# EFFECTIVENESS AND ESTIMATION OF THE LIKELY BENEFITS OF SIDE IMPACT AIRBAGS IN PASSENGER VEHICLES IN VICTORIA

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Paper Number 11-0245

## ABSTRACT

The safety benefits of side impact airbag (SAB) systems have been demonstrated in a number of studies. Side airbags were first fitted as standard equipment in a locally manufactured passenger vehicle in Australian in the 2000 model year. By 2006, only 33% of new passenger vehicles (cars, sports utility vehicles and people movers) sold in the State of Victoria were fitted with front curtain airbags as standard equipment. The Transport Accident Commission - which functions as a statutory road crash compensation agency for the State, actively promoted the benefits of SAB systems to encourage purchasers of new vehicles to choose vehicles with SAB systems fitted. By the last quarter of 2010 the percentage of new passenger vehicles sold with front curtain airbags fitted had increased to 72%.

The aim of this paper was to estimate the future economic benefits of side impact airbags fitted into passenger vehicles in Victoria for the period 2011 to 2040 under a 'business-as-usual' scenario. In doing so, the benefits to the driver involved in a near (struck) side crash of SAB systems that protect the head and torso are compared to those afforded by torso only systems.

A range of inputs were used to calculate the economic benefits associated with side airbags including published estimates of their effectiveness in mitigating injury; the future number of passenger vehicles and an estimate of the future number of crashes. A 7% discount rate was used and benefit-cost ratio values were derived.

Under a business-as-usual scenario, it was assumed that side airbags would be fitted to all new passenger vehicles by 2014. Hence, by 2037 all registered passenger vehicles in the fleet would be fitted with SAB systems.

It was estimated that over the 30 year period (2011-2040), 738 lives would be saved and 17,361 drivers would avoid serious injury. Financial savings to the Victorian community were estimated to be $A3.2 billion for an outlay of $A1.6bn in today's terms. The resultant overall BCR was 2.07:1 assuming an installation cost of A$600. The benefits were somewhat less when assuming torso-only SAB systems were fitted, although the BCR remained positive at 1.16:1.

The findings highlight the efficacy of SAB systems in mitigating individual and societal loss associated with side impact crashes. Moreover, the analysis lends weight to efforts by road safety stakeholders to increase the uptake of side airbag systems by consumers.

## INTRODUCTION

In Australia some 21 000 people are admitted to hospital annually due to traffic crashes; for every 1 fatality another 13 are seriously injured and another 135 sustain minor injuries.[1] The annual cost of these crashes to the community has been estimated at $A18 billion.[1] In the State of Victoria in 2006, 337 people were killed (21% of national total) and 8,225 were hospitalised due to their injuries, accounting for 21% and 26% of the national total respectively. In 2010, Victoria had the second lowest in fatality rate per capita at 5.2 deaths per 100,000 person, marginally higher than the Australian Capital Territory (cf. 5.0 per 100,000 persons).[2]

The high burden associated with crashes has been acknowledged by successive Federal and State Governments, who have recognised the need to be proactive in addressing the road toll. This has resulted in the development and implementation of road safety action plans supported by key government stakeholders.

The State of Victoria has an enviable road safety reputation and is widely viewed as being highly progressive. Victoria led the world with the introduction of mandatory seat belt laws and has implemented innovative road safety advertising campaigns, mass random alcohol and drug testing, and invested heavily into improved infrastructure and vehicle safety systems.[3-7] This application of the principles of the *safe systems approach* [8], inspired by the Haddon matrix[9], has delivered impressive reductions in the number of people killed in Victoria (Figure 1) as it has in other jurisdictions.[10] The articulation of the principles of the safe systems approach can be seen in Victoria's road safety strategy, *arrive alive* (http://www.arrivealive.vic.gov.au/).[11]

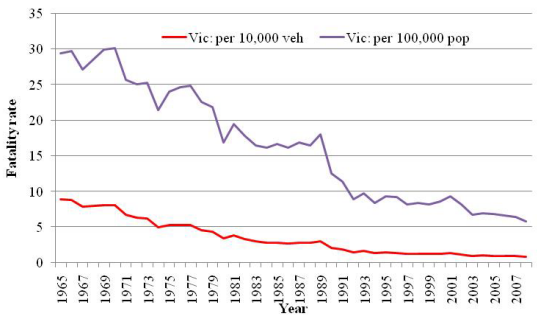



**Figure 1. Victorian road toll (killed), per 100,000 person per 10,000 vehicles**

Victoria has benefited from the introduction of Australian Design Rules (ADR) that sets the minimum safety performance of vehicle components and / or vehicle crashworthiness. The success of the ADR69 frontal crash protection performance-based standard –based on US FMVSS 208) - introduced in 1995 for new model year vehicles, well documented.[12, 13] More recent rulemaking by the Federal Government led to the introduction of a frontal offset protection standard (ADR73, introduced in 2000 for new model year vehicles; ECE R 94/01 equivalent)[14] and the side impact protection test (ADR72, introduced in 1999 for new model year vehicles; ECE95 equivalent).[15]

In recognition of the considerable harm associated with side impact crashes, there have been significant research programs that have defined the magnitude of the crash problem and devised effective countermeasures.[16, 17]

The side impact protection standard (ADR72) is a performance-based standard with manufacturers being free to meet this standard in any way they wish. Given the observed benefits afforded by frontal airbags, side impact airbags (SAB) were introduced as standard equipment in a locally manufactured (Australian) vehicle in the 2000 model year; this also included structural changes to the side structures of the vehicle, including the B-pillar, the door and other vehicle components.

