

Contribution of vehicle safety improvements and infrastructure investment on reducing road trauma in Victoria and projected future benefits

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Abstract

Vehicle safety and infrastructure improvements are two major road safety program areas that have made significant contributions to the reduction of road trauma under the Safe System. In Victoria over the past 10 years, there have been increasing improvements in the safety of the vehicle fleet and significant investment in safer road infrastructure through the TAC funded Safer Road Infrastructure Program (SRIP). The aim of this work was to estimate the impact of each road safety program area on road trauma as represented by measured improvements in the light vehicle fleet and major investment in safer infrastructure through SRIP, and to project their future benefits. Time series models were constructed over the period 2006 to 2014 with separate models developed for fatalities and serious injuries. These models were then used to produce forecasts of future trends in deaths and serious injuries. It was evident that each program area has been very successful in achieving significant savings in death and serious injury. However, the estimated fatal and serious injury future trends indicated that the ongoing issue of serious injury trauma will require particular focus and effort by road safety policymakers to address. Whilst this work demonstrates the effectiveness of vehicle safety improvements and infrastructure investment on preventing serious road trauma, the projected future benefits of these key road safety program areas highlight how critically important it is to continue to invest in proven road safety programs if the benefits that have been achieved thus far are to continue going forward.

Introduction

Vehicle safety and infrastructure improvements are two major road safety program areas that have made significant contributions to the reduction of road trauma under the Safe System. In Victoria over the past 10 years, there have been increasing improvements in the safety of the vehicle fleet and significant investment in safer road infrastructure through the TAC funded Safer Road Infrastructure Program (SRIP). Improvements in the overall safety of the vehicle fleet have been demonstrated by Newstead, Watson, and Cameron (2014) who found significant improvements in secondary safety of the Australian vehicle fleet as measured by crashworthiness, or the risk of driver death or serious injury in the event of a crash, with increasing year of manufacture. Early improvements can be attributed to the introduction of major Australian Design Rules (ADRs) for passenger vehicles with standards covering seatbelt fitment, energy-absorbing steering columns, head restraints and improved cabin strength, with more recent vehicle secondary safety improvements including seatbelt pre-tensioners, anti-whiplash seats, active head restraints and frontal, side and knee airbags (Langford, 2009). These improvements have translated into improvements in the average safety of the light vehicle fleet as a whole over time, as demonstrated by Newstead and Scully (2009), as older vehicles are removed from the fleet and safer new vehicles enter the fleet.

Major investment in road infrastructure through the SRIP program was announced by the Victorian government in 2004 with the aim of reducing deaths and serious injuries through infrastructure improvements on arterial roads. Stage 1 (2004-2008) delivered 113 projects focusing on run-off-road and intersection crashes at a cost of \$130 million. Run-off-road treatments included shoulder

sealing, safety barriers (wire rope barriers and/or guard fences) and tactile lines. Intersection treatments included fully controlled right turns, new traffic signals and roundabouts. Stage 2 (2006-2008) delivered 252 projects at a cost of \$110m continuing with run-off-road treatments and expanding the focus on intersection treatments. Stage 3 (from 2007) is delivering projects to the value of \$650m over a 10 year period, and also includes treatments at 40 km/h shopping strips, school zones and greyspots such as Y intersections.

The aim of the analysis presented in this paper was to estimate the individual impact of improvements in the light vehicle fleet and major investment in safer infrastructure through SRIP investment on overall road trauma in Victoria and to project their future benefits. Analysis is based on previous research evaluating the effects of each of these countermeasure areas on road trauma. The road trauma impacts of SRIP along with the economic worth of the program have been estimated through a comprehensive evaluation of each phase of the program detailed in Budd, Newstead and Scully (2011) and Budd, Scully and Newstead (2011a, 2011b). The impact of the changing composition of the light vehicle fleet on annual observed road trauma in Australia has been estimated by Budd, Keall and Newstead (2015).

Method

Time series models were constructed over the period 2006 to 2014 with separate models developed for fatalities and serious injuries. These models were then used to produce forecasts of future trends in deaths and serious injuries to 2025. Specifically, the effect of each program area on reducing fatalities and serious injuries at each time period was estimated based on prior research. The observed time series of data was then adjusted to give the expected time series of data had each program not been implemented (called the residual time series). Forecasts were then made on the residual time series to estimate expected future road trauma had vehicle safety improvement and SRIP investment not happened. Estimated future trauma reductions due to vehicle safety improvements and SRIP investment were then derived from the previous research and information on planned future SRIP expenditure to estimate the impact these programs will have on expected future road trauma. These estimates were applied to the forecast residual time series to quantify the trauma savings expected. Data was extracted from the VicRoads Road Crash Information System (RCIS), with fatality data used directly whereas serious injury data was validated against TAC claims data in order to overcome any reporting inaccuracies related to the measurement of serious injury in Victoria (D'Elia & Newstead, 2014). The periodicity on which the data was analysed was determined by the data quantities available in order to get reasonable periodic crash counts for analysis. Monthly data counts were found to be sufficiently large for both fatal and serious injury series for analysis.

