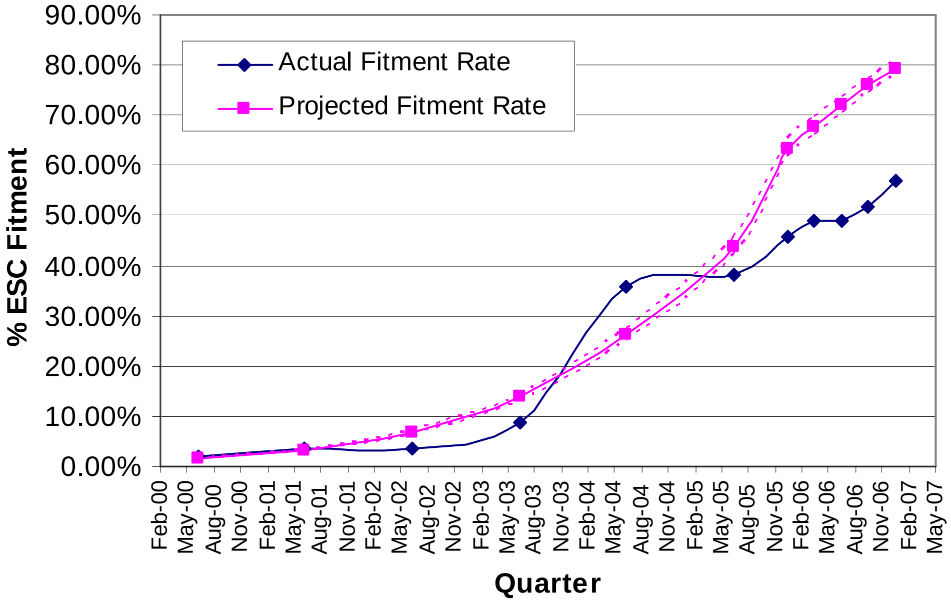

Figure B11: *Projected and Actual Rates of ESC Fitment to New Vehicles in Australia: Large 4WDs*

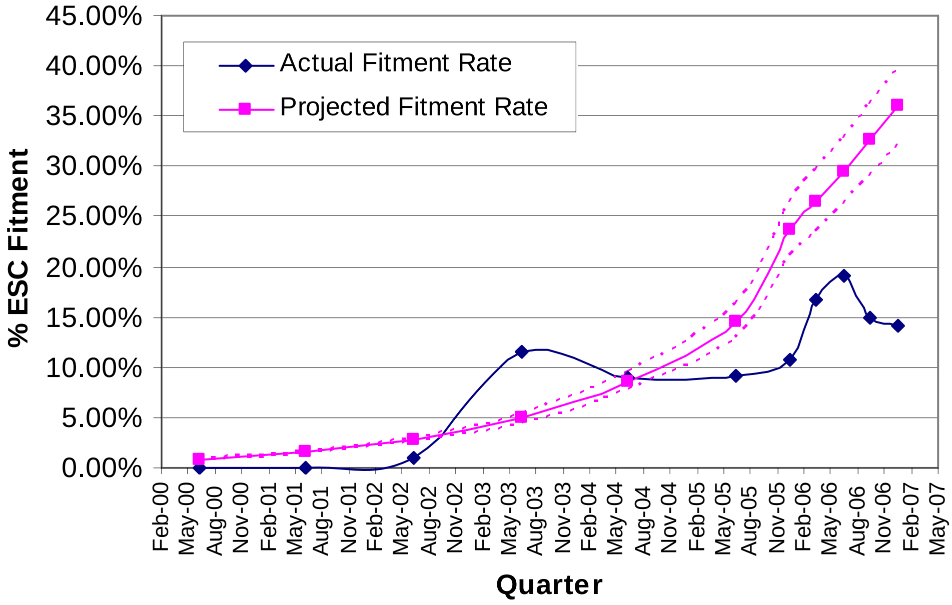

Figure B11: *Projected and Actual Rates of ESC Fitment to New Vehicles in Australia: Luxury 4WDs*