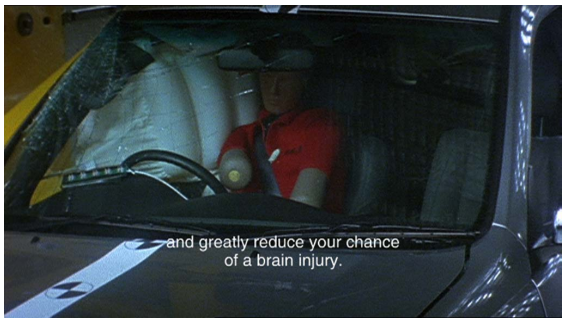
SAB are of two varieties: torso airbags designed to protect the thorax and abdomen, and combination airbags, or head/torso bags. The combination SAB systems have been shown to be most effective with Braver and Kyrychenko demonstrating a 45% reduction in risk of death due to combination SAB; but only 11% for the torso only SAB system.[18] The IIHS has shown a similar differential in SAB performance, noting a 37% reduction in fatality risk with the combination SAB in contrast to 26% for the torso only SAB system.[19]

In a study of injury severity, McGwin and colleagues estimated a 75%, reduction in injury risk to the head (RR: 0.25, 0.08-0.79) and a 68% reduction in thoracic injuries (RR: 0.32, 0.11-0.91).[20]

In recognition of the benefits associated with SAB, the Transport Accident Commission (TAC), Victoria's compulsory no-fault insurer, has promoted the uptake of SAB by vehicle purchasers though active promotions on their website and through other means of targeted advertising; this has been described previously by Truong and colleagues.[21] The intent of the program was to accelerate the uptake of SAB systems in two ways: first, the creation of consumer pressure to fit SAB as standard equipment; and second, to fit SAB systems where available as an option. The content of these promotions may be viewed at http://www.howsafeisyourcar.com.au as well as and on the TAC 'youtube channel' (http://www.youtube.com/user/TACVictoria) which features a number of its television compaigns (see Figure 2 and Figure 3 for screen grabs).

This approach has had positive outcomes, with the fitment of SAB into the vehicle fleet as standard equipment in Victoria outstripping fitment in the all other Australian jurisdictions (Figure 4). With respect to passenger vehicles (cars, SUVs, people movers), only 33% of passenger vehicles sold in Victoria in 2006 were available with front curtain airbags as standard equipment. This had increased to 72% by the last quarter of 2010.

**Figure 2. 'Screen-grab' of TAC SAB television promotion (courtesy of the TAC)**

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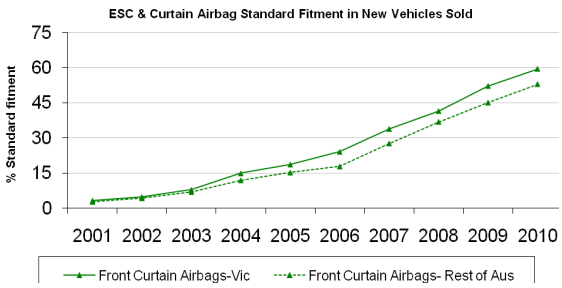


Source: Transport Accident Commission, VicRoads Safety Initiative Reports.

**Figure 4. Standard fitment rates for curtain airbags in new vehicles sold in Victoria and Australia.**

The SAB educational program follows significant financial investment by the TAC in earlier road safety campaigns that were designed to shape the perceptions of road users with respect to road safety. There has also been recognition that side impact crashes are costly – both to the individual and their family as well as in community costs - and that SAB systems have the potential to play a role in mitigating injury in side impact crashes.

This study therefore aims to examine the likely benefits associated with the fitment of SAB under a business-as-usual approach, and in doing so, estimates savings in terms of injury reductions and in financial terms. In doing so, the study determines the introduction costs of SAB systems into new passenger vehicles sold in Victoria, permitting benefit-cost ratio values to be derived.

## METHOD

The key parameter to estimate is the number of future crashes amenable to SAB systems, and then applying the injury reduction values attributable to SAB to determine the benefits on estimated injury numbers.

Using 2008 as the base year, the number of driver fatalities and the number seriously injured per registered passenger vehicle for drivers aged 15 years and older is derived. This data was obtained from Police Reported Casualty Crashes where fatalities were defined as death within 30 days of the crash and a 'serious injury' was an individual who had been admitted to hospital to at least 24 hours.

A number of successive steps were undertaken, these being:

- Step A: the number of drivers in near side impacts (damage on the right side) was determined;
- Step B: the rate of drivers involved in near side impact crashes per registered passenger vehicle was determined, by injury severity (Step B);
- Step C: Using the number of passenger vehicle registrations[22] and the Victorian population 15 years and older[23], the per capita vehicle penetration *(i.e., 'vehicle-population ratio')* was calculated;
- Step D: Using the ABS population projection by year, the *future number of registered passenger vehicles (for each year to 2040, 30 years)* given the derived 'vehicle-population ratio' is calculated (from Step C); this assumes no change in the vehicle penetration rate into the future;
- Step E: Using the crash rate per registered passenger vehicle (Step B) and the future number of registered passenger vehicles every year from 2011 to 2040 (Step D), the number of driver fatalities and those seriously injured for near side impacts is calculated; note that this assumes no other changes in the injury rate into the future with 2008 as the 'base' year.