The analysis was based on the structural time series models developed by Harvey (1989) which are formulated directly in terms of trend μ_t , seasonal s_t and irregular ε_t (noise) components. These models are like the classical decomposition model defined by:

$$y_t = \mu_t + s_t + \varepsilon_t$$

in which the components are of direct interest themselves. However, unlike the classical decomposition model, in which the trend and seasonal components are deterministic (fixed), structural time series models allow for random (stochastic) variation in these components.

The models were explicitly set up to examine the impact on road trauma of the two major road safety program areas highlighted by this paper, namely improvements in safety of the Victorian

light vehicle fleet and investment in road infrastructure improvements through SRIP. The effects of each program area were estimated as follows.

Estimating vehicle crashworthiness effects

The crashworthiness metric used in this analysis estimates the risk of vehicle occupant serious injury or death given involvement in a crash. Effects of vehicle crashworthiness improvement on monthly road trauma were estimated by quantifying the cross-sectional secondary safety of the crashed light vehicle fleet each year and estimating how this has changed over time. Budd, Keall and Newstead (2015) undertook this calculation for the Australian light vehicle fleet over the period 2000 to 2010 inclusive. They noted that during this time, the average cross-sectional crashworthiness of the Australian light vehicle fleet (the average risk of death or serious injury to the vehicle occupant in a crash) improved by 27%, an average of 3% compounding each year. These estimates were used to calculate the relative change in average crashworthiness of the vehicle fleet compared to year 2005 by:

$$Rel\ CWR(Year\ x) = \frac{CWR(Year\ x)}{CWR(2005)}$$

As evident from the data points in Figure 1, this trend was highly linear and was hence used to estimate the relative crashworthiness of the vehicle fleet from 2011 to 2025 assuming that the crashworthiness improvements would continue in the same way.

Crashworthiness improvements only apply to vehicle occupants so the estimated effects of vehicle safety improvements on overall fatalities and serious injuries were estimated by applying the proportionate improvements in vehicle crashworthiness from 2005 to that component of the overall trend that were vehicle occupants, typically around 85% of deaths or serious injuries. In estimating projected future impacts of vehicle safety improvement it has been assumed that vehicle occupants continue to represent 85% of deaths and serious injuries.

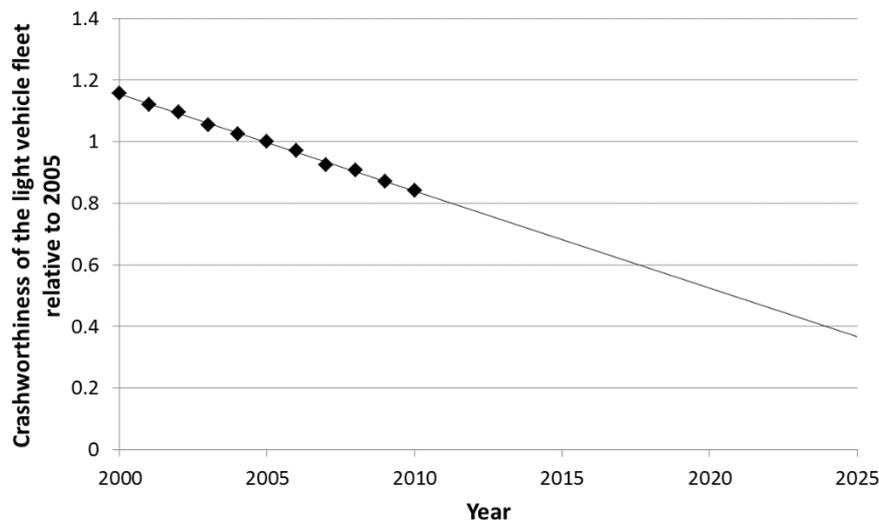


Figure 1: Average crashworthiness of the light vehicle fleet relative to 2005

Estimating SRIP effects

Effects of the SRIP program on past and expected future fatalities and serious injuries were estimated from the results of the evaluations of SRIP Stages 1, 2, and 3 (Budd, Newstead & Scully, 2011; Budd, Scully & Newstead 2011a, 2011b), and in particular estimates of program cost

