Introduction

This paper provides an economic evaluation of the major road safety programs in Australian from 1970 onwards. The year 1970 is significant for road safety in Australia. In 1970, road fatalities peaked and modern public safety programs began with the mandatory fitting of safety belts in all new vehicles. Since 1970, public safety programs of many kinds have been progressively introduced and road fatalities have declined steadily. By the late 1990s, total fatalities on roads had halved and fatalities per registered vehicle had fallen by 80 per cent.

The paper starts with an outline of the main road safety programs and expenditures in Australia since 1970. Following sections estimate the overall impact of these programs on fatalities and hospitalisations and summarise the results of selected studies of road safety programs and road accidents. The last part provides estimates of the benefits of road safety programs and an overall economic evaluation of road safety programs.

Main Road Safety Programs

There are many kinds of road safety programs.

- Road improvements: e.g. construction of divided roads, treatment of accident black spots, sealing of road shoulders, and improved road signage.
- Vehicle improvements: e.g. improved brakes and steering, installation of seat belts and air cushions, and cruise control.
- Controls on driver behaviour: notably regulations on vehicle speeds and drinking and driving, supported by enforcement instruments, for example speed cameras and random breath testing.
- Education programs designed to promote voluntary safe driving: e.g. fatigue management.
- A variety of related programs: e.g. road management (such as restrictions on right hand turns), local area traffic management schemes that reduce traffic speeds, mandatory motor cycle and bicycle helmets, and development of driver competency.

The focus of this paper is the total impact of road safety programs on driver behaviour by regulation or by voluntary change rather than on road and vehicle improvements.[1] However, the line between these behavioural road safety programs and general technical improvements in road and vehicle engineering is not always clear.

Table 1 shows major road safety programs introduced in Australia since 1970. Given the large number of such programs, the list is inevitably selective.

[1] Of course, policy decisions on road programs should be based on the expected marginal returns to incremental programs or expenditures.

Table 1 Selected Major Road Safety Programs 1970-2000

Year	Road safety program
1970	Mandatory fitting of seat belts in new passenger vehicles.
1973	All States and Territories require wearing of fitted seat belts in motor vehicles and helmets for motor cycle riders and passengers.
1976	Laws introduced to restrain children and babies in motor vehicles.
	Random breath testing (RBT) introduced into Victoria.
1980	Introduction of 0.05 gm / 100ml blood alcohol concentration law in NSW.
	RBT introduced in NT. Limited breath testing introduced in WA.
1981	RBT introduced in SA.
1982	RBT introduced in NSW and ACT.
1983	RBT introduced in Tasmania.
1984	NSW initiated Neighbourhood Road Safety Program.
1986	First phase of NSW government program to reduce traffic speeds.
	Victoria introduced speed cameras.
	Reduce Intoxicated Driving program introduced in Queensland.
1987	NSW published guidelines for local area traffic management, inc. 40 km/h speed limits.
	Monash University Accident Research Centre established primarily for road safety research.
Late 1980's	Major mass-media campaigns to improve road safety including speed reduction, seatbelt use, and avoidance of drink driving.
1988	RBT introduced in Queensland and WA.
1989	Federal Office of Road Safety released Ten-Point Safety Plan. Included 'black spot' elimination, research and public education, and establishment of national Road Trauma Advisory Council.
	Victoria reintroduced 100 km/h limit on freeways and introduced new speed cameras and RBT booze buses.
1990-92	Legislation requiring wearing of bicycle helmets. Victoria first in 1990.
1990-93	Commonwealth government ‘Black Spot’ program, $270m. Included 3176 projects at average cost of $85,000.
1990-94	Federal and State funded media campaigns to raise community awareness of the dangers associated with drink driving.
	Increased levels of random breath testing and reduced alcohol limits.
1991	NSW introduced radar speed cameras in dangerous metropolitan locations.
1991-92	Victoria and NSW issues detailed programs of road safety organisation and strategies together with targets.
1992	Victoria allocated $75 million to remove black spots over two years.
	National Road Safety Strategy introduced. States focussed on alcohol and driving, speeding, driver fatigue, and road hazards.
	Act and NRMA establish a Road Safety Trust to promote road safety.
1996	National Road Safety Action Plan. Contained 10 Priority Actions.
1996-00	New Commonwealth five year Black Spot Program ($187 million).
	NSW focuses on speed control enforcement with increased speeding fines and double demerit points for speed infringements over public holidays.
1998	Northern Territory introduces speed cameras.
	Queensland increased speed camera sites from 600 to 2400 in December and implemented a 50 km/h speed limit on streets in S.E.Queensland..

Some highlights of the road safety programs were:

- The mandatory fitting and use of seat belts in the early 1970s.
- The introduction and general extension of random breath testing from 1976 through the 1980s.
- Reductions in vehicle speed limits and increased enforcement of speed restrictions from the mid-1980s through the 1990s.
- The Commonwealth's support for black spot road improvement programs in the early and late 1990s.

Significantly, all of these programs were part of a steady increase in road safety measures over the 30-year period. Many programs were introduced incrementally over several years. For example, random breath testing (RBT) programs were progressively intensified and refined from the late 1970s to the 1990s. In most States, traffic speeds were increasingly controlled from the mid-1980s onwards (see, for example, controls in New South Wales, Croft, 1993).

When specific road safety programs are a small part of a large and continuous development of road safety, the contribution of each element to overall safety improvement is not easily identified. Most programs were introduced with media publicity. However, the intensity of the media programs varied and data on media campaigns are incomplete (Henstridge et al., 1997). Moreover, the effectiveness of regulations depends on how they are enforced. But the level of enforcement of regulations varies considerably over time and across difference parts of Australia. (Hakkert and McGann, 1996).

Another feature of road safety programs is the importance of the States and Territories in developing and enforcing programs. Over the study period, Victoria and New South Wales had the most intensive safety programs. Analysis of specific programs must therefore be done generally at State or Territory level.

Expenditures on Road Safety Programs

Estimating expenditures on road safety programs is complicated because there is no standard definition of a road safety program. Also, most programs are run by the States and Territories. Within the States and Territories, several agencies are often responsible for aspects of road safety programs, for example the main transport or road authority, the police, local government, and sometimes a special safety agency. Moreover, the State road authorities generally publish few details on their road safety programs.