The result of Step E returns the number of driver fatalities and those seriously injured for drivers involved in near-side impacts. These crashes are in the *field of influence of SAB systems.*

The results of Step A and Step B are presented in Table 1, while Table 2 shows the estimated future number of registered passenger vehicles given the known vehicle-population ratio. The estimated number of fatalities and serious injuries obtained

by applying the known injury ratio (Step B; Table 1) is also presented (Column C, D)

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

| Parameter | Value |
|---|---|
| Fatalities: number | 57 (46.3% drivers killed involved in collisions / rollovers) |
| Serious injury: number | 730 (24.8% drivers involved in collisions / rollovers and seriously injured) |
| Number of registered passenger vehicle[22] | 3,249,418 |
| Fatalities per registered passenger vehicle | 0.00001754 |
| Serious injuries per registered passenger vehicle | 0.000224656 |
| Population ≥ 15 years | 4,437,151 |
| Passenger vehicle per person ratio | 0.732 |

**Table 2. Estimated number of near side driver fatalities and serious injuries, 2011 to 2040**

| Year | Future pop. Estimate (Col. A) | Est. num. passenger vehicles† (Col. B) | Fatalities (Col. C)‡ | Serious injury (Col. D)‡ |
|---|---|---|---|---|
| 2011 | 4,506,713 | 3,300,360 | 58 | 741 |
| 2012 | 4,577,236 | 3,352,005 | 59 | 753 |
| 2013 | 4,647,000 | 3,403,095 | 60 | 765 |
| 2014 | 4,717,375 | 3,454,632 | 61 | 776 |
| 2015 | 4,787,792 | 3,506,200 | 62 | 788 |
| 2016 | 4,857,898 | 3,557,540 | 62 | 799 |
| 2017 | 4,927,693 | 3,608,652 | 63 | 811 |
| 2018 | 4,997,766 | 3,659,968 | 64 | 822 |
| 2019 | 5,068,720 | 3,711,929 | 65 | 834 |
| 2020 | 5,140,106 | 3,764,207 | 66 | 846 |
| 2021 | 5,213,825 | 3,818,193 | 67 | 858 |
| 2022 | 5,289,029 | 3,873,266 | 68 | 870 |
| 2023 | 5,366,645 | 3,930,106 | 69 | 883 |
| 2024 | 5,445,063 | 3,987,533 | 70 | 896 |
| 2025 | 5,524,205 | 4,045,490 | 71 | 909 |
| 2026 | 5,604,031 | 4,103,949 | 72 | 922 |
| 2027 | 5,684,745 | 4,163,057 | 73 | 935 |
| 2028 | 5,766,342 | 4,222,812 | 74 | 949 |
| 2029 | 5,848,795 | 4,283,194 | 75 | 962 |
| 2030 | 5,932,073 | 4,344,180 | 76 | 976 |
| 2031 | 6,016,117 | 4,405,728 | 77 | 990 |
| 2032 | 6,100,881 | 4,467,802 | 78 | 1004 |
| 2033 | 6,186,298 | 4,530,355 | 79 | 1018 |
| 2034 | 6,272,274 | 4,593,317 | 81 | 1032 |
| 2035 | 6,358,742 | 4,656,639 | 82 | 1046 |
| 2036 | 6,445,605 | 4,720,251 | 83 | 1060 |
| 2037 | 6,532,653 | 4,783,998 | 84 | 1075 |
| 2038 | 6,619,674 | 4,847,725 | 85 | 1089 |
| 2039 | 6,706,591 | 4,911,376 | 86 | 1103 |
| 2040 | 6,793,369 | 4,974,925 | 87 | 1118 |
| TOTAL | | | 2157 | 27,630 |

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

**Accounting for SAB fitment and penetration into the fleet**

While Step E returns the estimated number of driver near-side fatalities as shown in Table 2, we must then account for the number of SAB- fitted passenger vehicles and the increasing penetration into the fleet through time. This is the *SAB crash relevance factor.*

The number of passenger vehicles fitted in 2010 with SAB systems then becomes the 'base fitment level'. This approximates the level of fitment of SAB in the fleet and defines their influence in terms of crash numbers.

Using the SAB fitment growth rate of 14.8% over the period 2006 to 2010, we can project upwards to 100% fitment using 2010 as the base year; this is shown in Table 3. We observe that 100% fitment, based on past fitment trends will be achieved by 2013.

**Table 3. Current and future estimated SAB fitment as standard equipment in new passenger vehicles sold in Victoria**

| Year | % new passenger vehicles sold with SAB |
|---|---|
| 2006 | 33.1 |
| *2007* | 43.01 |
| *2008* | 52.04 |
| *2009* | 63.28 |
| 2010 (*base year)* | 72.10 |
| *Average. growth* | *14.8%* |
| 2011 | 82.8 |
| 2012 | 95.0 |
| 2013 | 100 |
| … | 100 |
| 2040 | 100 |

†relevant until all new passenger vehicles fitted

As SAB systems will be fitted to new passenger vehicles in accordance with the introduction schedule noted above, we must then account for the penetration of passenger vehicles into the fleet, given their crash involvement by vehicle age.