effectiveness in conjunction with past and planned expenditure on SRIP and estimates of SRIP treatment average lifetimes. Figure 2 shows the actual annual expenditure on SRIP from 2005 to 2014 along with the planned expenditure from 2015 to 2023. Past expenditure on SRIP has been based largely on the traditional black spot methodology for site selection apart from some small expenditure on potential blackspots. The TAC advised that SRIP expenditure from 2013 will include a component of what it terms Safe System expenditure on mass action programs expected to reduce crash frequency by at least 85% with a benefit to cost ratio of at least 1.5. Although a benefit to cost ratio for Safe System expenditure has been estimated the expected cost effectiveness of the Safe System expenditure corresponding to the estimated BCR has not been estimated but has been derived from the BCR figure based on the relationship between cost effectiveness and BCR estimates from the evaluations of SRIP (Budd, Newstead & Scully, 2011; Budd, Scully & Newstead 2011a, 2011b). Figure 2 shows the proportion of future funding allocated to Safe System expenditure.

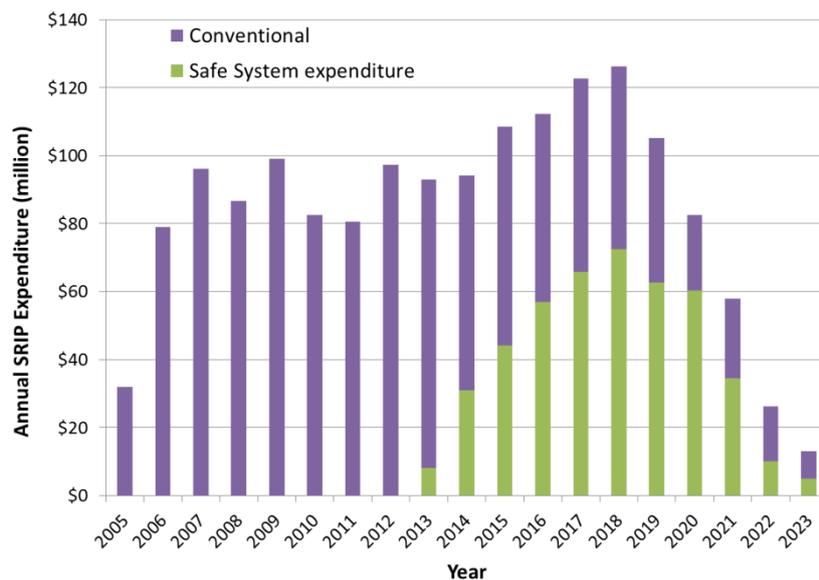


Figure 2: SRIP expenditure: actual 2005-2014, planned 2015-2023 (Source: TAC)

Cost effectiveness estimates from evaluation give the amount spent on the program to save each serious injury crash and fatal crash over the life of each treatment. Table 1 presents the cost effectiveness estimates for SRIP derived from the evaluations undertaken (Budd, Newstead & Scully, 2011; Budd, Scully & Newstead 2011a, 2011b). The program benefit to cost ratio is also given for comparison. No cost effectiveness estimates for fatal and serious injury crashes were available for the SRIP3 evaluation (only for all casualty crashes). For this study, an average of the cost effectiveness estimates for SRIP 1 and 2 were taken. An average benefit to cost ratio was also taken across the three SRIP evaluations. Cost effectiveness values were derived for the Safe System treatments based on the difference between the benefit to cost ratios between the regular SRIP treatments and the Safe System treatments (assuming the BCR of 1.5 which is an estimate unsubstantiated by formal evaluation) according to the following formula assuming that the cost effectiveness estimates will be inversely proportional to the benefit to cost ratios:

$$CE_{Safe\ System} = CE_{Regular\ SRIP} \frac{BCR_{Regular\ SRIP}}{BCR_{Safe\ System}}$$

Table 1: SRIP evaluation cost effectiveness estimates

	CE Fatal	CE Serious Injury	BCR
SRIP1	\$913,036	\$115,036	2.1
SRIP2	\$960,294	\$71,823	3.6
SRIP3	-	-	2.4
Average	\$933,690	\$96,150	2.6
Safe System Treatments	\$1,611,745	\$165,975	1.5

Crash based cost effectiveness estimates were transformed into person based cost effectiveness estimates by dividing the fatal crash and serious injury crash based cost effectiveness estimates by the number of fatalities per fatal crash and serious injuries per serious injury crashes estimated from the SRIP crash data. The person based cost effectiveness estimates were then transformed into annual fatality and serious injury savings by dividing the total SRIP expenditure in each category by the corresponding person based cost effectiveness estimates and dividing by the average treatment lifetime for treatments undertaken in that year (reflecting that the cost effectiveness figure is derived from the total capital expenditure and maintenance costs divided by total trauma savings over the life of the treatment). Table 2 gives the cost weighted average SRIP treatment lifetimes for SRIP1, 2 and 3 treatments implemented in each year from 2005 to 2010. The cost weighted average is the average treatment life for each treatment with each treatment weighted by the proportion of the total SRIP expenditure in that year each treatment represented. The average treatment life across all SRIP stages and years was 19 and did not vary greatly between years. It was assumed that all future SRIP treatments will also have an average treatment life of 19 years and that the cost effectiveness of regular treatment will remain similar.

