ELECTRONIC STABILITY CONTROL AND SIDE IMPACT CRASHES: 100% CURE OR A CASE OF REALIGNING SAFETY PRIORITIES

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ABSTRACT

Side impact crashes remain a key road safety priority. Electronic stability control (ESC) has been shown to be a life-saving technology and was heavily promoted as having significant benefits in reducing rollover crashes and run-off-road crashes in particular. Similarly, side impact airbags (SAB) offer considerable promise in reducing the number of people killed and seriously injured in side impact crashes.

The paper has two aims: 1 to estimate the likely crash reduction benefits and financial savings in terms of ESC in reducing pole side impact crashes in Victoria, and 2, to assess the need for, and type of, road safety countermeasures required to address the persisting side impact crash problem. In doing so, the role of side airbags was assessed, and a case for the pole side impact Global Technical Regulation (GTR) examined.

Using historical crash data from Victoria, vehicle ownership rates, actuarial determinations of crash risk and future population projections, future crash rates were determined. It was projected that in the period 2016 to 2045, a total of 1088 passenger car and SUV occupants were predicted to be killed and 8661 seriously injured due to pole side impact crashes. Given a range of evidence on the effectiveness of ESC, side impact airbags and the proposed new Pole Side Impact global Technical Regulation, the combined crash reduction benefit was established.

Given stated implementation scenarios and associated assumptions, the combined benefit of ESC, SAB and the proposed PSI GTR was a 50% reduction in the number of occupants killed and seriously injured in narrow object side impact crashes. Conversely, half of all projected fatalities and serious injuries still occur, translating to the likely deaths of 547 occupants and serious injuries sustained by 4145 occupants.

It is clear then that ESC and side airbags are highly effective however other crash prevention and injury mitigation countermeasures are required to address the remaining crash problem. Adoption of a broader view of side impact safety countermeasures, including improved infrastructure and safer road user behavior, is essential.

INTRODUCTION

Side impact crashes represent a significant proportion of the number of people killed and seriously injured. Fatalities due to narrow object side impact crashes range from 5.7% (USA) to 17.1% (Germany) of all occupants of 4-wheeled vehicles killed. Moreover, high numbers of people are seriously injured and admitted to hospital due to side impact crashes [1]. Narrow object impacts, such as trees and poles, carry an especially high risk of fatality; however they are generally fewer in number than vehicle-to-vehicle side impact crashes when fatality and injury crashes are considered together.[1] In Victoria, Australia, side impact crashes remain a key road safety priority, accounting for 35% of fatalities and costing the community an estimated $AUD 1.5 bn. per annum.

The injury risk associated with side impact crashes is well understood. [1-15] At particular risk in side impact crashes are the head and thorax body regions.

The search for improved side impact protection countermeasures has been the subject of considerable research over the past two decades. Recognizing the risk associated with side impact crashes, governments and manufacturers have adopted a range of countermeasure strategies and performance-based requirements, such as US FMVSS 214 and the UN ECE 95.[16, 17] To meet these requirements manufacturers have used a range of strategies, including for example, door padding, side intrusion bars, refinements to seat belts and seat technology, structural changes including stiffness and new materials, as well as side impact airbags. (SAB)[1, 10, 17, 18]

The safety improvements described above relate to ‘passive safety’, however with improvements in technology, ‘active safety’ systems offer scope for the crash to be either avoided entirely or injuries mitigated through reduced impact speeds or a more optimal crash geometry / trajectory. In particular, ESC – built off ABS, has been demonstrated to be highly efficacious in reducing run-off-road crashes, with some estimates pointing to a 65% reduction for SUV / light commercial vehicles, although the benefits to passenger cars is uniformly lower at up to 40%.[1, 19-22]

The focus on passive and active safety technology in the prevention and mitigation of side impact crashes has an important global context. 'Safer vehicles' falls directly under the ambit of the United Nations (UN) *Decade of Action for Road Safety 2011-2020* [23-25] and is one of the five key pillars of the *Decade 'Action Plan'*.[26] The *Action Plan* [26] for the Decade of Action specifically notes the role of passive and active safety technologies, such that it seeks to promote the...

