SAFETY BENEFITS OF IMPROVEMENTS IN VEHICLE DESIGN SINCE THE INTRODUCTION OF THE ANCAP CRASH TEST PROGRAM

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ABSTRACT

The Australian New Car Assessment Program (ANCAP) has for several years funded research at the Road Accident Prevention Research Unit at the University of Western Australia aimed at quantifying the value of reducing injuries by improving vehicle safety design. An injury cost database was developed using claims data from the Motor Accidents Authority of NSW (MAA) and additional cost data from other sources. These costs were used together with the measurements from the test instruments in the ANCAP crash tests to estimate the cost of injuries to front seat occupants in the ANCAP-tested vehicles. The aim of this study was to use the injury cost information from this previous research to estimate the safety benefits of improvements in vehicle design in cars entering the passenger vehicle fleet in Western Australia since the introduction of the ANCAP crash test program in 1992. The results of the study show significant safety benefits from the design and equipment changes introduced in new models of ANCAP-tested cars manufactured between 1992 and 1997. In crashes occurring in 1997 that involved these models and variants with a similar design, the safety benefits from improvements in vehicle design amounted to $42.6 million. Over the assumed 20-year lifetime of these vehicles, the benefits from vehicle safety improvements introduced in successive models was estimated to be $890.0 million. These findings show the considerable impact of improvements in vehicle safety design on the cost of road injuries to the community.

INTRODUCTION

Part 1 of this project involved the development of a Road Injury Cost Database using claims data from the Motor Accidents Authority of NSW (MAA) and additional cost data from other sources. This database contains information on the cost of road injuries by body region and injury severity level of the Abbreviated Injury Scale (Hendrie, Mullan & Ryan, 1999).

In Part 2 of the project, the cost of injuries sustained in each Australian New Car Assessment Program (ANCAP) crash test was estimated (Ryan et al., 1998). Measurements from the test instruments were converted to probabilities of injury using Injury Assessment Functions. These probabilities of injury, together with cost data from the Road Injury Cost Database, were used to estimate the cost of injuries to front seat occupants involved in each ANCAP crash test. For specific models, this cost information demonstrated the effect of successive design and equipment changes on the cost of injuries to front seat occupants.

AIM

The aim of this study was to estimate the safety benefits of successive design and equipment changes in cars entering the passenger vehicle fleet in Western Australia since the introduction of the ANCAP test program. These safety benefits were calculated for front seat occupants involved in frontal impact injury crashes. The expected cost of injuries sustained in crashes involving these new vehicles was estimated based on the successive test measurements – and the corresponding injury costs – associated with the ANCAP crash tests and the number of crashes involving ANCAP-tested models in Western Australia. This expected cost was compared with the hypothetical cost of injuries sustained in crashes involving these vehicles assuming that no improvements in vehicle safety design had occurred since the initial ANCAP testing in 1992 and 1993. The latter involved using the injury costs based on measurements from the first tests in 1992 and 1993 as the basis to calculate the cost of injuries sustained in crashes involving vehicles manufactured in later years. The difference in the expected and hypothetical cost of injuries – that is, costs with and without improvements in vehicle safety design – provided an estimate of the safety benefits of successive design and equipment changes in new models since the introduction of the ANCAP crash test program. These safety benefits were calculated for ANCAP-tested cars manufactured between 1992 and 1997, and variants with a similar design, for the calendar year 1997 and also for the estimated lifetime of these vehicles.

The ANCAP Crash Test Program

The first ANCAP tests carried out in 1992 and 1993 were full frontal barrier crash tests at 56 kmh^{-1} to selected makes and models of passenger cars.

Offset tests, with 40 percent overlap of the front of the vehicle into a deformable barrier, at an impact speed of 60 kmh^{-1} were introduced in 1994. In 1995 the impact velocity was increased to 64 kmh^{-1} to facilitate international comparisons.

In the crash tests, 50^{th} percentile Hybrid III anthropometric test devices are used for both the driver and front seat passenger. These dummies have the mass and dimensions of an average size adult male. The head, chest and legs are fitted with sensors to measure the forces and accelerations developed in the crash tests. These measurements provide an indication of the severity of injury to the head, chest and legs of front seat occupants in vehicles crashing under ANCAP test conditions.

In 1992 and 1993, ANCAP carried out tests on nine large-medium vehicle models and 12 small vehicle models. Further tests were carried out on later models when there was a substantial change in occupant protection design and equipment from model year to model year. While the majority of vehicles were tested at least twice in the six years between 1992 and 1997, a number of models were only tested once since no substantial changes were made during the period.

METHOD

The process of determining the safety benefits of design and equipment changes to new models entering the passenger vehicle fleet in Western Australia since the introduction of the ANCAP crash test program in 1992 involved a series of steps and assumptions. These are summarised below.