The Australian Used Car Safety Rating Database (UCSRD) held by Monash University contains details of drivers of passenger vehicles manufactured since 1964 that have been involved in crashes since 1982. As at the end of 2010, the UCSRD contains records of 185,514 drivers injured in Victoria. The UCSRD was used to establish the age of passenger vehicles at the time of its crash as this permits the estimation of the penetration of new technologies into the fleet whilst accounting for natural de-registration and vehicle write-offs following crashes.

Of interest is the cumulative percent of crash involved passenger vehicles by vehicle age (Table 4, Column A). The interpretation of this is that 76.4% of injury crashes in Victoria involved passenger vehicles up to 15 years of age; alternatively, 23.6% of drivers injured were in passenger vehicles greater than 15 years of age.

The age-based passenger vehicle crash distribution is critical to understand how new technology moves through the fleet. By way of practical example, if for instance a safety technology was introduced in all new passenger vehicles in year X (0, its first year of life – or newly registered), that technology will only be applicable to 2.1% of passenger vehicle injury crashes, and we can then estimate that it would take 10 years for this technology to potentially influence half (52%) of all injury passenger vehicle crashes.

With respect to the above logic, this is shown in Column B of Table 4, where we multiply the percent of passenger vehicles fitted with SAB (Table 3), assuming 2010 is year 11 (given that SAB first appeared in 2000 model year passenger vehicles), by the vehicles involved in crashes (Column A, Table 4); the product of these two parameters is known as the '*technology – vehicle penetration multiplier'*.

Having derived the 'technology-vehicle penetration multiplier' specific to SAB systems in Victoria, we then derive the total number of fatalities and serious injuries that the device will likely influence. We use the estimated number of fatalities and serious injuries presented in Table 2 and the above 'multiplier' (Column B) to determine the number of killed and seriously injured drivers where SAB will have an influence. This in effect states that 47.3% of passenger vehicles involved in crashes will have a side airbag in year 1 of this analysis, which is 2011.

**Table 4. Current and future estimated SAB fitment into passenger vehicles**

| Vehicle age at time of crash (given SAB fitted in 2000 MY vehicles) | Age of vehicles involved in injury crashes (cumulative % (Column A) | Year | Technology – vehicle penetration multiplier (Column B) |
|---|---|---|---|
| 11.00† | 0.57 | 2011 | 0.473 |
| 12.00 | 0.62 | 2012 | 0.589 |
| 13.00 | 0.67 | 2013 | 0.670 |
| 14.00 | 0.72 | 2014 | 0.717 |
| 15.00 | 0.76 | 2015 | 0.764 |
| 16.00 | 0.80 | 2016 | 0.805 |
| 17.00 | 0.84 | 2017 | 0.843 |
| 18.00 | 0.88 | 2018 | 0.875 |
| 19.00 | 0.90 | 2019 | 0.903 |
| 20.00 | 0.93 | 2020 | 0.925 |
| 21.00 | 0.94 | 2021 | 0.943 |
| 22.00 | 0.96 | 2022 | 0.957 |
| 23.00 | 0.97 | 2023 | 0.967 |
| 24.00 | 0.98 | 2024 | 0.975 |
| 25.00 | 0.98 | 2025 | 0.981 |
| 26.00 | 0.99 | 2026 | 0.985 |
| 27.00 | 0.99 | 2027 | 0.989 |
| 28.00 | 0.99 | 2028 | 0.991 |
| 29.00 | 0.99 | 2029 | 0.993 |
| 30.00 | 1.00 | 2030 | 0.995 |
| 31.00 | 1.00 | 2031 | 0.996 |
| 32.00 | 1.00 | 2032 | 0.997 |
| 33.00 | 1.00 | 2033 | 0.998 |
| 34.00 | 1.00 | 2034 | 0.999 |
| 35.00 | 1.00 | 2035 | 0.999 |
| 36.00 | 1.00 | 2036 | 0.999 |
| 37.00 | 1.00 | 2037 | 1.000 |
| 38.00 | 1.00 | 2038 | 1.000 |
| 39.00 | 1.00 | 2039 | 1.000 |
| 40.00 | 1.00 | 2040 | 1.000 |

† accounts for SAB being fitted in 2000MY vehicles (year 0, first year of life), so this commences at year 11.

Table 5 than presents the number of driver fatalities and those seriously injured that are amenable to the influence of SAB for each year 2011 to 2040, a 30-year period.

**Table 5. Likely number of driver fatalities and serious injuries where SAB systems present**

| Year | Fatalities† (Column A) | Serious injury‡ (Column B) |
|---|---|---|
| 2011 | 27 | 351 |
| 2012 | 35 | 444 |
| 2013 | 40 | 512 |
| 2014 | 43 | 557 |
| 2015 | 47 | 602 |
| 2016 | 50 | 643 |
| 2017 | 53 | 683 |
| 2018 | 56 | 720 |
| 2019 | 59 | 753 |
| 2020 | 61 | 783 |
| 2021 | 63 | 809 |
| 2022 | 65 | 833 |
| 2023 | 67 | 854 |
| 2024 | 68 | 874 |
| 2025 | 70 | 892 |
| 2026 | 71 | 909 |
| 2027 | 72 | 925 |
| 2028 | 73 | 940 |
| 2029 | 75 | 956 |
| 2030 | 76 | 971 |
| 2031 | 77 | 986 |
| 2032 | 78 | 1001 |
| 2033 | 79 | 1016 |
| 2034 | 80 | 1031 |
| 2035 | 82 | 1045 |
| 2036 | 83 | 1060 |
| 2037 | 84 | 1074 |
| 2038 | 85 | 1089 |
| 2039 | 86 | 1103 |
| 2040 | 87 | 1118 |
| TOTAL | 1992 | 25,534 |

†Note: product of Table 2-Column C* Table 4-Column B
‡Note: product of Table 2-Column D* Table 4-Column B

**Derivation of 'savings'**

Having established the number of driver fatalities and serious injuries amenable to SAB, we are then in a position to overlay the known injury reduction benefits associated with combination SAB systems; i.e., those that offer both head and thorax/abdomen protection. As noted in the Introduction, a number of studies have demonstrated the benefits of SAB with respect to reductions in fatalities and serious injuries.