> ...Global deployment of improved vehicle safety technologies for both passive and active safety through a combination of harmonization of relevant global standards, consumer information schemes and incentives to accelerate the uptake of new technologies...

This call for activity has been recognized by the UN ECE in the 154th Session WP.29 session (21-24 June 2011, agenda item 8.9.),[27] whereby activities under Pillar 3 that fall under the responsibility of WP.29 were to be defined. This culminated in the development of the UN ECE Decade of Action for Road Safety – UN ECE Plan 2011–2020 which outlines a number of innovations in the arena of active and passive safety systems.[28]

Further refinements and expansion of the ESC mandate, the proposal for the development of a Pole Side Impact Global Technical Regulation (PSI GTR) in order to overcome deficiencies in the current barrier test (see unece.org), and the promotion of technologies such as lane departure warning, fatigue monitoring and vehicle-to-infrastructure systems are indicative of the motivation to reduce the frequency and severity of side impact crashes.

That improved side impact protection has been a priority is also evidenced by New Car Assessment Program (NCAP) encouraging the fitment of side curtain airbags and rewarding vehicles that do so. The moves by NCAP in adding ESC and other safety assist technologies to the 'road map' is a further important step in improving vehicle safety.[29, 30]

The crash reduction and injury mitigation benefits of ESC and side impact airbags, respectively, are now well understood. Together both offer considerable promise in realizing significant road safety benefits, particularly in relation to run-off-road side impact crashes. The question is whether these two countermeasures represent 100% 'cure' for this highly injurious crash type, and if not, what more can be done?

Hence this paper has two aims: 1 to estimate the likely crash reduction benefits in terms of ESC SAB and the PSI in reducing the number and severity of run-off-road pole side impact crashes, using Victoria (Australia) as an exemplar jurisdiction, and 2, to assess the need for, and type of, road safety countermeasures required to address the persisting side impact crash problem.

METHOD AND RESULTS

The Method used to derive crash and injury reduction benefits were described in detail previously[31] and can also be found in a full report on the *Assessment of the need for, and the likely benefits of, enhanced pole side impact global technical regulation.*[1] The reader is referred to these complementary publications; however a broad overview of the analysis method is presented below.

The analysis refers only to passenger vehicles, these being defined as passenger cars and sports utility vehicles (SUVs); these are known as category M1 vehicles within the UN ECE framework.

The principal question of this paper is:

> What is the crash reduction and injury mitigation benefit of ESC, SAB, and the proposed PSI GTR?

In answering this question, the balance between the projected number of crashes per annum and the associated savings is the number requiring alternative safety countermeasures.

To address this question, a number of accurate data sources are required in order for the necessary inputs derived. The key steps in the analysis are as follows:

1. Project the future number of crashes given the population estimates:
    - this relies on the historical relationship between crashes (by type) and the number of registered vehicles, and population projections modeled by the Australian Bureau of Statistics[32];
    - the historical vehicle ownership ratio, expressed as the number of registered vehicles[33, 34] per persons aged 15 years and older in the population, and
    - using the above two inputs, the number of registered vehicles can be derived for each year, 2016 – 2045 is derived. The next step is to determine the number of

expected fatalities and injuries for each year in the future. To do so, we use the historical vehicle involvement rate in side impact fatalities to establish the 'fatalities per registered vehicle' and 'serious injuries per registered vehicle; note that this assumes no other changes in the injury rate into the future as the 'base' crash year.

The inputs here are the:

a. Number of registered vehicles for each year of available crash data [33, 34], and

b. Number of persons killed and injured [35-37]

The end result is the estimation of the number of fatalities and persons injured for every future year. The key parameter to estimate is the number of future crashes amenable to ESC and SAB systems.

