Estimated Fatality Reduction by the Use of Electronic Stability Control from 2016 Fatal Crashes

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Abstract

The Transport Accident Commission has persistently campaigned in support of the safety benefits of various vehicle technologies, including Electronic Stability Control (ESC). ESC has been demonstrated to be an effective countermeasure in Australia, leading to reductions in loss of control situations that result in serious injuries and fatalities (Scully & Newstead, 2010). Recent analysis of 2016 Victorian fatal crashes, where ESC could have been effective (lane departure, n=140), estimated the potential for ESC to have saved lives in these crashes. It was estimated that 41 deaths could have been avoided, had the crash involved vehicles been fitted with ESC.

Background

Since 2011, ESC technology has been mandated for all new passenger vehicle models in Australia and from 2013 all new passenger vehicles must have ESC (Dept. Infrastructure and Transport, 2009). However, approximately 31% of all cars registered in Victoria in 2016 were fitted with ESC (2016, ABS census). ESC is effective in assisting drivers to avoid loss of control events (Lie, Tingvall, Krafft & Kullgren, 2006). Lane departure events sometimes result from loss of control situations, which are generally sensitive to the effects of ESC. A detailed analysis of fatal crashes that involved a lane departure event and occurred in Victoria during 2016 was completed.

Method

The Transport Accident Commission, Monash University Accident Research Centre and the Swedish Transport Administration conducted a desk based analysis of Victorian road deaths that occurred in 2016, using fatality data reported by Victoria Police, to assess the role that ESC could have played in preventing fatalities. Previously, research using similar methodology had been conducted by Langwieder, Gwehenberger, Hummel & Bende, in 2003 and also Sferco, Page, Le Coz & Fay in 2001. This study focused on the following. There were 277 crashes resulting in 291 road deaths in 2016. Of these, 140 lane departure crashes were selected on the basis that they appeared to be loss of control situations and therefore were likely to be ESC sensitive crashes. Loss of control events occur when the vehicle does not respond as expected, to the driver's steering input. These typically result from oversteer or understeer when the friction force is exceeded. After detailed investigation, it was determined that this sample of lane departure crashes included loss of control crashes (ESC-sensitive) and those crashes without loss of control (ESC-insensitive). For each of the 140 lane departure fatalities, the likelihood that ESC would have prevented the fatal outcome, had it been installed in the vehicles, was estimated. Evidence of ESC's effectiveness under different circumstances was applied to assess the likelihood of fatality avoidance for each crash. The study sample contained cars with and without ESC.

Each of the fatal lane departure crash circumstances resulting in 140 fatalities were individually evaluated by experts[1]. A decision was made for each crash, assessing whether it was a loss of

[1] The experts included the authors plus the acknowledged researchers.

control situation, thereby distinguishing ESC-sensitive from ESC-insensitive crashes. Judgements were made for each crash based on two categories: where ESC was fitted and where ESC was not fitted, in the vehicle(s) that experienced loss of control.

The following criteria were used to evaluate each crash and likelihood ratings were applied to each crash.

Was ESC relevant (ESC-sensitive) or not (ESC-insensitive) in this particular crash?
If yes, a likelihood rating, that functioning ESC could have prevented the fatal outcome, was decided for each crash. The ratings applied were: Very Low, Low, Medium or High (Table1.)
If ESC was not relevant in the crash (ESC-insensitive), the "Not Applicable" rating was assigned (Table 1).

Table 1. Likelihood ratio matrix used to assign a rating factor by experts in determination of each lane departure crash investigated

Likelihood that ESC could have avoided fatal crash outcome	**High**	**Medium**	**Low**	**Very Low**	**Not Applicable**
Rating: Arbitrary ESC prevention factor	0.8	0.5	0.1	0.05	Not Applicable

The likelihood ratings were assigned by crash investigation experts based on their specialist knowledge of ESC effectiveness and limitations in different circumstances. These determinations were the subjective opinion of the experts based on their prior research and knowledge of ESC effectiveness and limitations. For fatalities with higher ESC prevention factors assigned to them, the likelihood of fatality prevention was higher (0.8) therefore resulting in a higher number of preventable deaths than those in the very low ESC prevention category (0.05), or not applicable, with no ESC prevention factor. The not applicable assigned crashes were not included in the number of preventable fatalities.