The SAB head-torso ('combination') system benefit values used here are:

- 37% reduction for fatalities[19], and
- 68% reduction for serious injuries (relevant for thorax, but higher for head injury reduction)[20].

An analysis was also conducted of the benefits and associated costs of torso only SAB systems given that a number of manufacturers install these systems. The derived savings values therefore represent an absolute lower band of benefits. Based on the published literature, the following benefit values were used:

- 26% reduction for fatalities[19], and
- 34% reduction for serious injuries, which is half that for combination SAB systems[20].

Application of the SAB effectiveness estimate to the number of driver fatalities and serious injuries presented in Table 5 returns the estimated injury reduction savings for each year and severity (see Table 6). This becomes the basis for the estimation of the financial benefits associated with SAB.

**RESULTS**

Application of the process described above results in the estimation of driver fatality and serious injury savings associated with SAB system fitment.

Table 6 provides the injury savings for each year. These savings account for the projected number of crashes, SAB fitment and penetration into the fleet, and device effectiveness. Over the 30 year period, the installation of SAB head-torso systems would be expected to result in 738 lives being saved and 17,361 serious injuries being mitigated, assuming no other changes occur in crash rates and risk.

Reference to Table 2 shows that 17.2% (10 of 58) of fatalities would be expected to be avoided while 32% of driver near side serious injuries would avoided (i.e., 238/741) in 2011.

It is important to note that we do not account for a shift in injury severity in the above calculations, although it is reasonable to assume that those involved in side impact crashes would remain injured; the exact severity shift is however unknown. It would be reasonable to assume that those 'previously killed' and 'previously seriously injured' would sustain 'minor injuries'. This is an important point as it recognises that SAB systems do not necessarily prevent all injuries sustained. This is accounted for by using the injury 'cost' value for minor injuries; the result of this is that the overall cost savings associated with SAB systems are somewhat less than if it was assumed these drivers would escape injury entirely. In the calculation of financial benefits, we thus assume that all drivers previously killed would sustain minor injuries, while those previously sustaining serious injuries would shift to the minor injury category with respect to financial values.

**Table 6. Driver fatalities and serious injury reductions due to the influence of SAB for each year 2011 to 2040, accounting for fitment and penetration through the fleet**

| Year | Fatalities† | Serious injury‡ |
|---|---|---|
| 2011 | 10 | 238 |
| 2012 | 13 | 302 |
| 2013 | 15 | 348 |
| 2014 | 16 | 379 |
| 2015 | 17 | 409 |
| 2016 | 19 | 437 |
| 2017 | 20 | 465 |
| 2018 | 21 | 489 |
| 2019 | 22 | 512 |
| 2020 | 23 | 532 |
| 2021 | 23 | 550 |
| 2022 | 24 | 566 |
| 2023 | 25 | 581 |
| 2024 | 25 | 594 |
| 2025 | 26 | 606 |
| 2026 | 26 | 618 |
| 2027 | 27 | 629 |
| 2028 | 27 | 639 |
| 2029 | 28 | 650 |
| 2030 | 28 | 660 |
| 2031 | 28 | 671 |
| 2032 | 29 | 681 |
| 2033 | 29 | 691 |
| 2034 | 30 | 701 |
| 2035 | 30 | 711 |
| 2036 | 31 | 721 |
| 2037 | 31 | 731 |
| 2038 | 31 | 740 |
| 2039 | 32 | 750 |
| 2040 | 32 | 760 |
| TOTAL | 738 | 17,361 |

†Note: product of Table 5-Column A* SAB effectiveness (37%)
‡Note: product of Table 5-Column A* SAB effectiveness (68%)

**Translation of benefits into financial savings**

The translation of these injury reductions in terms of people killed and seriously injured into financial terms provides the basis for a BCR analysis.

**Derivation of the present day value of crashes -**To derive the economic benefit associated with these predicted savings presented in Table 6, the Australian Government *Best Practice Regulation Guidance Note: Value of statistical life* was used as the basis of financial savings estimates. This guidance note stipulates an economic cost of $A3.5 million per fatality on average expressed in 2007 dollars.[24] This value was inflated by a factor of 1.1049 to bring this value to 2010 dollar values (ABS, Consumer Price Index, CPI values).[25] It is necessary to derive the cost of serious injury, minor injury and property damage only (PDO) crashes by using the ratio of the BITRE costs shown in Table 7 and applying this to the current and known cost of a fatality.[1]

The ratio of fatal to other injury severities was established using the cost of crashes estimated by the BITRE, which were based on 2006 crashes and associated costs.