2. Determine the likely benefit of ESC in reducing side impact crashes;

3. Account for the rate of penetration of side impact airbags though the fleet and their effectiveness in mitigating fatalities and injuries;

4. Determine the benefits afforded by the proposed PSI GTR, by injury severity;

5. Determine the total benefits of ESC and SAB, and derive the outstanding balance of fatalities and serious injury crashes.

With knowledge of the future population and the vehicle: person ratio, the number of registered vehicles into the future can be projected. Using the 'base-year' number of fatalities and injuries sustained in side impact crashes, the future number of side impact fatalities and injuries can also be determined. This is done so on the basis of the number of known fatalities and serious injuries per registered vehicle in the 'base year', this being the 2010 Victorian Police Reported Casualty data. Within this database, fatalities are defined as death within 30 days of the crash and a 'serious injury' was an individual who had been admitted to hospital for at least 24 hours.

Using the crash data, we determine the number of occupants involved in single vehicle run-off-road side impact crashes (Table 1). These fatalities and serious injuries are in the *field of influence of ESC and SAB systems*. Using the number of registered vehicles for 2010, the ratio of fatalities and serious injuries is derived. Similarly, using the population estimate for 2010, a passenger vehicle per person ratio is determined. These inputs form the basis of future fatality and serious injury estimations using projected population estimates as the key input.

Table 1. Estimation of current driver fatality and serious injury rates per registered passenger vehicles

Parameter	Value
Fatalities: number	27 (53% drivers killed involved in side impact crashes)
Serious injury: number	189 (17.8% drivers involved in collisions / rollovers and seriously injured)
Number of registered passenger vehicle[33]	3,280,682
Fatalities per registered passenger vehicle	0.00000823
Serious injuries per registered passenger vehicle	0.00006554
Population ≥ 15 years	4,467,428
Passenger vehicle per person ratio	0.734

Table 2 presents a snapshot of the projected narrow object impact crash projections, for the period 2016 / 2017 to 2045, as well as the total number across the 30 year period. These values are derived as per the process described above.

Table 2. Estimated number of run-off-road narrow object side impact fatalities and serious injuries, 2016 to 2045

Year	Future pop. estimate	Est. num. passenger vehicles†	Fatalities ‡	Serious injury‡
2016	4,857,898	3,567,426	29	234
2017	4,927,693	3,618,680	29	237
...	....	....	....	....
2044	7,138,348	5,242,088	43	344
2045	7,233,288	5,311,808	44	348
TOTAL			**1088**	**8661**

† Predicted number of passenger vehicles = future ABS population* passenger vehicles per person ratio (0.734)
‡Estimates number future passenger vehicles*fatality rate (per registered passenger vehicles) (& *serious injury rate per registered passenger vehicle)

Based on current fatality and serious injury rates, and given population growth and vehicle ownership, over the 30 year period 2016 to 2045, 1088 occupants are projected to be killed and 8661 seriously injured.

ESC fitment rates and the effectiveness of ESC in preventing crashes – The crash reduction benefits of ESC is well documented. For the purposes of obtaining the crash reduction benefit of ESC for run-off-road crashes, a 20.74% crash reduction value was adopted. This crash reduction value is specific to the Australian context and relates to passenger cars and SUVs, with consideration given to the differential effectiveness of ESC in passenger cars (18.6% reduction, 94.3% occupants) and SUV crashes (56% reduction, 5.6% of occupants), as well as vehicle ownership. These values were derived by the Monash University Accident Research Centre in an evaluation on ESC using police-reported crash data from five Australian states and NZ as part of the Used Car Safety Ratings program; the research examined the crash involvement of 175 1998 Model Year and newer vehicles with (n = 27, 252 vehicles) and without ESC fitted (n = 439,543).[38, 39]

The fitment rate of ESC into new vehicles is a critical consideration in its impact in reducing crashes. Figure 1 presents the percent of new car sales with ESC fitted as standard equipment in Victoria for the period 2006 to 2012.