Table 2: SRIP treatment lifetimes

	2005	2006	2007	2008	2009	2010
SRIP1	18.46	20.57	17.31	29.06	-	-
SRIP2	-	16.09	16.94	18.57	-	-
SRIP3	-	-	16.49	18.50	18.93	18.55
Cost Weighted Average	18.46	20.41	16.98	19.60	18.93	18.55
Overall Average	18.96					

The fatality or serious injury savings in a particular year (x) are calculated by the following formula:

$$\text{Injury Savings in year } x = \sum_{x-19}^x \frac{\text{SRIP Expenditure in Year } x}{\text{Cost Effectiveness} \times \text{Average Treatment Life}}$$

This formula was applied to regular SRIP expenditure and Safe Systems expenditure separately and the resulting savings added.

Results

SRIP and vehicle safety effects

Estimated monthly savings in deaths and serious injuries in Victoria associated with SRIP expenditure over the period 2005-2025 is shown in Figure 3. The effect of vehicle safety improvements on deaths and serious injuries is shown in Figure 1. The estimated annual reduction

in deaths and serious injuries due to vehicle secondary safety improvements is around 3%. Since the crashworthiness estimates used to derive Figure 1 give the risk of death or serious injury, it has been assumed that vehicle secondary safety improvement impact deaths in the same way as serious injuries.

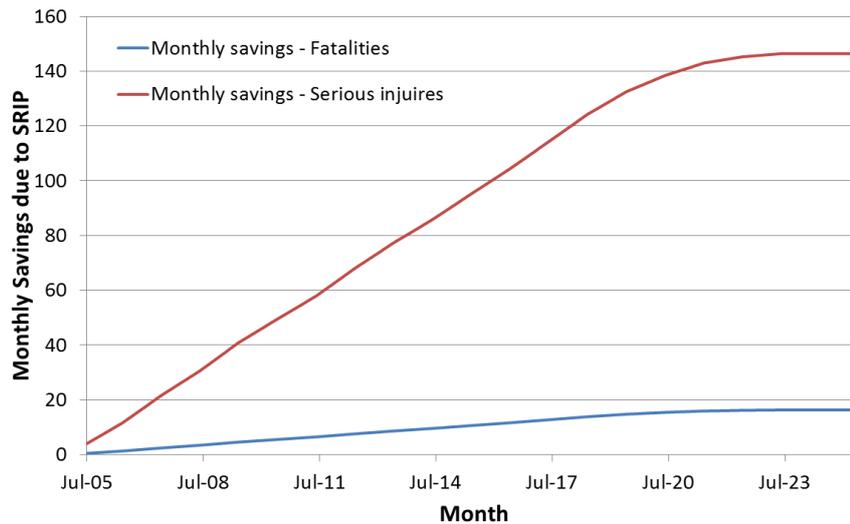


Figure 3: Monthly savings in deaths and serious injuries due to SRIP investment: 2005-2025

Crash data time series and forecasts

Figure 4 shows the observed monthly number of fatalities and serious injuries in Victoria over the period January 2006 to December 2014. Figure 5 shows the deaths time series alone for greater resolution.