Thus, estimating expenditures on road safety programs over 30 years from the early 1970s would be a large research task in its own right and beyond the scope of this study. In order to understand the issues and numbers involved, we examine some data that we have obtained from publications in four States and make some order-of-magnitude estimates of historical expenditures on road safety programs across Australia.

South Australia has possibly the most comprehensive budget for road safety expenditures. In 1998-99, South Australia spent $85 million (about 20 per cent of its total road related expenditures) on road safety. This figure includes payments for police services, register information for vehicle and driver enforcement, small expenditures on accident black spots, and accident investigations (see Table 2). However, much of this expenditure is general traffic and vehicle administration. Specific road safety programs comprise only a small part of the road safety budget.

By comparison, in 1992-93, Transport South Australia spent $34 million on the State's road safety program, less than half the amount in 1998-99.[2] Three-quarters of this program ($25 million) was expenditure on traffic engineering and black spots. Only $5 million was spent on road user safety and $4 million on vehicle operations. Presumably the definition of a road safety program was narrower in 1992-93 than in 1998-99.

Table 2 Road safety expenditures in South Australia in 1998-99

Category of expenditure	$m
Road user safety	
Mass media expenditure	5.1
Road safety promotional materials	1.6
Payment for police services	14.7
Fee collection and transaction processing for other agencies	13.6
Register information for vehicle and driver enforcement	12.4
Other enhanced enforcement activities	14.3
Total	61.8
Road safety education	
Driver training and school education	1.0
Road safety environment	
Accident black spots	3.5
Accident investigation and prevention	17.3
Road safety audits	1.6
Speed management	0.1
Total	22.5
Road safety development	0.1
Grand total	85.4

Source: Transport South Australia.

In **New South Wales**, the Roads and Traffic Authority (RTA) spent $311 million on road safety and traffic management in 1998-99 (14 per cent of its total budget).[3] Road safety and traffic management included improvements to the behaviour of road users through public and school education campaigns, traffic management planning, improvements in pedestrian and cyclist safety, and treatment so local area black spots. In addition, the RTA spent $248 million on driver and vehicle policy and regulation (another 11 per cent of RTA's budget).

[2] Source: Transport South Australia, *Annual Report, 1992-93*.
[3] NSW Roads and Traffic Authority, *Annual Report, 1998-99*.

There are some comparable data for the 1990s but few data for earlier years. RTA expenditure on road safety and traffic management totaled $48 million in 1989/90 and $57 million in 1990/91 (about 3 per cent of total RTA expenditure). Motor traffic services totaled $109 million and $133 million in these two years respectively (another 7 per cent of RTA expenditures). However, by 1996-97, expenditure on road safety and traffic management had risen to $305 million and expenditure on driver and vehicle policy and regulation was $197 million. As for South Australia, it is not clear how much of this increase in expenditure was increased expenditure on road safety and how much reflected changes in definitions of road safety programs. Also, the figures for road safety and traffic management are sensitive to capital expenditure on black spots.

In **Victoria**, current reporting distinguishes between road safety and traffic management. In 1997-98, Vic Roads spent $39 million on road safety, $69 million on traffic and road use management, and $75 million on registration and licensing. The figures in 1996/97 were similar. The $39 million expenditure on road safety represented slightly less than 4 per cent of the total Victorian roads budget of about $1.1 billion.

Expenditure on transport safety in **Queensland** totaled $65 million in 1992-93 but fell to $15 million in 1994-95.[4] These expenditures cover all transport modes, but relate mainly to roads (for which the total budget is about $1.0 billion). The decline in road safety expenditure over these three years reflects a fall in Commonwealth funding for the black spot program. Comparable figures for expenditure on transport safety are not given in the Department of Transport's latest (1998-99) annual report.

In summary, definitions of transport safety expenditure vary over time and States. Excluding traffic management and vehicle policy and regulation from the NSW figures, NSW and South Australia currently spend about $300 million a year on road safety. On the other hand, using narrower definitions of road safety, Victoria and Queensland spend about $60 million a year. In relation to road budgets, reported expenditure on road safety varies from 3 per cent to 20 per cent of the budget. For this evaluation, we allow that current Australia-wide expenditure on road safety is about $600 million per annum or slightly less than 10 per cent of national road-related expenditures.

From our limited historical data on road safety programs, expenditures on road safety appear to have increased. For the evaluation, we allow that real national expenditure on road safety in the 1970s up to the mid-1980s was half the level of the late 1990s (i.e. $300 million per annum). We allow a gradual increase in real expenditures from the mid-1980s (Table 9).

Reductions in Accidents due to Road Safety Programs: An Overview

Fatalities from road crashes in Australian rose steadily from 1925 to 1970, when they peaked at 3798 fatalities in the year. Fatalities then declined to 1758 by 1998 (see Figure 1).

[4] Source: Annual Reports of the Queensland Department of Transport.

On the other hand, road fatalities per 10,000 registered road vehicles fell steadily from 1925 through 1970 right up to the present. Figures 2 and 3 show fatalities per 10,000 registered road vehicles on an arithmetic and logarithmic scale respectively.

In this paper we follow the convention of analysing road safety in terms of crashes per registered vehicle (for convenience per 10,000 registered vehicles) because this measure is a proxy for crashes per unit of distance travelled and standardises accident data relative to risk of accident.