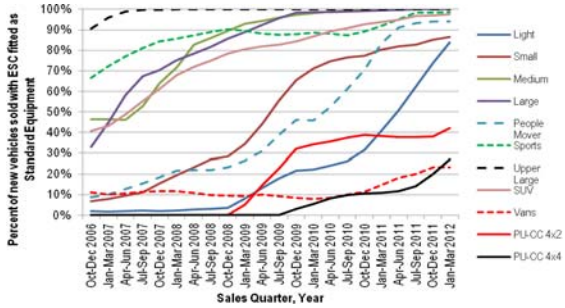

Figure 1. ESC fitment as standard equipment into passenger vehicles (M1) and light commercial vehicles (N1)

The rapid acceleration in the fitment of ESC (Figure 1) is in response to a number of factors, principally that from 1 November 2011 under Australian Design Rules all new model M1 vehicles will require ESC to be fitted, and in addition, from 1 November 2013 ESC must be fitted to all new vehicles sold. Consequently, 100% of all new vehicles purchased and entering the fleet will be fitted with ESC prior to the application of a pole side impact standard in Australia. Fitment rates in Victoria were likely also influenced by measures undertaken by the Victorian Government that required all newly registered vehicles by fitted with ESC from 1 January 2011.[40] Finally, fitment of ESC to vehicles would have been influenced by GTR 8 (UN R13H) as well as NCAP 5-star rating requirements.

A series of computational steps are required to account for the fitment rate of ESC, and hence the penetration through the fleet. Using a series of multiplier values that account for vehicle age, scrapage and turnover, an estimate of the number of vehicles fitted with ESC in each forward year can be derived (this process is described elsewhere in detail[1]). To this, we overlay the crash reduction benefit of ESC of 20.74%.

Table 3. Estimated number of run-off-road narrow object side impact fatalities <u>saved</u> due to ESC 2016 to 2045

Year	Fatals (Pred)	Prop fleet with ESC	ESC effectiveness multiplier (*20.7%)	ESC benefit per annum (PSI lives saved)
2016	29	0.7637	0.158	5
2017	30	0.8047	0.167	5
...				
2044	43	1.0000	0.207	9
2045	44	1.0000	0.207	9
TOTAL	**1088**			**218**

Table 3 shows a clear benefit of ESC, with 218 fatalities avoided over the 30 year period. Importantly, once saturation of the fleet is achieved (2043), the benefit of ESC is fully realized.

Table 4 uses the same method to derive savings in serious injuries due to ESC.

The results presented in Table 3 and Table 4 highlight the value of ESC in preventing run-off-road side impact fatalities and serious injuries. It can also be observed that over the 30 year period, ESC alone will reduce fatalities and serious injuries by 20%, leaving 80% requiring another form of safety countermeasure; this translates to 869 fatalities and 6922 persons seriously injured.

Table 4. Estimated number of run-off-road narrow object side impact serious injuries saved due to ESC 2016 to 2045

Year	Fatals (Pred)	Prop fleet with ESC	ESC effectiveness multiplier (*20.7%)	ESC benefit per annum (PSI lives saved)
2016	234	63.53%	0.13176	37
2017	237	70.53%	0.1463	40
...				
2044	344	100%	0.207	71
2045	348	100%	0.207	72
TOTAL	**8661**	**-**	**-**	**1739**

What benefits will side impact airbags deliver?

The analysis above indicates that ESC will reduce fatalities and serious injuries by 20%; hence, 80% of run-off-road side impact fatalities and serious injuries would still occur, given the 'base fitment rate' and crash risk of the 2010 crash year. Expressed in an alternative manner, side impact airbags (and other countermeasures) can play a role in the reduction of the 869 fatalities and 6922 persons seriously injured, after the effect of ESC is considered; these remaining crashes represent the field of crashes that SAB can influence.

Following regulatory intervention and increased consumer pressure – via NCAP and associated promotional advertising, the fitment of side airbag systems as standard equipment on new vehicles (in Australia) has increased (Figure 2).

As with ESC, the safety benefits associated with SAB depend on fitment and the penetration rate into the vehicle fleet.