The number of ESC preventable deaths was calculated by multiplying the number of fatalities assigned to each likelihood category by the corresponding prevention factor. The sum of these results formed the estimated number of preventable deaths. No single fatality was determined to have been 100% preventable by the introduction of functioning ESC.

The Victoria Police (VicPol) Traffic Incident System (TIS) reports from each crash were analysed, including crash reconstructions and photographs where this information was available. These TIS reports were extracted from by TAC, on the basis of the crash type recorded by VicPol attending members at the time of the crash.

Additional research into the specific vehicles involved was completed to determine whether or not they were fitted with ESC. Each VIN was looked up, however due to limitations in freely available Australian data from certain vehicle manufacturers, it was impossible to determine definitively, in all cases for certain models, whether or not ESC was present. In multi vehicle crashes, the vehicle that lost control was the focus of this ESC assessment. Of the vehicles involved in fatal crashes, 102 did not have ESC, 31 had ESC and for 7 vehicles, the presence of ESC was unable to be determined (Table 2). The crashes in which ESC equipped vehicles were involved were mostly not involving loss of control. There were some loss of control situations that involved a vehicle fitted with ESC.

Despite having ESC, there were cases where vehicle did not respond as expected. Where ESC was present and driver input evident, it was considered likely that the ESC had been switched off manually prior to the crash in some cases. Lack of seatbelt use was highly likely to have contributed to the fatal outcome in ESC fitted, ESC sensitive cases. In other ESC fitted, ESC sensitive cases, circumstances such as post impact fire could have also caused fatal outcomes.

Table 2. ESC fitment rate in the vehicles in which deaths occurred, based on available evidence.

Was ESC fitted?	Yes	No	Maybe
	29	105	6

Note: Potential exists for some of these to be incorrect despite best efforts to assess the specific crash involved vehicles.

The following questions summarise those answered by the seven experts about each crash, in order to assess the likelihood of ESC preventing the fatal outcome:

- Is there reasonable evidence to indicate that this crash involved loss of control?
- Was driver input evident, such as steering or braking, to determine that ESC could have had an effect on the crash circumstances, had ESC been fitted or functioning?
- If sufficient driver input was evident, was it likely that ESC could have altered the crash dynamics to avoid the crash completely or reduce the severity of the crash?
- Was the driver distracted, fatigued, asleep or otherwise impaired by substances (alcohol, licit or illicit drugs) at the time of the crash?
- Was the condition of the road surface and the area around the road rough or smooth, wet, dry or icy and was it sealed or unsealed?
- What were the road and road shoulder gradient(s)?
- What was the speed of travel at the time of the loss of control incident?

The following rules were applied in determining likelihood:

- o If there was no evidence of evasive action such as steering input having been taken by the driver, then ESC effectiveness likelihood was rated not applicable.
- o In cases where driver fatigue was evident as the cause of crash, ESC was deemed to not be relevant, as these were not considered to be loss of control crashes. These were for cases where the driver was thought to have been asleep, rather than ‘fatigued’.
- o In cases where driver distraction, alcohol and or drug use was evident, ESC was deemed to be relevant. Only minimal driver input is required for ESC to be effective. However, if the driver was unconsciousness, there would be no evasive input and not included as a loss of control case.
- o If the speed was very high for the driving situation then the likelihood of ESC effectiveness was given a lower rather than higher rating. Higher speeds allow less

time per distance travelled for ESC corrective actions to prevent crashes in a loss of control situation.

Additional investigation (this was not a factor in the determination of likelihood):

If ESC was fitted in the vehicle which experienced loss of control, did ESC function as expected under the specific crash circumstances?

This sample invites further investigation across a broader sample of fatal or non-fatal injurious crashes to identify safe system factors where targeted preventative countermeasures could be implemented. As this extends past the main theme of the paper, it was completed as a demonstration assessing a sample of the crashes, rather than all crashes.

Table 3 shows the total number of fatal lane departure crashes analysed, the number of deaths and whether they were single or double fatality crashes.