Figure 1 Fatalities from road accidents 1925-99

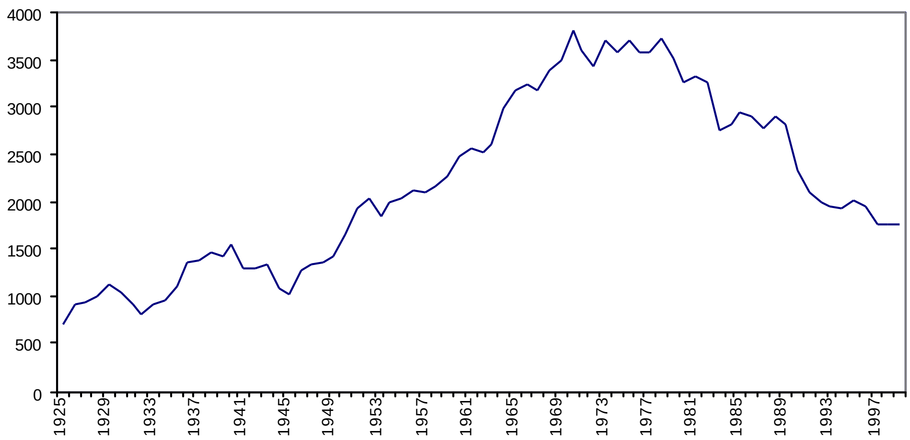


Figure 2 Fatalities per 10,000 vehicles 1925-97

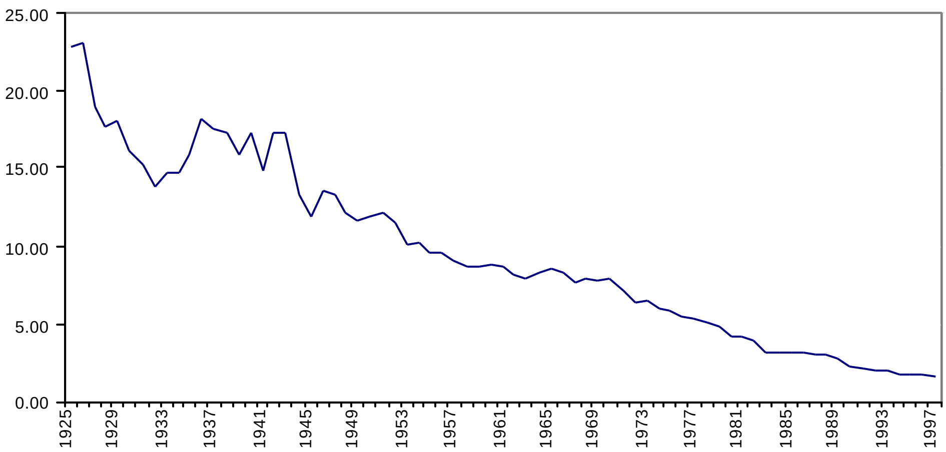
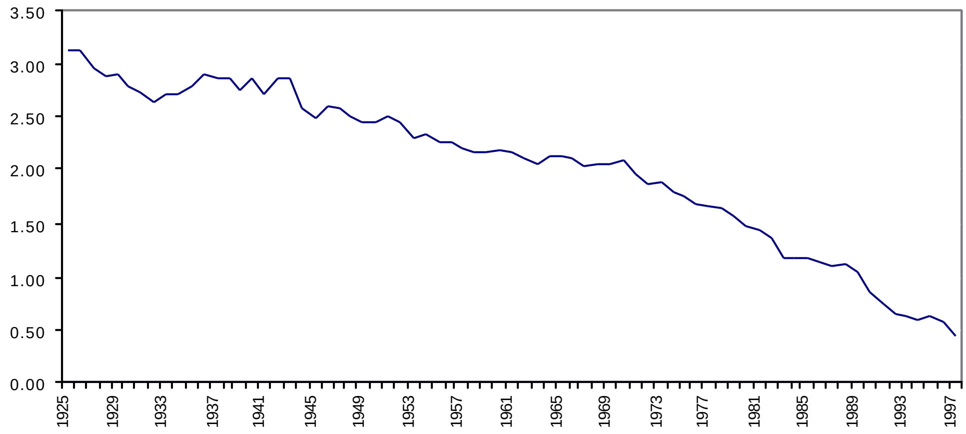


Figure 3 Log of fatalities per 100,000 vehicles 1925-97



Second, we examine the *percentage change* in fatalities per registered road vehicle rather than the absolute change in fatalities. It is easier to save 10 lives when there are 4000 fatalities a year than when there are 2000 fatalities. Thus, the percentage change in fatalities (and in other accidents) is considered a better measure of the effectiveness of road safety programs. Table 3 shows the percentage changes in fatalities per 10,000 registered road vehicles over 10 year periods from 1925. The rate of decline in fatalities was much greater after 1975 (although the decline was nearly as high between 1925 and 1935). This result is mirrored in Figure 3, where the slope of the line, which represents the rate of change in fatalities at any point in time, increases from about 1970.

Table 3 The decline in road fatalities

Year	Fatalities per 10,000 registered vehicles	Per cent decline in fatalities per registered vehicle in previous 10 years
1925	22.9	
1935	16.0	-30.1
1945	11.9	-25.6
1955	9.6	-19.3
1965	8.5	-12.5
1975	5.8	-31.8
1985	3.2	-44.8
1995	1.6	-50.0

Source: Federal Office of Road Safety, 1998a.

One way to estimate the effect of the road safety programs introduced after 1970 is to use a dummy variable for the post-1970 period. Following Wang et al. (1999), the percentage change in fatalities per 1000 vehicles can be modeled in terms of a trend variable and a dummy variable to represent the introduction of road safety programs. For example, let

$$\text{Log}(F/V) = a + bY + cD \quad (1)$$

where F is the number of road fatalities, V is registered vehicles in 1000's, Y is the time trend, and D is zero up to 1970 and one from 1971 onwards. The results are:

$$\text{Log}(F/V) = \underset{(64.4)}{3.2} - \underset{(-15.9)}{0.029Y} - \underset{(-2.7)}{0.216D} \qquad \text{adj.}R^2 = 0.939 \quad (2)$$

where the figures in brackets are t-statistics. The adjusted R^2 is high and all coefficients have the expected sign and are statistically significant at the 5 per cent level. Equation (2) indicates that fatalities per 1000 vehicles fell by 2.9 per cent per annum and that the road safety programs reduced fatalities by a further 21.6 per cent below the trend level.

However, Equation (2) implies that road safety programs reduced road fatalities by 21.6 per cent below the trend level in every year from 1971 onwards. This is not a realistic interpretation of the data. It is more likely that road safety programs had a progressive impact, small at first and increasing over the period. To model this process, Wang et al. introduce an extra regressor—the interaction between D and Y, as in:

$$\text{Log}(F/V) = a + bY + cD + dDY \quad (3)$$

and obtain the following results:

$$\text{Log}(F/V) = \underset{(116.4)}{3.0} - \underset{(-23.3)}{0.023Y} + \underset{(12.4)}{1.669D} - \underset{(-14.7)}{0.036DY} \qquad \text{adj.}R^2 = 0.985 \quad (4)$$

The R^2 is now 0.985 and all coefficients again have the expected sign and are statistically significant at the 5 per cent level. Wang et al (1999) show graphically that Equation (4) represents the data better than Equation (2), i.e. it has less serial correlation, but they do not give quantitative serial correlation diagnostics. In order to interpret Equation (4), note that Y = 47 in year 1971. This means that when the effects of the D and DY regressors are combined, there is an estimated decline in fatalities in 1971 even though the coefficient for D is positive.