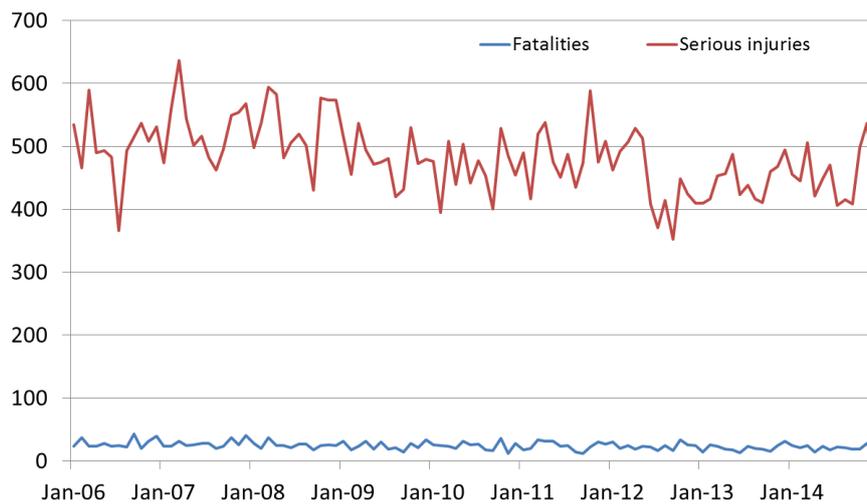


Figure 4: Observed monthly deaths and serious injuries in Victoria: 2006-2014

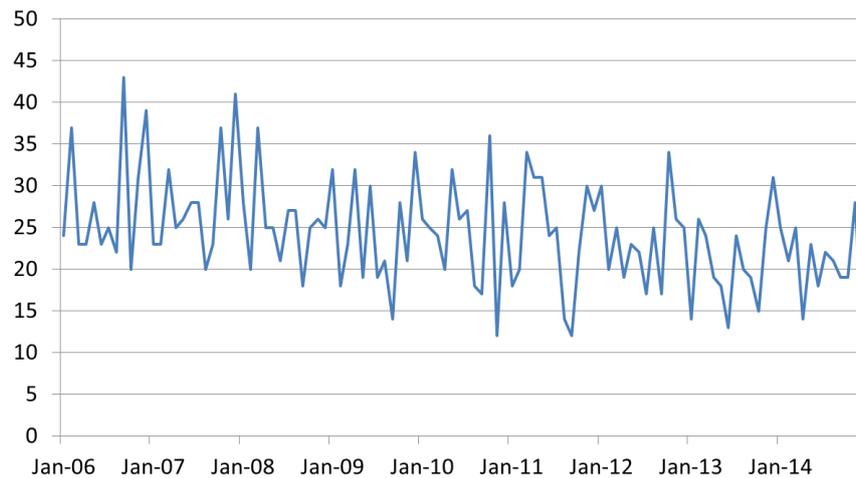


Figure 5: Observed monthly deaths in Victoria: 2006-2014

Figure 6 shows the effects of adjusting the effects of SRIP crash and vehicle secondary safety improvements from the serious injuries time series. The top line in the chart is the residual time series from which the time series model was estimated and the expected future trend forecast. Figure 7 shows the corresponding chart for the fatality time series.

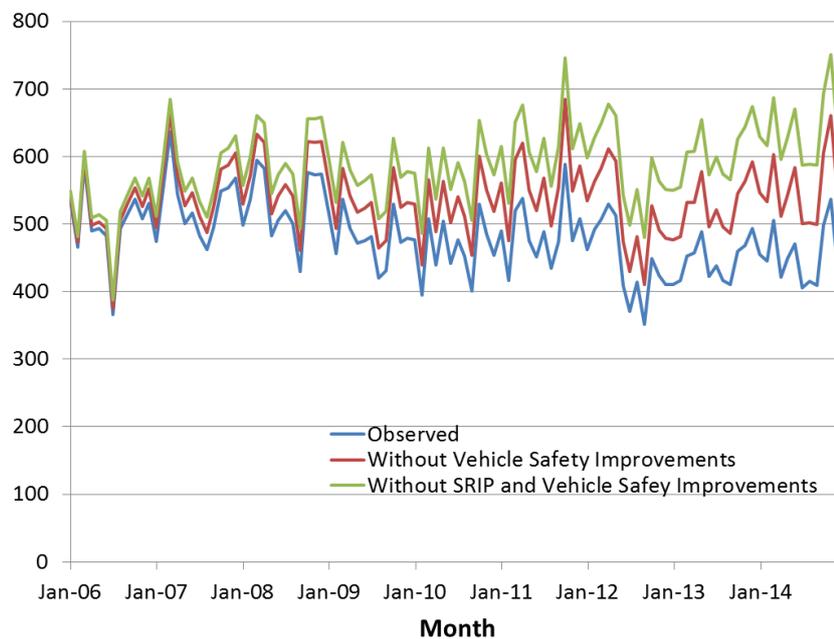


Figure 6: Residual trend in serious injuries in Victoria after removing the effects of SRIP and vehicle secondary safety improvements