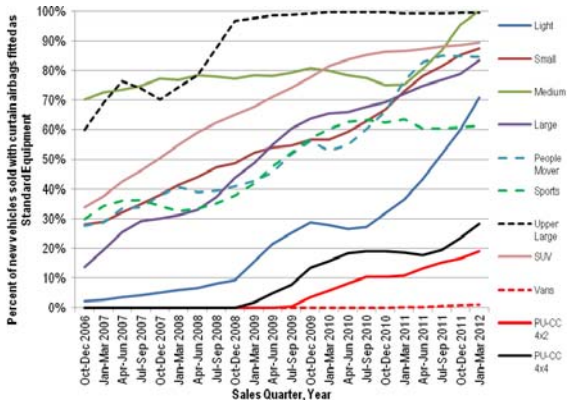

Figure 2. Side airbag fitment as standard equipment into passenger vehicles (M1) and light commercial vehicles (N1)

It was assumed that by the end of 2015, the percent of vehicles fitted with side impact curtain airbags and thorax airbags as standard equipment is as per Table 5. The forward projections are based on an on average 5.9% increase in the new car sales fitted with curtain side airbags as standard equipment per quarter since 2006 (Figure 2), however it is recognized that some segments will fail to reach 100% standard fitment. This is despite the requirement by NCAP for head protecting side impact airbags to be fitted for vehicles to achieve a 5-star ANCAP rating in 2012 for the front row and in 2014 for the rear seats. The ANCAP Road Map specifies fitment of head protecting side impact airbags at other star-rating levels in the period 2012-2017.

Table 5. Projected fitment rates of head protecting side airbags at the end of 2015

M1 vehicle sales class	Percent of M1 new vehicle sales	Side airbag fitment rate at end 2015 in vehicle class
Light	14.6%	90%
Small	28.1%	95%
Medium	11.7%	100%
Large	16.6%	100%
People mover	1.6%	95%
Sports	2.4%	85%
Upper large	0.8%	100%
SUV	24.2%	100%
Total	100%	

Using the historical and projected SAB fitment rates based on current vehicle sales and fitment rates, a penetration factor can be determined; this is the *SAB crash relevance factor*. The SAB relevance factor peaks at 96% in 2022 (Table 6); in the absence of a mandate is expected to remain at that level; this is described fully in Fitzharris and Stephan[1]. More precisely, the portion of the 869 fatalities and 6922 persons seriously injured is what SAB can reduce multiplied by the SAB fleet

penetration rate (Table 6, column G), which is reflected in Table 6 – Column H and I. Based on this, in the period 2016 – 2045, 803 of the 869 and 6393 of the 6922 fatalities and persons seriously injured can be influenced by the protective benefits of SAB. Ultimately, the reductions in the fatalities and serious injuries are a product of the efficacy of the SAB itself.

Real-world effectiveness of SAB – A comprehensive review of SAB effectiveness was undertaken and reported as part of the *Assessment for the PSI GTR*. [1] On the basis of the fatality studies examined, and specifically the strength of the research conducted by Braver and Kyrychenko [41] and McCartt and Kyrychenko [42], we use a 32% reduction in fatalities due to the presence of a curtain plus thorax side airbag system. This value represents a lower bound, as their estimates are as high as a 45% reduction in fatality risk.

Similarly, we use the point estimate from the UAB CIREN Center as the basis of benefit ascribed to curtain plus thorax side airbag systems.[43] Specifically, we adopt a value of 34% as our basis of reduction in injuries.

Table 6. Fatalities and injuries possibly influenced under a business-as-usual side airbag implementation scenario

	Side impact fatalities and injuries post-ESC benefit (amenable to SAB)		**% fleet with side airbags**	**Open to influence from SAB / exposed given SAB fitment**	
	F_f	**F_i**	**G**	**H**	**I**
Year	Fatal	Serious injury	SAB penetration multiplier	Fatal	Serious injury
2016	25	197	0.582	14	115
2017	25	198	0.650	16	128
...					
2044	34	272	0.96	33	261
2045	35	276	0.96	33	265
Total	**869**	**6922**		**803**	**6393**

Using the observed real-world effectiveness values of SAB, we then reduce the number of occupants killed and seriously injured by this factor; this is presented in Table 7. The sum total savings associated with SAB is then 257 fatalities avoided and 2174 serious injuries.