Equation (4) implies that there has been a long-term trend decline in fatalities per 1000 registered vehicles of 2.3 per cent per annum. This trend reflects the general improvements in roads and vehicles and increased driver skills and experience that have occurred ever since the introduction of motor vehicles. *In addition*, road safety programs of various kinds introduced since 1970 have reduced road fatalities per 10,000 registered vehicles by an estimated 3.6 per cent per annum. In effect, the road safety programs since 1970 have been responsible for just over 60 per cent of the reductions in road fatalities per 1000 registered vehicles.

Of course, this analysis is broad-brush. As far as we are aware, no one has developed a long-term multivariate model of road safety for Australia, although some short-term state models have been estimated (see below). In a recent econometric model of road safety in Israel, Beenstock and Gafni (2000) conclude that most of the decline in road accidents is due to the global influence of technical progress in vehicle design rather than to local factors. However, as a proxy for the quality of the vehicle fleet in Israel the authors use a 'world accident rate variable' which is a weighted average of the accident rates in five major countries. This proxy is not satisfactory because these accident rates presumably also reflect local factors. On the other hand, several case studies of Australian road safety programs support the view that road safety programs accounted for about half the decline in fatalities from road crashes since 1970.

For our central case evaluation below we allow that road safety programs were responsible for half the reductions in fatalities after 1970 (Table 4 and Figure 4). We estimate that, without the road safety programs, there would have been 2783 fatalities in 1997 compared with the actual 1768 fatalities. In round numbers, road safety programs reduced annual fatalities by 100 per annum in the early 1970s, by 500 per annum in the mid-1980s and by 1000 per annum in the late 1990s. However, we also run a sensitivity test on the assumption that the safety programs accounted for only a quarter of the reductions in fatalities, i.e. for half of these estimated reductions in fatalities.

Persons hospitalised due to motor vehicle crashes

Persons hospitalised due to vehicle accidents fell by 30 per cent between 1982 and 1997, from 30,654 in 1982 to 21,531 in 1997 (see Table 4).[5] By comparison, fatalities due to crashes fell by 45 per cent over this same period. In 1982, 9.4 persons were hospitalised for each fatality. In 1997, 12.2 persons were hospitalised for each fatality. It appears that road safety programs had more impacts on fatalities than on less severe accidents. It is also possible that some accidents that would have caused fatalities in the 1970s resulted in non-fatal injuries in the 1990s.

In order to estimate the impacts of road safety programs on hospitalisations, we estimated (i) actual hospitalisations due to road crashes from 1970 onwards and (ii) the hospitalisations that would have occurred without any road safety programs. To estimate the former, we allow that the ratio of hospitalisations to fatalities declined by 0.1 in each year from 9.4 in 1982 to 8.5 in 1973. To estimate savings in hospitalisations, we assume again that road safety programs were responsible for 50 per cent of the reductions in hospitalisations. The resulting estimates are shown in Table 4 and Figure 5. We estimate that road safety programs reduced hospitalisations due to road crashes by a few hundred per annum in the 1970s rising to about 5000 per annum in the 1990s.[6]

[5] Comparable data on hospitalisations are not available for earlier years. The Australian Bureau of Statistics reports on severe accidents, not on persons hospitalised, in the 1970s.

[6] Tthe rounding method used to backcast actual hospitalisations results in one anomaly: more estimated hospitalisations occur with road safety programs than without them in 1978. Although this result is inappropriate, the estimation method and overall results for the 1970s appear realistic.

Table 4 Fatalities and hospitalisations due to road accidents

Year	Fatalities (no.)	Fatalities per 10,000 vehicles	Persons Hospitalised[a]	Estimates: no safety programs Fatalities	Estimates: no safety programs Hospitalisations	Savings due to safety programs Fatalities	Savings due to safety programs Hospitalisations
1970	3798	7.96	32283	3798	32283	0	0
1971	3590	7.12	30515	3694	31399	104	884
1972	3422	6.43	29087	3610	30685	188	1598
1973	3679	6.53	31272	3739	31777	60	506
1974	3572	5.97	30719	3685	31501	113	782
1975	3694	5.82	32138	3746	32210	52	73
1976	3583	5.44	31530	3691	31907	108	376
1977	3578	5.25	31844	3688	32064	110	219
1978	3705	5.21	33345	3752	32814	47	-531
1979	3508	4.77	31923	3653	32103	145	180
1980	3272	4.32	30102	3535	31193	263	1090
1981	3321	4.19	30885	3560	31584	239	699
1982	3252	3.90	30654	3525	31469	273	815
1983	2755	3.21	28080	3277	30182	522	2102
1984	2822	3.19	28794	3310	30539	488	1745
1985	2941	3.23	29248	3370	30766	429	1518
1986	2888	3.11	29169	3343	30726	455	1557
1987	2772	2.96	29698	3285	30991	513	1293
1988	2887	3.02	29705	3343	30994	456	1289
1989	2801	2.86	28460	3300	30372	499	1912
1990	2331	2.31	24961	3065	28622	734	3661
1991	2113	2.13	22528	2956	27406	843	4878
1992	1974	1.93	21512	2886	26898	912	5386
1993	1953	1.87	21557	2876	26920	923	5363
1994	1928	1.80	22133	2863	27208	935	5075
1995	2017	1.84	22368	2908	27326	891	4958
1996	1970	1.77	21935	2884	27109	914	5174
1997	1768	1.58	21531	2783	26907	1015	5376
1998	1758					(1020)	(5450)
1999	1759					(1030)	(5550)
Projections							
2000	1727		21036	2763	26659	1035	5624
2001	1696		20657	2747	26470	1051	5813
2002	1666		20285	2732	26284	1066	5999
2003	1636		19920	2717	26102	1081	6181
2004	1606		19562	2702	25922	1096	6361
2005	1577		19210	2688	25746	1110	6537
2006	1549		18864	2673	25573	1125	6710
2007	1521		18524	2660	25404	1138	6879
2008	1494		18191	2646	25237	1152	7046
2009	1467		17863	2632	25073	1166	7210
2010	1440		17542	2619	24912	1179	7371

(a) Figures for 1970 to 81 are estimates (see text).

Source: Federal Office of Road Safety (1998a), Consultant estimates (see text).