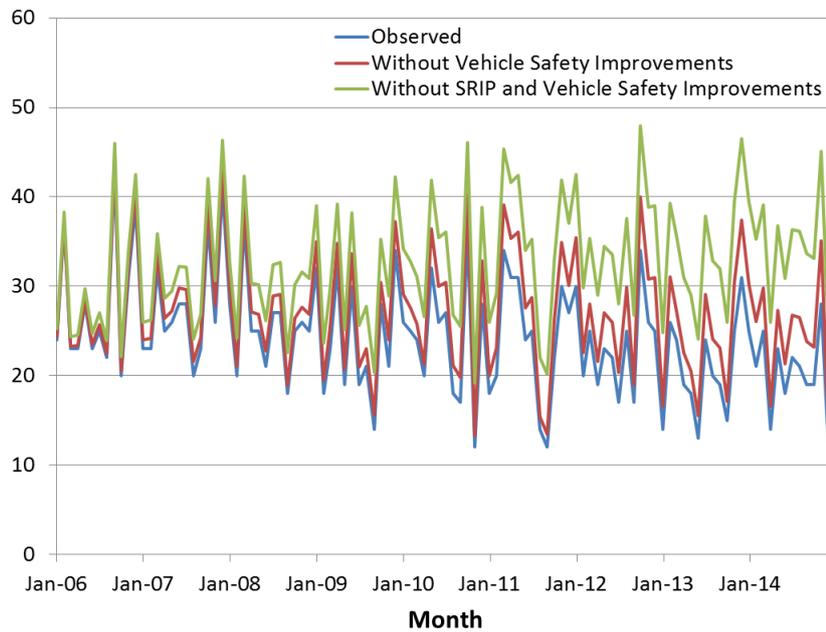


Figure 7: Residual trend in fatalities in Victoria after removing the effects of SRIP and vehicle secondary safety improvements

Using the structural time series model estimated from the residual serious injury trend in Figure 6, a forecast of the expected future residual trend over the period 2015-2025 was estimated. The resulting forecast is shown in Figure 8. The corresponding residual fatality series forecast is shown in Figure 9.