Table 3. Number of fatal crashes, fatalities and whether there were one or two fatalities in each crash analysed in this study

Single or Double fatality crash	Number of crashes	Number of Fatalities
Single	122	122
Double	9	18
TOTAL	**131**	**140**

Results

Of 291 Victorian road deaths in 2016, 140 deaths occurred in lane departure crashes (131 crashes in total). It was estimated that 41 deaths could have been avoided had the involved vehicles had ESC (Table 4). Table 4 shows the breakdown of overall judgements made about the likelihood of ESC fatality prevention in ESC sensitive crashes and those judged to be ESC-insensitive and not applicable (NA = Not Applicable).

Table 4. Number of fatalities assigned to each ESC preventable likelihood ratio, corresponding multiplicative factor and calculation of the number of preventable fatalities, with ESC

Likelihood ratio	High	Medium	Low	Very Low	NA	Total
Arbitrary ESC prevention factor	0.8	0.5	0.1	0.05	0	-
Fatalities	36	22	13	8	61	140
Preventable fatalities	28.8	11	1.3	0.4	0	**41.5**

Note: The final figure was chosen to be conservatively rounded down from 41.5 to 41.

Of the preventable deaths, 10 were of the head on crash type, the remaining 31 were single vehicle run-off-road crashes into fixed objects or roll-overs. Table 5 shows the numbers of fatal crashes and those likely to be avoided with ESC in terms of the speed zones where they occurred and the crash types.

Table 5. Lane departure fatalities and number determined to have been avoided, by crash type and posted speed zone

	Head On		Single Vehicle		TOTAL		
Speed Zone *(km/hr)*	**Number of fatalities**	**Fatalities avoided**	**Number of fatalities**	**Fatalities avoided**	**Number of fatalities**	**Fatalities avoided**	**Proportion of fatalities avoided**
< 60	8	3.5	16	3	24	6.5	27%
70 - 90	9	1.6	15	6.4	24	8	33%
100 - 110	32	5	60	22	92	27	29%
TOTAL	**49**	**10.1**	**91**	**31.4**	**140**	**41.5**	**29%**

Each fatal crash involved vehicle was assessed as to whether it was equipped with ESC. Of the 140 fatalities, 105 vehicles involved were found to not have ESC fitted, 29 vehicles were fitted with ESC and there were 6 vehicles in which it was unable to be determined whether or not ESC was fitted. Of the 29 vehicles determined to be ESC equipped, 10 were involved in ESC sensitive crashes. Some unusual circumstances were recorded in the 10 ESC equipped vehicles involved ESC sensitive fatalities. Three cases involved situations where despite evidence of evasive actions, the ESC did not function to redirect the path of travel as would be expected in the loss of control situations. In two of these three cases, the vehicle lost control in the road side area where the surface might have been too rough for the ESC system to be able to stabilise the vehicle. In one case, acceleration in a curve on a gravel road prior to loss of control suggests that ESC was switched off and potentially completely overridden. The remaining seven ESC-sensitive, ESC-equipped cases where ESC ‘should’ have worked were further assessed. High speed is thought to have contributed in all 10 ESC-sensitive ESC equipped fatality cases, trailer involvement may have contributed to the crash outcomes in another of the seven cases, and an old roadworthy vehicle was a potential causal factor. However, for all 10 of these cases, the excessive travel speeds were thought to have led to loss of control scenarios outside the effective envelope of ESC.

There were 91 single vehicle and 49 head on fatalities analysed. The effectiveness of ESC in these fatalities was disaggregated according to posted speed zone in which the crash occurred. Head on fatalities at 60km/hr or less were more likely (44%) to be avoided than single vehicle fatalities (19%). This analysis showed at 70km/hr plus, ESC had limited effectiveness in head on crashes, being more effective for single vehicle crashes. At 100 – 110km/hr, 29% of fatalities from lane departure crashes were potentially avoided with ESC. Due to a small sample size and the fact that no statistical testing was completed it should be noted that the results of this study throughout are unlikely to be statistically significant and have not been tested.