Figure 4 Fatalities with and without road safety programs, 1970-97

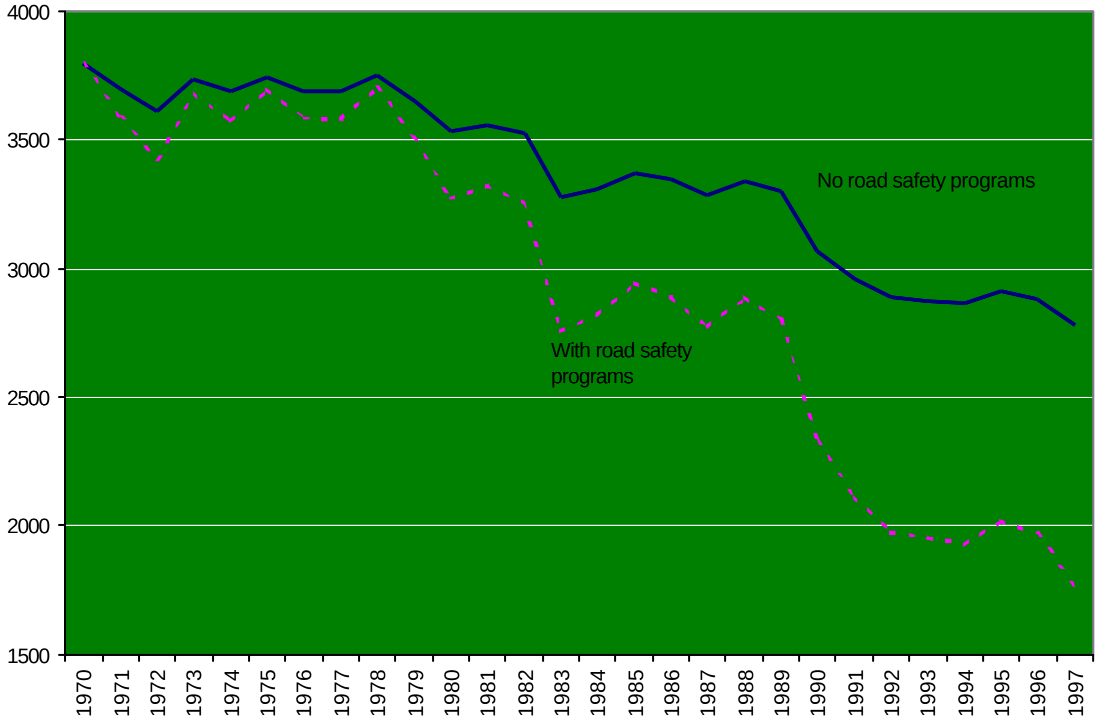
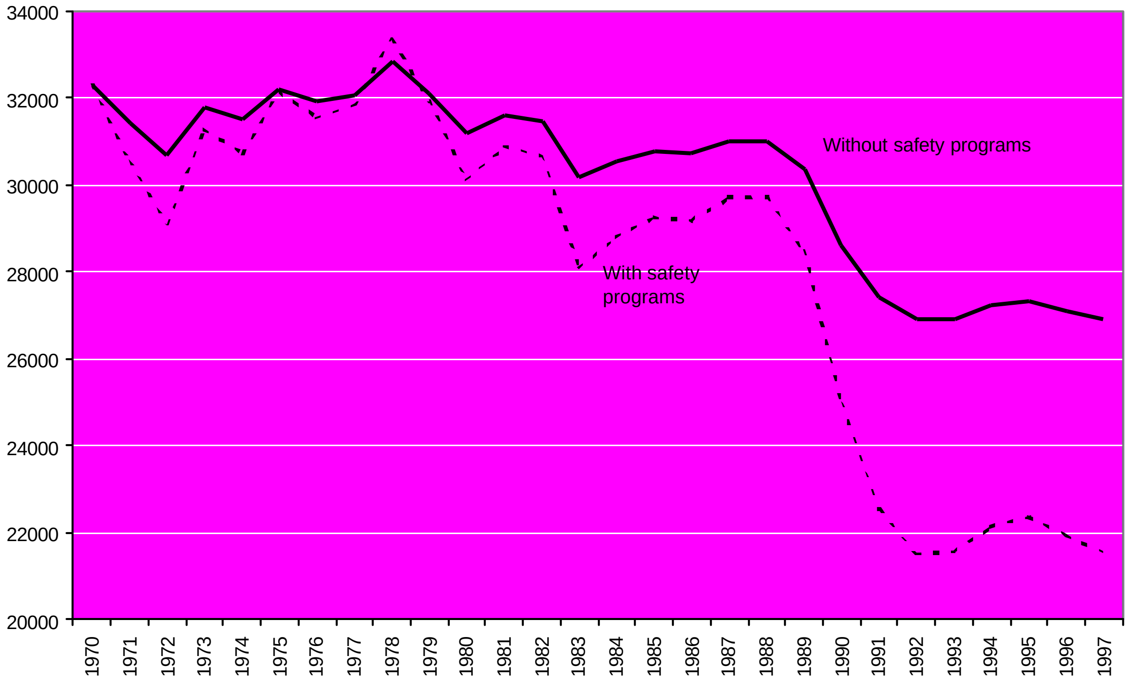


Figure 5 Hospitalisations with and without road safety program 1970-97



Other vehicle crashes

There are no comparable longitudinal data on minor vehicle accidents and property damage only accidents. Accident reporting practice has varied and, in any case, is not universal. In so far as there is a trend towards less serious crashes, there would be smaller decline in minor accidents than in other accidents. We make some conservative assumptions below about the possible benefits of reduced minor vehicle and property damage only accidents.

Road Safety Programs and Vehicle Accidents: Results of Studies

Applied Economics (2000) reports on the results of selected studies of the effects of road safety programs. The aim was to determine whether the results of these more detailed studies were consistent with our overall picture. In this paper I provide a summary version.

Drinking and driving

In the early 1980s, road fatalities averaged 3200 per annum, of which approximately 1350 deaths were associated with driving with a high alcohol content (Federal Office of Road Safety, 1997) By the mid-1990s, fatalities totaled about 1900 per annum, of which 550 deaths were associated with a high alcohol concentration. If alcohol was the primary cause of these road fatalities, reduction in alcohol intake saved 800 lives a year by the mid-1990s. Given that fatalities declined by 1300 over this period, reduced drinking was responsible for an estimated 60 per cent of the decline in road fatalities. This is consistent with the more sophisticated analysis by Henstridge et al (1997) that suggests that random breath testing reduced total fatalities by about 30 per cent.