**Table 7. Financial value of injuries, by severity (2010 values, $AUD)**

| Injury Severity | BITRE injury cost ratio | CPI | $A2007, Dept of Finance (Fatal: $A3.5m, 2007 as index value) |
|---|---|---|---|
| Fatal | 1 | 1.1049 | $3,867,346.94 |
| Serious | 0.099625 | 1.1049 | $385,284.44 |
| Minor | 0.005506 | 1.1049 | $21,293.61 |

**Calculation of financial benefits associated with the reductions due to SAB -** The number of fatalities prevented and serious injuries mitigated (Table 6) provides the basis for the calculation of the bottom line cost savings associated given the installation of SAB under a 'business-as-usual scenario', assuming a 37% fatality reduction benefit and a 68% serious injury reduction benefit due to the deployment of the SAB.

*To obtain the financial savings we simply multiply the reductions in fatalities and serious injuries by the crash costs, and we subtract the cost associated with these same drivers sustaining minor injuries.*

The total benefit savings by injury severity and the aggregate financial benefit are expressed in 2011 dollar values, however it is important to *discount* the benefit values per the practice as articulated by the Office of Best Practice Regulation [24]. A 7% discount factor was used and calculated for each year so that the total benefit in each of the 30 years can be determined. The discount rate is calculated by the following: $[1/(1.07)^{\text{number of years}}]$).

After applying the 7% discount factor for each successive year, the total cost saving associated with the installation of SAB to passenger vehicles for drivers under the business-as-usual scenario was estimated to be $A3.2 billion over the 30 year period.

**Table 8. Financial savings ($A) associated with SAB installation from 2010 – 2040 under a business-as-usual scenario**

| Severity | Person-based reduction | Financial benefits |
|---|---|---|
| Fatal | 738 | $1,014,107,336 |
| Serious | 17,361 | $2,259,025,240 |
| TOTAL | - | $3,273,132,576 |

**Derivation of Benefit – Cost ratio for ESC (BCR)**

Having obtained the aggregate financial benefits associated with SAB, the determination of costs follows which in turn permits the calculation of BCR for SAB.

**Estimation of new passenger vehicles** – For each year in the period, 2011–2040 inclusive, the number of new passenger vehicles entering the fleet must be estimated. Simple linear regression was used to construct a prediction model to calculate the number of new passenger vehicles registered for the first time. The predictive model was constructed by using the historical relationship between new passenger vehicles and the population of Victoria 15 years and older in the period 2006-2010.[26, 27]

The basic linear regression model is shown in Equation 1.

$$Y\ [passenger\ vehicle\ sales] = \alpha + \beta x_i + \xi_i \qquad [1]$$

where:

$\alpha$ is an unknown parameter (model constant)

$\beta_i$ is an unknown parameter, estimated using values of x

$\xi_i$ is the *error term*

Equation 2 shows the derived relationship between new passenger vehicle sales and the Victorian population with a weak linear trend being evident. This model, while relatively poorly specified, serves as the basis for future estimates of the number of new passenger vehicles entering the fleet. By substitution of future population projection values, the number of new passenger car sales into the future can be estimated.

$$Y\ [passenger\ vehicle\ sales] = -56268.75 + 0.051997 * x_i \qquad [2]$$

where:

$\alpha$ is the model constant

$\beta_i$ is the estimated population coefficient

$x_i$ *represents the (future) population values for Victoria as shown in Table 2.*

These projection results rely on a number of assumptions, these being:

1. observed economic growth will continue, on an average basis, into the future, over the life of the projections
2. there is no change in the factors associated with the purchase of passenger vehicles for individual buyers, that is, demand side factors remain constant
3. there is no change in the factors relating to the production of passenger vehicles, that is, supply side factors remain constant
4. that the vehicle technology as of today remains constant with respect to the influence such technology has on vehicle purchasing choice
5. the impact of any future regulatory change on purchasing choices cannot be accounted for, and
6. that the projected population estimates derived by the Australian Bureau of Statistics (ABS) are i. accurate within their stated assumptions and limitations, and ii. the analysis here does not account for the possibility of future re-estimation by the ABS.

Given these assumptions, the number of new passenger vehicles entering the fleet over the next 30 years is presented in Table 9.

**Accounting for SAB fitment rates into new passenger vehicles, and associated cost** - As the benefits are derived on the basis of standard SAB fitment, the number of new passenger vehicles entering the fleet fitted with SAB for each year must be used rather than the overall total. We therefore use the product of the estimated number of new passenger vehicles by the SAB fitment rate for each year as shown in Table 3.

Following the derivation of the number of passenger vehicles fitted with SAB by calendar

year, and using the fitment value of $A600 per passenger vehicle due to the need to fit both driver and passenger airbags and with a 7% discount factor applied for each year, the yearly and hence total cost over the 30 year period of SAB fitment is derived (Table 9).

There are two observations to be made:

1. the yearly cost increases, and is highest at 2013 – which coincides with all new passenger vehicles being fitted with SAB as standard equipment, and

2. from 2014 the total cost of installation falls per year, despite the increasing number of passenger vehicles sold, a feature that is in accord with the 7% discounting of the device cost.

As shown in Table 9, across the entire 30 year period the estimated total cost of SAB fitment assuming a device cost of $AUD600 into the fleet in today's terms (i.e., 2011 dollars) was estimated to be A$1.582 billion.