The types of vehicles involved, with an estimate of the number of fatalities avoidable with ESC are shown in Table 6. It was estimated that 50% of fatal crashes involving station wagons and light commercial vehicles could have been avoided with ESC. Twenty six percent of fatalities in car crashes and 33% of fatalities in utilities could have been avoided with ESC. Fatalities from single vehicle type crashes were more likely to be avoided (34%) with ESC, than fatalities which were determined to be avoided from head on type crashes (22%), for each crash type.

Table 6. Number of lane departure fatalities determined to have been avoided, by crash type and vehicle type

	Head On		Single Vehicle		TOTAL	
Vehicle Type	**Number of fatalities**	**Fatalities avoided**	**Number of fatalities**	**Fatalities avoided**	**Number of fatalities**	**Fatalities avoided**
Car	38	6.3	59	18.9	97	25.2
Light Commercial Vehicle	2	0.9	-	-	2	0.9
Station Wagon	5	1.6	9	5.0	14	6.6
Utility	4	1.3	23	7.6	27	8.9
TOTAL	**49**	**10.1**	**91**	**31.5**	**140**	**41.5**

Discussion

The effectiveness of ESC to reduce fatal crash outcomes is influenced by various factors with highest ESC effectiveness being under normal driving conditions (Lie, 2012). Extreme driving conditions including excessive speeds and very low friction can lead to ESC systems failing to maintain control of the vehicle (Lie, 2012). These factors can be controlled by the driver through choice of travel speed, risk taking driving manoeuvres, the condition of the vehicle brakes and tyres and the amount and distribution of weight loaded on the vehicle. Factors not controlled by the driver include the road conditions, road and roadside surface type and conditions and gradients. If any of the tyres lose contact with the road surface then the ESC would be quite ineffective. ESC cannot ensure that a driver maintains control of a vehicle in all situations. The crash scenarios selected in this study are those in which a lane departure event occurred. These were selected as being potentially ESC sensitive crashes. ESC sensitive crashes are those in which ESC is thought to have an effect, when the vehicle is involved in a loss of lateral stability event. Some of the lane departures included events where the driver was unable or did not attempt to prevent the crash via steering and braking inputs and these crashes were considered to be without loss of control. The without loss of control crashes were likely to have been caused by impairment, distraction or deliberate intent. Another consideration was that some of the vehicles involved in these without loss of control fatal events, were in fact fitted with ESC.

At least 29 vehicles in the study were fitted with ESC, 105 did not have ESC and in 6 vehicles ESC fitment was unable to be determined. The 29 cases of ESC equipped vehicles being in crashes resulting in at least one fatality were investigated. Various potential explanations for ESC fitted vehicles not always functioning as expected in crashes were considered. It is important to note that some of the ESC fitted cars were without loss of control (not prevented by ESC) and sometimes the ESC system was insufficient to prevent the loss of control crashes. In at least one case, the ESC was thought to have been manually switched off prior to the crash. There were 7 ESC equipped, ESC-sensitive cases, where a fatal outcome was not avoided, where ESC was not thought to have been switched off. Despite these cases being determined as ESC-sensitive crashes in ESC equipped vehicles, there were extenuating circumstances such as extreme speed which still resulted in fatal outcomes. It is unknown if these ESC equipped, ESC-sensitive fatalities were the result of insufficient ESC system, tyres and brakes maintenance or if there was a failing in the functioning of the fitted ESC technologies for some reason, therefore there was insufficient evidence to definitively conclude that ESC could have prevented fatality in these cases therefore they were assigned likelihood ratings of low to very low.

ESC-sensitivity was assumed based on modern ESC, in good condition, not disabled and appropriate travel speeds. Anecdotal evidence suggests that ESC technologies in older vehicles which are not as refined or effective as the newer ESC technologies in circumstances such as low friction and traction (gravel, dirt, clay or icy roads) and vehicles towing trailers could be attributable to the fatalities. Newer ESC technologies are far more effective at managing trailer sway, physical forces present when a vehicle is towing a trailer. The assessments of ESC fatal prevention likelihood were completed on the basis of whether a modern ESC system would have prevented the fatal outcome. Therefore older vehicles, with older ESC technologies, may not have performed as effectively as a newer ESC counterpart. Older ESC systems would be inferior to newer refined ESC systems now available. Modern ESC systems are highly equipped to deal with very low traction conditions and vehicles towing trailers. Having said this, different makes and models will have different ESC characteristics.