There is also evidence that alcohol consumption is a falling cause of hospitalisation from car crashes. The percentage of drivers and motorcycle riders admitted to hospital with a blood alcohol concentration of over 0.05 gm/100 ml fell from 19 per cent in 1990 to 15 per cent in 1996 (Federal office of Road Safety, 1998b). The declines were most marked in the ACT, Queensland and Tasmania.

Long-term effects of random breath testing

Henstridge et al (1997) made detailed time series analyses of daily data on accidents in New South Wales, Tasmania, Queensland and Western Australia. The study controlled for economic factors like unemployment conditions and road use, as well as for weather, public holidays and so on. Overall, it appears that, in the long run, random breath testing reduced fatalities in NSW, Queensland and WA by about 30 per cent and reduced serious accidents by about 12 per cent. The estimated long-term effects of full-scale random breath testing for these three states are summarised in Table 5. De facto RBT programs and reduced intoxication programs had about half the impact of full random breath testing programs.

Table 5 Estimated long-term effects of random breath testing

	NSW Dec.82-Dec.92		WA Oct.88-Dec.92		Qld.Dec,88-Dec.92	
Type of accident	Per cent reduction	Accidents prevented p.a.	Per cent reduction	Accidents prevented p.a.	Per cent reduction	Accidents prevented p.a.
All serious	3-18	674	13	335	19	785
Fatal	17-42	149	28	71	35	192

Source: Henstridge, Homel and Mackay, 1997.

Traffic speeds and crashes

Several studies of traffic speeds and crashes in Australia have been made. Collectively they point to a significant relationship between speeds and crashes, but the results of the studies are not unanimous.

In Victoria, in June 1987, speed limits on freeways were increased from 100 km/h to 110 km/h. In September 1989, speed limits were reduced back to 100 km/h. According Sligoris (1992), reported by Barton and Cunningham (1993), the effects on accidents were substantial. For the whole of Victoria, the increase in the speed limit in June 1987 led to an estimated 24.6 per cent increase in the casualty rate per vehicle km travelled. On the other hand, the reduction in speed limit in September 1989 led to an estimated 19.3 per cent fall in the casualty rate. Barton and Cunningham conclude that there 'is little doubt that lower speed limits did save lives and reduce injuries and accidents.'

A more recent Victorian study (Newstead and Narayan, 1998) found less clear effects of speed limits on road accidents. This study examined five sets of reductions in speed limits (from 100 km/h to 90 km/h, from 100 km/h to 80 km/h, from 90 km/h to 80 km/h and so on) and four sets of increases in speed limits. The study found that overall, in Melbourne, casualty crashes increased by 9 per cent when zone speeds increased, but that casualty rates did not fall when speed limits were reduced. However, there were several anomalous results when crashes increased at lowe speeds and fell at higher speeds. The study also found no effect of changes in traffic speeds outside Melbourne.

Overview of causes of reductions in serious accidents in Victoria 1990-93

In the late 1980s, Victoria introduced several measures to reduce road accidents, including increased random breath testing using 'booze buses', lowering the freeway speed limit to 100 km/h, new speed cameras, bicycle helmet laws, a black spot program and special enforcement programs, all with mass media publicity. The programs had a major effect. Fatalities fell from 776 in 1989 to 392 in 1992 and to 435 in 1994. Serious injuries fell by over a third in 3-4 years. Hospitalisation rates fell from 242 per 100,000 people in 1988 to 133 per 100,000 people in 1992. Newstead et al. (1995) estimated that the road safety programs reduced serious crashes by 46 per cent below the expected trend.

General conclusions

It is difficult to isolate the effects of particular road safety programs and risky to generalise. Reducing speed limits sometimes reduces road accidents, but not always. Overall, the studies cited above support the view that behavioural road safety programs (i.e. programs that educated the public, reduced traffic speeds, and reduced drinking and driving,) brought about a substantial part of the fall in road crashes post 1970.

Benefits of Road Safety Programs

The benefits of road safety programs are a product of reductions in accidents (estimated above) and cost per accident saved. In order to estimate cost per accident, we draw on the Bureau of Transport Economics (BTE, 2000). The BTE's estimates of the costs of road crashes in 1996 are shown in Table 6. Using a 4 per cent discount rate, the estimated total cost was $15.0 billion. This includes $8.4 billion in human costs, $4.1 billion in total vehicle costs, and $2.5 billion in other costs. However, some costs (for example long-term care) are sensitive to the choice of discount rate. With a 7 per cent discount rate, the estimated total cost was $13.2 billion.

Costs to government are also high. The direct costs include medical ($361 million) and long-term care costs ($1.4 - $2.0 billion depending on the discount rate). The latter costs reflect an average cost of $26,000 per annum per disabled person. Also, government bears police costs, some legal costs, workplace disruption costs, vehicle repairs, travel delays, and insurance costs. Allowing that it would bear 20 per cent of these latter costs, in line with its productive share of gross domestic product, this would be another $1.5 billion in costs. The total cost to government would be $3.5 - $4.0 billion per annum.

The $15.0 billion estimate is $6 billion higher than in BTCE (1992). The main factors contributing to this increase are the inclusion of long term care costs, an extra $1.0 billion of travel delays, use of a 4 per cent discount rate instead of a 4 per cent rate, and inclusion of several new costs that were not previously estimated. However, in two major areas the BTE figures appear high. One is fatality cost. The BTE estimates this as the sum of loss of output in the workplace and home and the loss of quality of life. Wage rates are applied to unpaid work. For a fatality the human cost totaled $1,359,000 (with a 4 per cent discount rate). This included $540,000 for loss of workplace labour, $500,000 for loss of home and community labour, and $319,0000 for loss of quality of life. This is neither a human capital approach nor a willingness to pay value. It is also odd to include loss of quality of life for a fatality. The total figure is high compared with most human capital estimates, but low by comparison with many willingness to pay estimates (Applied Economics, 2000). The second issue is the inclusion of government payments for long-term care. These are transfer payments to make good loss of output and quality of life and represent double counting in Table 6. In fact they almost exactly double the costs associated with seriously injured persons.[7]

[7] In the BTE report, the sum of loss of output in the workplace and household and the loss of quality of life for seriously injured persons is $1868 million.