Table 7. Fatalities and injuries avoided under a business-as-usual side airbag implementation scenario, after ESC

	Open to influence from SAB / exposed given SAB fitment		**BAU SAB reduction benefit**	
	H	**I**	**J**	**K**
Year	Fatalities	Injuries	Fatalities avoided @ 32% SAB	Injuries avoided @ 34% SAB benefit
2016	14	115	4.6	38.9
2017	16	128	5.2	43.6
...				
2044	33	261	10.50	89
2045	33	265	10.64	90
Total	**803**	**6393**	**257**	**2174**

Effect of a PSI GTR on run-off-road narrow object side impact crashes

The proposal to adopt a new performance-based Global Technical Regulation on Pole Side Impact Crashes, led by the Australian Government, was in recognition of the persistently high risk of death and serious injury, in spite of the present regulatory regime. The reader is referred to the draft proposal: ECE/TRANS/WP.29/GRSP/2013/7 - (Australia) Proposal for a global technical regulation on Pole Side Impact; this can be found at the WP29 site: (http://www.unece.org/trans/main/wp29/wp29wgs/wp29grsp/grsp2013.html).[44]

The effect of the GTR would be two-fold: 1) side curtain airbags fitment to all new vehicles would be assured, and 2) the protective value of side airbags would offer an incrementally higher level of protection. This would be the consequence of the increased safety demands of the oblique test and associated performance criteria. It is assumed that the GTR requirements would results in an incremental benefit of 30% over and above current side impact systems, which in effect is an added benefit of 9.6% and 10.2% for fatalities and serious injuries, however the enhanced SAB would also take time to completely penetrate the fleet (+ 30 years).

The practical effect of the fitment of side airbags to all vehicles would be a very small acceleration in the fleet penetration, but it would importantly guarantee that fitment reaches 100%. Following the same method described above, the number of fatalities and serious injuries avoided can be determined.

Table 8. Fatalities and injuries avoided due to the proposed PSI GTR.

	GTR benefit – 100% fitment and enhanced efficacy	
Year	**Fatalities avoided**	**Injuries avoided**
2016	0.08	0.64
2017	0.22	1.83
...		
2044	3.7	31.2
2045	3.7	31.7
Total	**66**	**563**

Hence, the proposed PSI GTR would result in an additional saving of 66 lives and prevent 563 serious injuries.

Summary of ESC, SAB and PSI GTR benefits: a 100% cure?

This paper set out to determine the likely benefits of ESC, SAB and the proposed PSI GTR. Of particular interest was the degree to which these three safety interventions would reduce the number of occupants killed and seriously injured in run-off-road narrow object pole side impact crashes.

To recap, over the period 2016 to 2045, 1088 fatalities and 8661 occupants were projected to be seriously injured. ESC alone reduced this by 20% (218 fewer fatalities; 1779 fewer seriously injured). Added to this is the safety effect of SAB, which results in an added saving of 257 lives and prevents 2174 occupants from being seriously injured. Added to this is the benefit afforded by the proposed PSI GTR. This is summarized in Table 9 below, which shows that the three interventions result in a halving of the number of occupants killed and seriously injured in run-off-road narrow object side impact crashes. The corollary of this is that half of the fatalities and serious injuries in this crash type are not amenable to reduction by these three advances in active and passive safety.

Table 9. Narrow object side impact fatalities and injuries occurring and avoided due to the ESC, SAB and the proposed PSI GTR.