In one crash involving an ESC fitted vehicle, which was considered an ESC sensitive situation, it was inferred that the ESC was switched off, due to people taking part in risk taking behaviours. By disabling the ESC in the vehicle and driving on a gravel road at high speeds, the car will be likely to yaw and slide without regaining its intended direction of travel easily with driver steering and braking inputs, as ESC is intended. While it is an assumption that ESC was switched off, this type of behaviour could be prevented by removing the manual switch to disable ESC from vehicles. At least 10 drivers were thought to have been travelling at excessive speeds. While ESC acts on the engine power and brakes the wheels to control speed at the time of a loss of control situation, it does not have an inherent ability to control the vehicles speed prior to a loss of control event. Complimentary technologies such as Intelligent Speed Assist (ISA) speed limiting technologies are suggested to assist in trauma reductions. There were 3 crashes where the vehicle occupants who died were not wearing their seatbelts. The fact that seatbelt use could have avoided fatal crash outcomes, regardless of ESC, is very telling. Mandating seatbelt interlock technology, where the engine will not start if the occupants do not have their seatbelts fastened could greatly reduce trauma in these scenarios. These two risk taking behaviours are conscious decisions of vehicle drivers and occupants. From a safe system perspective, reducing the ability of the vehicle occupants to partake in these risk taking behaviours by shifting these human decisions to technology based solutions has the potential to prevent or reduce crash severity. It is possible that if the vehicles were not serviced sufficiently that their ESC systems, tyres and brakes were in disrepair, meaning they would not function with maximum effectiveness. An example from the study included an old un-roadworthy vehicle, which was unlikely to have been serviced. If ESC was fitted to this vehicle the technology would be unlikely to function effectively, due lack of servicing.

Conclusions

This analysis estimated that 41 (29%) of the 140 fatal crashes in Victoria in 2016 that involved lane departure, death could have been prevented had the vehicle been fitted with ESC. Also, ESC was estimated to be far more effective in single vehicle loss of control crashes compared to head on crashes, particularly at higher speeds. As described in Lie (2012), loss of control crashes (at normal speeds) are unlikely to occur with modern ESC systems, unless there are unique circumstances observed (for example extremely high speeds).

The determination of 10 ESC equipped, ESC sensitive cases resulting in fatalities, invites further analysis of these cases, particularly in the cases were ESC was not thought to have been switched off. Access to download the airbag control module data to check for ESC activation and pre-impact velocity, change in velocity at point of impact, service history of the vehicles if available, physically checking the condition of the vehicles brakes and tyres and searching for any modifications such as changes to the suspension system which could negatively affect ESC's performance, have the potential to provide valuable evidence to use in developing preventative crash countermeasures.

Further crash mitigating factors can contribute to ESC's effectiveness. These factors include road type and conditions; vehicle age and type; travel speed and driver behaviour. Modern ESC systems are highly effective in circumstances when there is high speed, low friction and if the driver is impaired as they both mitigate over-steering and constantly apply small corrections to prevent instability occurring, with minimal driver input required.

Key lessons and recommendations include the removal of the manual ESC switch (if practical, otherwise only allowing ESC to remain turned off when travelling at speeds of less than 10 km/h) to ensure that all drivers are protected by these technologies. Also, a mandate of ESC technology to the remainder of the Victorian vehicle population as this mandate only currently stands for passenger vehicles and does not extend for other vehicle types including appropriate ESC type technologies in heavy vehicles. Whilst not thoroughly investigated in this study, the lack of seatbelt use noted by VicPol in some cases, suggests that mandatory seatbelt interlocks may be beneficial in trauma reduction.

This analysis invites future research into ESC relevance in non-fatal injury crashes where ESC is likely to have similar trauma reduction outcomes. This research further highlights the positive effects of ESC and its potential to prevent loss of control crashes and resultant fatalities and injuries.

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