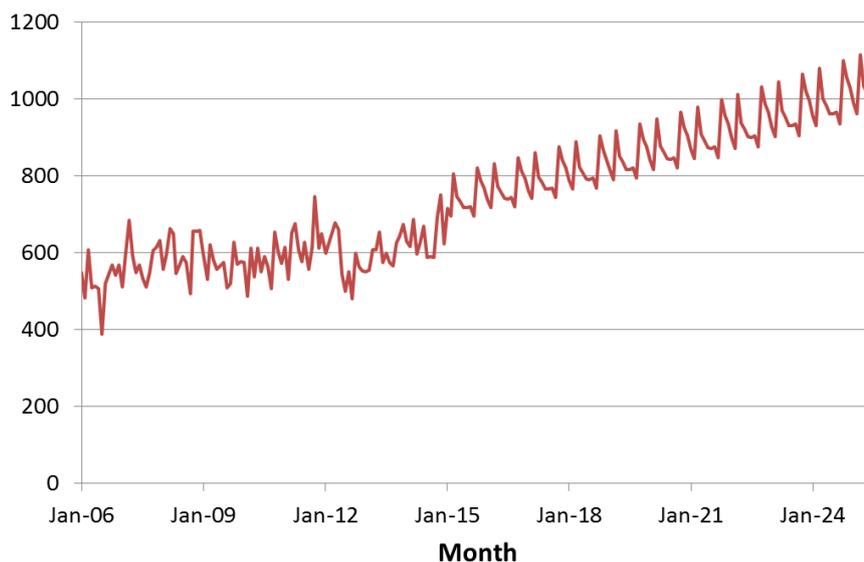


Figure 8: Forecast residual trend in serious injuries: 2015-2025

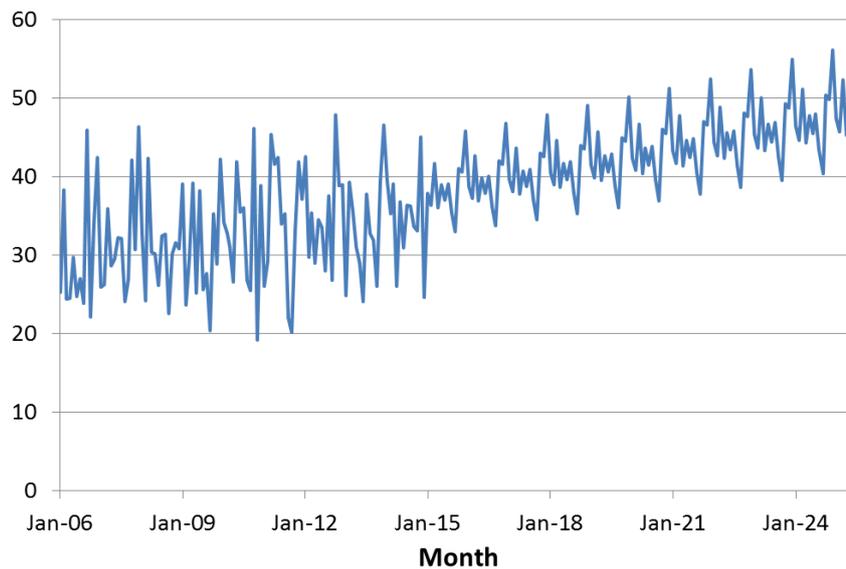


Figure 9: Forecast residual trend in fatalities: 2015-2025

The residual trend time series is driven by all other factors influencing road trauma apart from vehicle secondary safety trends and crash reductions attributable to SRIP. These factors might include exposure effects such as population growth; population age and gender mix; travel mode shifts (e.g. driving versus cycling, walking and public transport use); environmental (e.g. weather patterns, built environment, road environment development other than SRIP); changing behaviour (e.g. changes in alcohol use, drug use and driver distraction); and other road safety programs (e.g. enforcement, GLS, emerging vehicle primary safety technology).

Time series model forecasts were constructed on the premise that the underlying factors driving the variation in the data continue to act in the way that they have in the past. The forecasts produced for the residual fatal and serious injury time series assumes all of the factors influencing these trends, including those listed above, will continue to operate into the future either at their current static level or changing at the rate they have been changing in the past whilst continuing to influence the trauma outcome in the same way. Whether this is ultimately the case remains unknown and if any of these conditions change, the time series forecast will be compromised. It should be noted that the longer the forecast of a time series the less confidence there is in the likely accuracy of the forecast. A 10 year forecast is extremely long so confidence in the residual road trauma predictions out to 2025 will not be high.

Forecast future serious injuries over the period 2015-2025 including the effects of SRIP and vehicle secondary safety improvements are shown as the bottom line in Figure 10. Figure 11 shows the corresponding forecast fatality series with both figures showing the estimated contributions of vehicle safety improvements and SRIP expenditure.

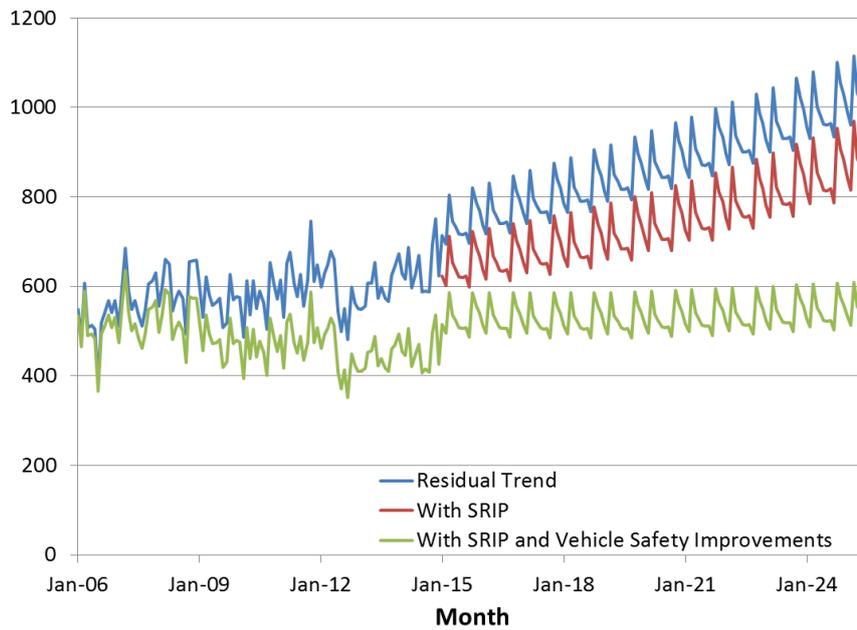


Figure 10: Forecast trend in serious injuries including the estimated effects of vehicle safety improvements and SRIP: 2015-2025