**Table 9. Total number of new passenger vehicles entering the market and cost of SAB installation (base price, $600, 7% discount rate)**

| Year | Num new. pass vehicles | New pass vehicles with SAB† | Cost at 7% disc. rate† | Install cost ($A) |
|---|---|---|---|---|
| 2011 | 178070 | 147442 | $561 | $82,677,716 |
| 2012 | 181737 | 172650 | $524 | $90,479,594 |
| 2013 | 185365 | 185365 | $490 | $90,787,619 |
| 2014 | 189024 | 189024 | $458 | $86,523,257 |
| 2015 | 192685 | 192685 | $428 | $82,429,226 |
| 2016 | 196331 | 196331 | $400 | $78,494,090 |
| 2017 | 199960 | 199960 | $374 | $74,715,005 |
| 2018 | 203604 | 203604 | $349 | $71,099,485 |
| 2019 | 207293 | 207293 | $326 | $67,652,205 |
| 2020 | 211005 | 211005 | $305 | $64,358,527 |
| 2021 | 214838 | 214838 | $285 | $61,240,837 |
| 2022 | 218749 | 218749 | $266 | $58,276,195 |
| 2023 | 222784 | 222784 | $249 | $55,468,575 |
| 2024 | 226862 | 226862 | $233 | $52,788,598 |
| 2025 | 230977 | 230977 | $217 | $50,230,061 |
| 2026 | 235128 | 235128 | $203 | $47,787,588 |
| 2027 | 239325 | 239325 | $190 | $45,458,483 |
| 2028 | 243568 | 243568 | $178 | $43,237,749 |
| 2029 | 247855 | 247855 | $166 | $41,120,407 |
| 2030 | 252185 | 252185 | $155 | $39,101,700 |
| 2031 | 256555 | 256555 | $145 | $37,176,906 |
| 2032 | 260963 | 260963 | $135 | $35,341,675 |
| 2033 | 265405 | 265405 | $127 | $33,591,753 |
| 2034 | 269875 | 269875 | $118 | $31,922,975 |
| 2035 | 274371 | 274371 | $111 | $30,331,602 |
| 2036 | 278888 | 278888 | $103 | $28,813,942 |
| 2037 | 283414 | 283414 | $97 | $27,365,969 |
| 2038 | 287939 | 287939 | $90 | $25,984,004 |
| 2039 | 292459 | 292459 | $84 | $24,665,279 |
| 2040 | 296971 | 296971 | $79 | $23,407,320 |
| **Total** | 178070 | 147442 | | $1,582,528,340 |

†Obtained by multiplying the SAB fitment values from Table 3

Using these fitment cost values and the financial savings, the BCR values for each year and across the entire period can be calculated (Table 10).

The calculated BCR using a $A600 SAB fitment cost across the entire period (in 2011 dollar values), assuming the business-as-usual fitment scenario and a 7% discount rate was 2.07:1

**Table 10. Per annum BCRs with the aggregate BCR for SAB fitment over the 30 year period**

| Year | BCR |
|---|---|
| 2011 | 1.42 |
| 2012 | 1.54 |
| 2013 | 1.65 |
| 2014 | 1.76 |
| 2015 | 1.87 |
| 2016 | 1.96 |
| 2017 | 2.04 |
| 2018 | 2.11 |
| 2019 | 2.17 |
| 2020 | 2.22 |
| 2021 | 2.25 |
| 2022 | 2.27 |
| 2023 | 2.29 |
| 2024 | 2.30 |
| 2025 | 2.31 |
| 2026 | 2.31 |
| 2027 | 2.31 |
| 2028 | 2.31 |
| 2029 | 2.31 |
| 2030 | 2.30 |
| 2031 | 2.30 |
| 2032 | 2.29 |
| 2033 | 2.29 |
| 2034 | 2.28 |
| 2035 | 2.28 |
| 2036 | 2.27 |
| 2037 | 2.27 |
| 2038 | 2.26 |
| 2039 | 2.25 |
| 2040 | 2.25 |
| *Overall* | *2.07* |

**Summary of findings**

A summary of the findings are presented in Table 11. The values rely on a number of inputs and these are:

- the ratio of injuries to registered passenger vehicles;
- the passenger vehicle penetration rate into the population; *note:* any potential future changes that might occur in this ratio due to an ageing population and a trend toward increasing urbanisation is not considered;
- the fitment rate of SAB systems into new passenger vehicles;
- the number of new passenger vehicle sales, and the progressive penetration of the fitted SAB into the fleet;
- The effectiveness estimate of the SAB system itself in mitigating fatalities and serious injuries, and the related assumption that these drivers would sustain minor injuries for financial cost purposes, and
- A discount rate of 7% over the 30 years.

It is important to note that while these inputs were based on historical trends, and were derived using the best available inputs at the time of analysis, it remains the case that any variation in any of these inputs would influence the number of drivers affected, and hence the overall BCR obtained.

In short and as can be observed from Table 11, the findings reported here are highly favourable and suggest significant savings will be made in the reduction of injuries sustained by drivers involved in near side impacts due to SAB systems.

**Table 11. Overall view of person-based injury reductions, financial savings and benefits, and the overall BCR for combination SAB fitment**

| Benefit | Estimates |
|---|---|
| *Reductions in injuries (people)* | |
| Fatality savings @37% effectiveness | 738 |
| Serious injury savings @68% effectiveness | 17,361 |
| *Financial savings (@ 7% discount rate)* | |
| Fatality savings | $A1,014,107,336 |
| Serious injury savings | $A2,259,025,240 |
| *Total savings* | $A3,273,132,576 |
| *Total cost* | $A1,582,528,340 |
| *BCR (saving & device cost of $A600 @ 7% discount rate)* | |
| *BCR* | 2.07:1 |

**Estimation of torso SAB effects**

In the above calculation it is assumed that 100% of the SAB systems fitted would be combination SAB systems. It is the case however that a number of manufacturers choose to install torso only systems and this may be accompanied by substantial changes to the side structures of the vehicle. It is thus important to estimate the savings and costs associated with torso SAB systems. For this purpose, the fitment cost is as per the combination SAB system. For brevity, the only the results of the calculations are presented in Table 12 and Figure 5. This allows a direct comparison with the benefits and costs associated with the assumed 100% fitment of combination SAB systems.