Table 6 Estimated Costs of Road Crashes in 1996 ($ million)

Cost component	Costs at a given discount rate 4%	7%
Human costs		
Medical / ambulance/ rehabilitation	361	361
Long-term care	1990	1372
Labour in the workplace	1625	1045
Labour in the household	1493	870
Quality of life	1769	1769
Legal	813	813
Workplace disruption	313	313
Other[a]	21	21
Total human costs	8385	6564
Vehicle costs		
Repairs	3885	3885
Unavailability of vehicles	182	182
Towing	43	43
Total vehicle costs	4110	4110
General costs		
Travel delays	1445	1445
Insurance administration	926	926
Police	74	74
Other[b]	40	40
Total general costs	2485	2485
Total all costs	14980	13159

(a) Correctional services, funeral and coroner costs.
(b) Property and fire costs.
Source: Bureau of Transport Economics, 2000.

Table 7 shows BTE's estimates of the total costs, and costs per crash, by type of crash. For our purposes, serious crashes equate approximately to crashes that involve hospitalisation. The estimated total cost of fatal and serious crashes was $10.1 billion in 1996. Minor and PDO crashes cost an estimated $4.9 billion.

Table 7 Summary of Crash Costs in 1996 by Crash Type

Crash type	Total costs ($bn)	Per crash ($)	Per person injured ($)
Fatal	2.92	1 652 994	1 500 000
Serious	7.15	407 990	324 000
Minor	2.47	13 776	11 611
PDO	2.44	5 808	0
Total	14.98	24 716	na

Source: Bureau of Transport Economics, 2000.

The estimated benefits of lower road accidents in 1996 due to road safety programs are shown in Table 7 using BTE and the author's estimated parameter values.[8] The latter allows $1.1 million per fatality and $160,000 per person injured in a serious crash. This fatality valuation allows $1.0 million for loss of life and $100,000 for other costs of a fatality. Our valuation per hospitalised person takes out the double counting of costs in the BTE report. In addition, we allow savings for minor and PDO crashes equal to one-sixth of the savings on fatal and serious crashes. This allows that minor and PDO crashes account for one third of all crash costs, but that savings on these accidents would be half the rate of savings for fatal and serious crashes.

Using BTE cost parameters, we estimate that crash costs would have been $3.5 billion (23 per cent) higher in 1996 if there had been no road traffic safety programs since 1970. Using the author's lower cost parameters, crash costs would have been $2.1 billion higher in 1996.

Table 8 Estimated benefits of road safety programs in 1996

Savings	No[a]	Value[b] ($)	Total[b] ($m)	Value[c] ($)	Total[c] ($m)	Government savings[d]
Fatalities	914	1 500 000	1 371	1 100 000	1 005	27
Hospitalisations	5 174	324 000	1 676	160 000	828	546
Sub-total			3 047		1 833	573
Other crashes			508		306	77
Total			3,554		2 139	650

(a) Estimates taken from Table 4.
(b) Based on BTE estimated parameter values.
(c) Based on author's estimated parameter values.
(d) Author's estimates (see text).

In terms of public health expenditures, Table 6 shows that, discounting long-term care expenditures by 4 per cent, the present value of medical and long-term care expenditures for 1996 crashes was $2.4 billion. This cost included government expenditure of $26,000 per annum for long-term care patients. Most of these costs are included in the serious crash component of $7.2 billion shown in Table 7.

To estimate the cost savings accruing to government, some other estimates are required. Only a small part of the costs of fatalities would be borne by government—say $30,000 of the $100,000 costs associated with the fatality (not including the loss of life itself). On the other hand, government would bear a high part of the cost of hospitalised persons in health care costs, long-term care transfer payments, and various ancillary costs. We assume that the government bears two-thirds of these costs. Thirdly, we assume that government bears one-quarter of all other costs. In total, government saved an estimated $650 million in 1996 due to the road safety programs from 1970 onward.

[8] These are based on the author's work reported in Applied Economics, 2001.

Economic Evaluation of Road Safety Programs

The economic evaluation runs from 1970 to 2010. Drawing on the discussion above, in 2000 dollars, the estimated costs of road safety programs rise from $300 million a year in the-mid 1980s to $600 million a year in the late 1990s, and then stay constant to 2010. The benefits are the product of the estimated reductions in fatalities and hospitalisations and the savings per fatality and hospitalisation given in Table 7.[9] We factor the benefits up by one-sixth to allow for savings in minor crashes and property damage only accidents. Benefits are projected to 2010 based on accident trends observed in the 1990s.

The results are shown in Table 9. The present value of the costs of the safety programs discounted at 5 per cent to 1971 is $6.6 billion. However, the present value of the benefits of the programs is $16.4 billion. Therefore the net benefit is $9.8 billion. The results are sensitive to the choice of discount rate. Using a 7 per cent discount rate, the discounted net benefit falls to $5.7 billion.

If the road safety programs were responsible for only one quarter of the reduction in traffic accidents, instead of one half of the reduction as allowed in the central case, the net present value of the programs falls to $1.6 billion with a 5 per cent discount rate.

Arguably, these cases are not comprehensive because they do not include the private welfare costs of conforming to the regulations. This produces an inconsistency in the evaluation. Given that the BTE includes travel time savings as a benefit of reduced accidents, regulations that slow down road trips should incur a penalty. To illustrate the kind of travel time cost involved, suppose that five million vehicles in Australia travel an average of 15,000 km per annum or a total of 75 billion km in a year. Suppose further that speed restrictions affected these trips as follows. The average speed on 15 billion km falls from 120 km to 110 km per hour; the average speed on another 15 billion km falls from 70 km to 60 km per hour; the average speed on the other 50 billion km is unchanged. There would be an additional 39 million trip hours in a year.[10] Allowing $14.58 per vehicle hour (as per BTE, 2000), the travel time costs would be $568 million per annum.

Consider now, for indicative purposes, the welfare costs of impositions on drinking and driving. Suppose that, on average, 100,000 Australians would like to drink more than the regulations allow when driving on a Friday and Saturday evening, and that they would be willing to pay a modest $10 per night for this right. These drivers would be willing to pay $2 million a week, or about $100 million a year, to drink more alcohol than the regulations allow. In other words, they consider themselves to be (at least) $100 million a year worse off as a result of the regulation.[11]

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[9] The difference between 1996 and 2000 prices for valuation of crash costs is assumed to be negligible.
[10] The reduction in speed from 120 km/hr to 110 km/hr for 12.5 billion km increases trip time by 9.5 million hours. The reduction in speed from 70 km/hr to 60 km/hr for 12.5 billion km increases trip time by 29.6 million hours.
[11] On the other hand, non-drinkers may be willing to pay something for the extra safety on the roads on Friday and Saturday nights.