	Killed		**Seriously injured**	
	Num	%	Num	%
Projected, 2016-2045	1088		8661	
ESC benefit	218↓	20.0	1779↓	20.5↓
Open to SAB influence	*803*		*6393*	
SAB reduction (BAU)	257↓	23.6	2174↓	25.1↓
PSI GTR benefit	66↓	6.1↓	563↓	6.5↓
SAB + PSI GTR	*323↓*	*29.7↓*	*2737↓*	*31.6↓*
Savings due to ESC, SAB, GTR	**541↓**	**49.7↓**	**4516↓**	**52.1↓**
Remaining	547	50.3	4145	47.9

DISCUSSION

Using a range of assumptions, in the period 2016 to 2045 a total of 1088 persons were predicted to be killed due to narrow object (pole / tree) side impact crashes. Given the current ESC fitment rate, the expected fatality reduction benefit associated with ESC was 218 fewer occupants killed. Consequently, 803 fatalities would still occur. Side impact airbags provide further significant benefits, and this is improved even further by the adoption of the proposed UN ECE pole side impact GTR. The triple antigen of ESC, SAB and the PSI GTR offer significant reduction benefits for serious injury crashes also.

The combined benefit of ESC, SAB and the proposed PSI GTR is a 50% reduction in the number of occupants killed and seriously injured in narrow object side impact crashes. Hence, half still occur, translating to the likely deaths of 547 occupants and serious injuries sustained by 4145 occupants.

A broader search for side impact safety – a realignment of priorities and a continued search for vehicle safety options

From the analysis presented above, and given stated limitations, it is clear that ESC and SAB systems – including the added benefit of the proposed pole side impact GTR will deliver considerable safety benefits. Two things are evident: 1. due to the pace of introduction of ESC and SAB and vehicle turnover rates, the full benefit

of these safety technologies will not be realized for a considerable period of time, and 2. a large number of run-off-road side impact crashes not amenable to ESC or the safety benefits of side airbags will continued to occur. This future scenario clearly points to the need to take a holistic view of the run-off-road side impact crash problem.

As outlined in the discussion, safer vehicles represent one of the five action pillars for the Decade of Action, along with road safety management structures; road user behavior; road infrastructure; and 5. post-crash care [26]. The Action Plan is built on the safe systems model of road safety, whereby safe speeds, safe roads and roadsides, as well as safer vehicles act in concert to both prevent crashes that result in serious injury (Figure 3). The safe system model places the human in the centre of the road transport system, recognizing that humans make errors and are vulnerable to injury. By recognizing the ethical imperative that no road death is acceptable [45-48], policy action across the entirety of the system is demanded. Inspired to the work of Haddon [49] the safe systems approach posits that to central to achieving optimal reductions in road trauma is recognition that multiple risk factors need to be addressed, ideally simultaneously. [45-48, 50]

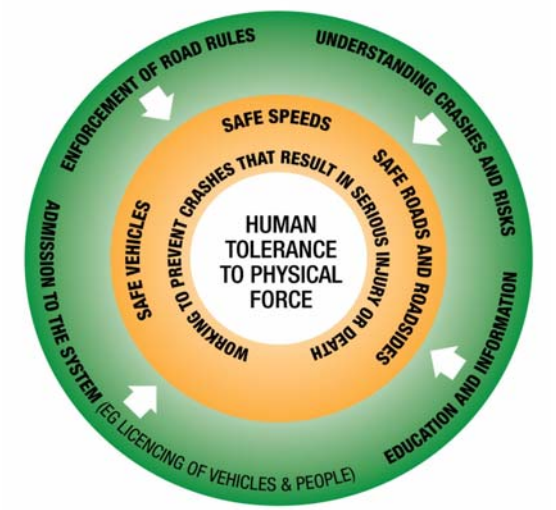

Figure 3. The Safe Systems Approach to Road Safety (Source: WHO, 2009)[51]

Within the vehicle safety domains, a range of new technologies, including lane departure warning, centre mounted airbags (Figure 4), improved seat design, and optimized seat restraints offer considerable promise in further reducing fatalities and injuries associated with side impact crashes.[52-56]

Figure 4. Front-centre mounted airbag (Source: Sikora[57])

Other factors such as pedestrian safety requirements and environmental concerns will likely lead to changes in vehicle design with respect to vehicle mass and vehicle geometry; these changes may have significant implications for side impact crashes with respect to run-off-road crashes, but will also influence injury outcomes from vehicle-to-vehicle side impact crashes to a greater extent.