**Table 12. Overall view of person-based injury reductions, financial savings and benefits, and the overall BCR for torso only SAB fitment**

| Benefit | Estimates |
|---|---|
| *Reductions in injuries (people)* | |
| Fatality savings @26% effectiveness | 518 |
| Serious injury savings @ 34% effectiveness | 8680 |
| *Financial savings (@ 7% discount rate)* | |
| Fatality savings | $A712,615,966 |
| Serious injury savings | $A1,129,512,620 |
| *Total savings* | $A1,842,128,586 |
| *Total cost* | $A1,582,528,340 |
| *BCR (saving & device cost of $A600 @ 7% discount rate)* | |
| *BCR* | 1.16:1 |

Figure 5 shows the BCR's calculated for both SAB system configurations across an installation cost range of $A400 to A$1250. The break-event cost for the combination SAB system was $A1325 and $A700 for the torso only SAB system.

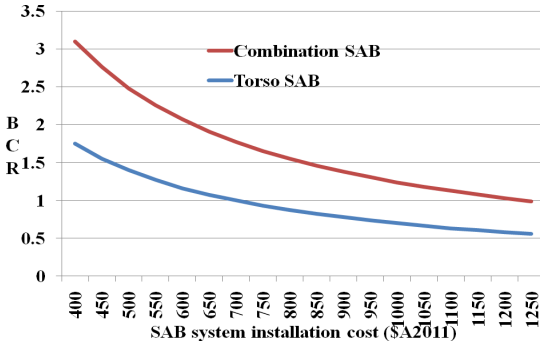


**Figure 5. BCR value given SAB system fitment cost and benefits for combination and torso systems**

## DISCUSSION

The findings of this analysis estimate that the fitment of SAB systems fitted into new passenger vehicles sold in Victoria would be associated with 738 fewer deaths and 17,361 fewer serious injuries to drivers involved in near side impact crashes from 2011-2040. The financial savings are in the order of $A3.273 billion with an expect outlay of $A1.582 billion given SAB installation cost of $A600 in today's dollar terms and the overall BCR was found to be 2.07:1.

The alternative analysis where the benefits of torso only SAB are used – and assumed to be fitted to all existing and new passenger vehicles are logically lower than those for described for combination SAB systems. In short, it could be expected that there would be 518 fewer deaths and 8680 fewer serious injuries to drivers involved in near side impact crashes over a 30-year period. The financial savings are in the order of $A1.8 billion with an expect outlay of $A1.582 billion given SAB installation cost of $A600 in today's dollar terms. The overall BCR was found to be 1.16:1 over the next thirty years.

Consumer safety programs, such as NCAP and www.howsafeisyourcar.com.au have a significant role to play in creating consumer demand for improved passive and active safety features such as SAB, but also Electronic Stability Control, Brake Assist and an array of emerging life-saving technologies. The considerable savings – and the positive benefit-cost ratio, reported here, provide the basis for programs that encourage buyers of purchase passenger vehicles with SAB systems fitted, or alternatively, to elect to fit SAB where available as an optional extra.

The present paper has a number of limitations. First, we report only a single effectiveness value for fatal and serious injuries for each SAB configuration; ideally we would conduct a sensitivity analysis using a lower and upper range of benefits, and this is planned for the future work program. Second, we ideally require estimates of SAB effectiveness from the Australian fleet. Third, it is important to model the head injury benefits of side airbag systems, particularly given the significant life-time costs for those with severe traumatic brain injury; the mitigation of these types of injuries would result in larger financial savings, let alone the vastly different quality of life of those injured. Fourth, the analysis would benefit from more robust estimates of the future number of crashes and a differentiation of standard or optional SAB system fitment as well as the type of SAB system fitted into passenger vehicles in Victoria.

While the above points may be considered limitations, they also point a way forward to providing the basis for more robust estimators as well as the inputs required to assess the effect any changes in the fitment rate – either accelerated or slower, than the current business-as-usual model.

## CONCLUSIONS

In summary, this analysis points to significant benefits to the Victorian community of the continued uptake of SAB into passenger vehicles through a significant reduction in the number of drivers killed and seriously injured in near-side impact crashes. These benefits were found to be greater for combination airbags which offer both head and torso protection as compared to torso only SAB. The benefits reported here are likely to be conservative given that only the driver in near side impacts was examined. It is important to note that the inclusion of drivers involved in far-side impacts and the inclusion of the front passenger would result in higher savings due to the dual deployment in the case of side impact crashes, with no additional fitment cost.

It is thus imperative that consumers are educated as to the benefits of choosing the safest car they can afford at the time of purchase. Consumer safety programs such as those initiated and supported by the TAC have a significant role to play in creating consumer demand for safer passenger vehicles and promoting the installation of new technologies. With this continued and sustained investment, the lives of a significant number of Victorians will benefit well into the future.

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