Table 9 Economic Evaluation of road safety programs (Year 2000 $s, million)

Year	Costs	Central case: Benefits: reductions in Deaths	Hospital	Other	Total	Net benefit	Adding private costs: Private Costs	Net benefit	Return to government: Savings	Net benefit
1970	300	0	0	0	0	-300	0	-300	0	-300
1971	300	114	141	42	298	-2	20	-22	107	-193
1972	300	207	256	77	539	239	40	199	194	-106
1973	300	65	81	24	171	-129	60	-189	61	-239
1974	300	124	125	41	291	-9	80	-89	96	-204
1975	300	57	12	11	80	-220	100	-320	12	-288
1976	300	118	60	30	208	-92	120	-212	50	-250
1977	300	121	35	26	182	-118	140	-258	33	-267
1978	300	51	-85	-6	-39	-339	160	-499	-56	-356
1979	300	160	29	31	220	-80	180	-260	31	-269
1980	300	289	174	77	541	241	200	41	142	-158
1981	300	262	112	62	436	136	220	-84	96	-204
1982	300	300	130	71	502	202	240	-38	112	-188
1983	300	574	336	151	1061	761	260	501	275	-25
1984	300	537	279	135	951	651	280	371	233	-67
1985	300	471	243	119	833	533	300	233	203	-97
1986	330	501	249	124	874	544	320	224	209	-121
1987	360	564	207	128	899	539	340	199	184	-176
1988	390	501	206	117	825	435	360	75	179	-211
1989	420	548	306	142	996	576	380	196	252	-168
1990	450	807	586	231	1624	1174	400	774	466	16
1991	480	927	780	283	1991	1511	420	1091	611	131
1992	510	1003	862	310	2174	1664	440	1224	673	163
1993	540	1015	858	311	2184	1644	460	1184	672	132
1994	570	1029	812	306	2146	1576	480	1096	640	70
1995	600	980	793	294	2067	1467	500	967	624	24
1996	600	1005	828	304	2138	1538	520	1018	650	50
1997	600	1117	860	328	2305	1705	540	1165	680	80
1998	600	1122	872	331	2325	1725	560	1165	689	89
1999	600	1133	888	335	2356	1756	580	1176	701	101
2000	600	1139	900	338	2377	1777	600	1177	710	110
2001	600	1156	930	346	2432	1832	620	1212	732	132
2002	600	1173	960	354	2487	1887	640	1247	754	154
2003	600	1189	989	362	2540	1940	660	1280	776	176
2004	600	1205	1018	369	2592	1992	680	1312	797	197
2005	600	1221	1046	376	2644	2044	700	1344	818	218
2006	600	1237	1074	384	2694	2094	720	1374	838	238
2007	600	1252	1101	391	2744	2144	740	1404	858	258
2008	600	1267	1127	398	2792	2192	760	1432	878	278
2009	600	1282	1154	404	2840	2240	780	1460	897	297
2010	600	1297	1179	411	2887	2287	800	1487	916	316
NPV @ 5%	6605	8115	5916	2329	16360	9755	4699	5056	4708	(1897)

NPV Results	@ 3%	@ 5%	@ 7%
Central case: full benefits	17116	9755	5676
Central case: 50% benefits	3797	1575	417
Central case: + private costs	9643	5056	2999
Impact on government	(1775)	(1897)	(1842)

In the economic evaluation, we allow private costs associated with traffic safety regulations of $600 million per annum in year 2000, with costs decreasing by $20 million per annum back to 1970, and increasing by $20 million per annum to 2010. If these costs are included with the base costs and benefits the road safety programs, the net present value of the road safety programs falls to $5.1 billion with a 5 per cent discount rate and to $3.0 billion with an 7 per cent discount rate.

Finally, we consider the impact of the road safety programs on government. For this purpose, we employ the same benefit parameters as we used to estimate the savings of $650 million in 1996 above. Estimated gross and net government savings are shown in the last two columns of Table 9. Despite the estimated savings to government, the net present value of the road safety programs to government is -$1.9 million with a 5 per cent discount rate. The results are not sensitive to choice of discount rate.

Conclusions

Australian road accidents have fallen substantially since their peak in 1970. The number of fatalities fell from 3798 in 1970 to 1759 in 1997. Fatalities per 100,000 vehicles fell from 7.96 to 1.58 over the same period.

Since 1970, there have been many road safety programs. Major features were the mandatory fitting of seat belts, campaigns against drinking and driving, reduction in vehicle speed limits and increased enforcement of speed restrictions, and accident black spot programs. In addition, road authorities have paid increasing attention to traffic management.

Macro econometric analysis in this paper supported by many micro studies of the impacts of road safety programs suggest that road safety programs were responsible for half of the reductions in road accidents. The other half reflects mainly improved roads and safer vehicles.

However, the analysis is hampered by lack of clear and consistent definitions of road safety programs across the States and over time. For the purpose of the economic evaluation, we estimated that Australian governments currently spend $600 million a year on road safety. However, it would be possible to obtain a figure of half this amount using a narrow definition of a road safety program or a figure of double this amount using a broad definition of a road safety program.

On the other hand, we estimate that the road safety programs were responsible for saving about 1000 lives and 5000 hospital cases per year, as well as some other property damages, in the late 1990s. The estimated value of these savings amounted to $2.3 billion.

Overall, there was a substantial net benefit from the road safety programs. Excluding any private costs associated with observing traffic safety regulations, such as increased travel time, the estimated net present value of the benefits of the road programs from 1970 to 2010, using a 5 per cent discount rate, is $9.8 billion. Including some crudely estimated private costs associated with the regulations, the net present value of the programs falls to $5.1 billion. With a discount rate of 7 per cent, the net benefit of the programs falls to $5.7 billion and $3.0 billion respectively.

Finally, the road safety programs have saved governments an estimated $650 million a year in the late 1990s. Despite these estimated savings to government, the net present value of the road safety programs to government is -$1.9 million with a 5 per cent discount rate. The main benefits have been to the road user.

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