An important premise of the safe systems approach and Vision Zero is that humans are error prone and the system needs to be designed in such a way to tolerate these errors. Fatigue, intoxication and inattention – which include distraction, remain significant issues that need to be addressed. In a study of 340 crashes examined as part of the Australian National Crash In-depth study, 11.8% of drivers stated they fell asleep, 10.9% stated they were fatigued, 13.5% were intoxicated (an BAC > 0.05), and 16% stated they were distracted; passenger distractions were the most common form of distraction (8.8%) immediately leading up to the crash.[58, 59] The mitigation of these behaviors sits within the ambit of safer road users and hinge on education and enforcement strategies.

In addition to improved vehicle safety, safer infrastructure can continue to play a critical role in mitigation both the occurrence and severity of run-off road crashes. For instance, Candappa et al demonstrated the value of flexible barrier systems, reporting an on average 44% reduction in serious injury crashes where flexible wire rope barrier systems were implemented; the benefits of WRB systems in some locations was as high as 86% reduction.[60] Further, extensive research has demonstrated the benefits of other infrastructure treatments such as rumble strips, shoulder treatments and clear zones.[60-63] It has also been shown that road design factors play an integral role in speed choice, and can be used as an effective speed control mechanism.[64]

As is evident, run-off-road crashes into fixed objects resulting in side impact crashes carry a high risk of serious injury. While further refinements to passive and active safety systems are likely, there is a need to continue to look to infrastructure improvements and addressing aspects of road user behavior in mitigating this serious crash problem. This approach is an explicit statement of the importance of adopting the safe systems approach to road safety.

Limitations

In the formulation of crash estimates, a number of assumptions were made and these are clearly stated. The present paper reports the findings from a single effectiveness value of ESC, side airbag systems and the effect of the PSI GTR. Ideally a sensitivity analysis would be conducted, however the point here is to demonstrate the principle that a broad range of interventions are required to address the run-off-road narrow object side impact problem. The effectiveness values used were drawn from the published literature, including from studies published using Australian and Victorian crash data. This provides confidence in the analysis reported here. Assumptions were required concerning the projected fitment and penetration rates for ESC and side airbags, although historical data forms the basis of these. This paper does not present the cost-effectiveness estimates of the three interventions, and an estimate of the cost-effectiveness of ESC remains to be determined; suffice to say the significant savings and the low cost of ESC fitment point to a strong benefit-cost ratio. Finally, the paper does not address the injury severity category shifting; that is, there is no consideration of occupants previously classified as being killed into the serious injury category and so on into the minor and involved but uninjured category. Finally, safety improvements to the road network and changes in driver behavior – hence crash risk, are not modeled here.

CONCLUSIONS

The analysis demonstrates the significant impact of ESC and side airbags in reducing death and serious injury stemming from run-off-road pole side impact crashes. Further benefits are observed from the proposed PSI GTR. Due to the pace of introduction of the new technologies as standard equipment, and the age of the vehicle fleet, the full benefits are not realized until at least 25 years. The combined benefit of ESC, SAB and the proposed PSI GTR is a 50% reduction in the number of occupants killed and seriously injured in narrow object side impact crashes. Hence, half still occur (given no other safety improvements), translating to the likely deaths of 547 occupants and serious injuries sustained by 4145 occupants. Following this, innovative passive and active safety solutions need to be found. Perhaps in time vehicle-to-infrastructure intelligent transport technologies will prove to be the silver bullet in preventing run-off-road crashes altogether. In the meantime, a continued focus on mitigating road user error, aberrant behaviors and the provision of appropriate infrastructure is required.

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