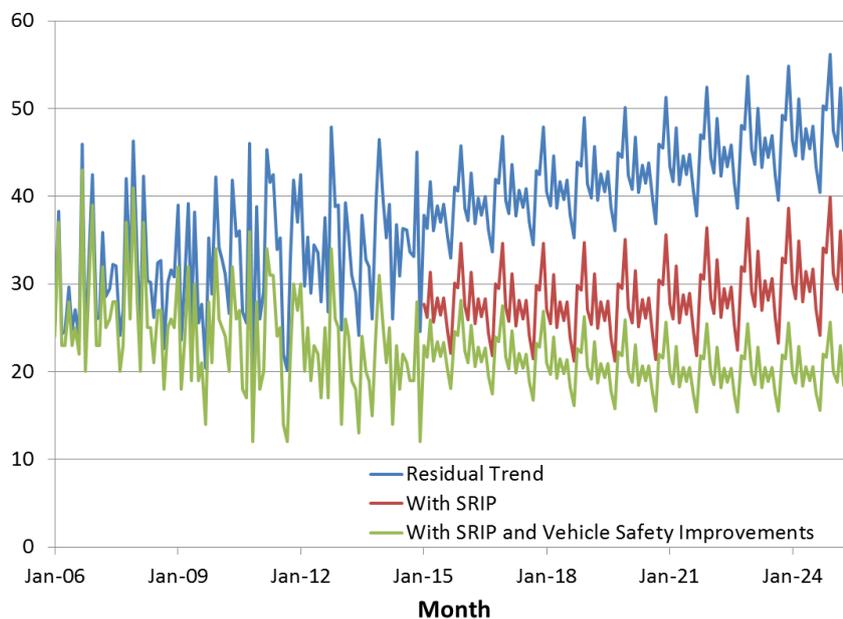


Figure 11: Forecast trend in fatalities including the estimated effects of vehicle safety improvements and SRIP: 2015-2025

Discussion and Limitations

This study has attempted to quantify the past and likely future impacts of two major road safety program areas, vehicle secondary safety improvement and the SRIP infrastructure program, on fatal and serious road trauma trends in Victoria. It has used existing research in the form of evaluations of Stage 1, 2 and 3 of SRIP and research estimating the impact of vehicle crashworthiness improvements, to quantify the effects of these two major, long term road safety programs. Whilst evaluations of the effects of individual road safety programs are common in the literature, research estimating the global effects of combinations of major programs on the totality of the road trauma problem is relatively novel. This project has established a methodology for undertaking this high level analysis and applied it to the Victorian context. It has demonstrated the major impact that

vehicle safety improvements and SRIP investments have had in reducing serious road trauma in Victoria. Analysis has shown that without these two major programs, fatalities and serious injuries in Victoria would have continued to rise over the past decade rather than falling as observed. It also predicted that without continued future investment in these programs, fatalities and serious injuries would also rise. This is not to say that other road safety programs have made no contribution to reducing road trauma. Indeed the predicted past and future increases would be even more pronounced without any strategic road safety intervention.

Since they are based on robust evaluations of vehicle safety performance and SRIP crash effects, the contribution of these two programs to past road trauma trends is also likely to be reasonably robust. A number of assumptions underpin the estimates of the likely future contributions of these programs. Estimates of future SRIP crash effects rely heavily on the assumption that the economic worth of the SRIP program continues at the same level as for the first three stages. Given the consistency in economic worth of the first 3 stages of SRIP this assumption does not seem unreasonable however the economic worth ultimately realised will depend heavily on the continued focus on successfully identifying and treating high risk crash sites. Trends in improvement in the crashworthiness of the vehicle fleet are likely to be more robust since they have been stable over a long period and have a high degree of momentum due to the size of the fleet. Budd et al (2015) undertook some sensitivity analysis of these predictions and found that even if the improvement in the crashworthiness of new vehicles entering the fleet slowed dramatically, similar future benefits would still accrue simply due to the regeneration of the fleet. One limitation is that crashworthiness considers improvements to fatal and serious injuries equally. It is possible that fatal and serious injuries are impacted differently by vehicle safety improvements although the difference is not likely to be extremely large. It has also been assumed that the benefits of vehicle safety improvement are unaffected by the change in infrastructure quality brought about by SRIP and hence the impacts of the two programs can be considered independent. It is possible that Safe System conditions could be achieved purely through infrastructure works making vehicle safety performance redundant. However, given the scale of SRIP works and the average crash reduction effects measured for SRIP, the SRIP program is still a long way from making all Victorian infrastructure Safe System compliant. Hence it seems reasonable to assume vehicle safety effects operate largely independently of infrastructure over the past decade and for many years into the future.

As noted, the forecasts of future residual road trauma trends on which the benefits of SRIP and vehicle safety improvements were based are also based on a number of assumptions, the most important of these being that the underlying drivers of road safety performance remain the same into the future. Whether this assumption will remain valid is difficult to predict, however this will have little effect on the magnitude of contribution that vehicle safety and SRIP are predicted to make, only impacting the estimates of absolute road trauma expected without these programs

Conclusion

It is evident that improvements in vehicle safety and major investment in safer infrastructure through SRIP have been very successful in achieving significant savings in death and serious injury. However, estimated fatal and serious injury future trends indicate that the ongoing issue of serious injury trauma will require particular focus and effort by road safety policymakers to address. Whilst this work does demonstrate the effectiveness of vehicle safety improvements and infrastructure investment on preventing serious road trauma, the projected future benefits of these key road safety program areas highlight how critically important it is to continue to invest in proven road safety programs if the benefits that have been achieved thus far are to continue going forward.

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