1. The number of injury crashes in Western Australia involving passenger vehicles manufactured between 1992 and 1997 was obtained for 1997 from the Western Australian Road Injury Database at the Road Accident Prevention Research Unit.

2. From these crashes, the number of injury crashes involving ANCAP-tested cars was determined. Only the makes and models involved in the initial tests in 1992 and 1993, and model variants with a similar design, were included (ANCAP, 1997; Glass's Guide, various years).

3. Sixty percent of these injury crashes were assumed to have been frontal impacts either at 11, 12 or 1 o'clock (Fildes et al., 1991; Ryan and Mackay, 1969).

4. A standard set of injury crashes involving ANCAP-tested cars by make, model and year of manufacture was assumed to have occurred each year. This standard set of crashes was derived from the average crash involvement by make, model and year of manufacture of passenger vehicles involved in injury crashes in Western Australia in 1997.

5. On the basis of the injury costs presented in Hendrie, Mullan and Ryan (1998), Ryan et al. (1998) calculated the expected injury costs to front seat occupants for the injuries predicted by each ANCAP crash test for vehicles tested between 1992 and 1997. Only costs relating to the injured person were included in these calculations (e.g. medical, hospital, economic loss, general damages, etc.); costs relating to the vehicle (e.g. property damage) and the crash incident (e.g. travel delay, crash investigation) were excluded. The injury costs to front seat occupants for the injuries predicted by each ANCAP frontal test were adjusted for impact velocity and vehicle occupancy to reflect the crash circumstances of 'real world' crashes. The adjustments were based on information obtained from Ryan and MacKay (1969), Fildes et al. (1991) and Kloeden et al. (1997).

6. In the ANCAP test program, vehicles with and without airbags have been tested. In order to calculate the safety benefits of successive design and equipment changes in new cars entering the fleet, an estimate had to be made of the percentage take up of airbags in models tested between 1992 and 1997. These estimates were based on information obtained through personal communication with manufacturers and from previous research (Fildes et al., 1996; Glass's Guide, 1998a; Glass's Guide, 1998b). Several assumptions had to be made in developing these estimates.

7. The expected cost of injuries sustained in crashes occurring in 1997 in ANCAP-tested models and their variants was calculated for each vehicle model by year of manufacture on the basis of the standard set of injury crashes and the injury costs to front seat occupants calculated by Ryan et al. (1998), adjusted for impact velocity and vehicle occupancy. The proportion of each vehicle model that was estimated to have been fitted with airbags was taken into account in determining these costs. The total injury costs sustained in crashes involving these vehicles was obtained by aggregating the cost over all ANCAP-tested cars.

8. On the assumption that no vehicle safety improvements had occurred in ANCAP-tested models and their variants manufactured between 1992 and 1997, the hypothetical cost of injuries in the standard set of crashes in 1997 was calculated on the basis of the test measurements and corresponding injury costs in the first set of tests conducted in 1992 and 1993. For cars for which

the first test was conducted in 1993, the test measurements and corresponding costs for 1993 models were assumed to apply to 1992 models.

9. The safety benefits in 1997 of design and equipment changes in ANCAP-tested vehicles and their variants manufactured between 1992 and 1997 were calculated as the difference between the estimates of the expected and hypothetical cost of injuries obtained in Steps 7 and 8 above.

10. The safety benefits over the lifetime of the ANCAP-tested cars and their variants manufactured between 1992 and 1997 were calculated in a similar way to that described for 1997, using an estimated lifetime of a vehicle of 20 years (Holgate, 1997; Australian Bureau of Statistics, 1997) and a discount rate of 5% (to express all values in 1997 dollars).

The remainder of this section provides additional information regarding the methods and assumptions used in the calculations.

Variants of ANCAP-tested Cars

Variants of the ANCAP-tested cars were known to have introduced the same design and equipment changes as the ANCAP-tested models. Since these variants would have achieved the same safety benefits as the ANCAP-tested models, crashes involving these vehicles were also included in the calculations of injury cost savings and safety benefits. The sources used to identify the variants that were equivalent to the ANCAP-tested models were –

1. The *Buyers Guide to Used Car Safety Ratings - Passenger Vehicles Built 1982-1995* (MUARC, 1997) which classifies used vehicles by their safety rankings based on statistics collected from crashes on New South Wales and Victorian roads.

2. Several editions of the *Black and White Data Book* (Glass's Guide, various years) which groups various Australian-built models with their similarly designed equivalents.

The vehicle variants included in the extended set of ANCAP-tested models are shown in Table 1 below.

Table 1.
ANCAP-tested Models and their Variants

Model Year	ANCAP-tested Model	Equivalent Model Year	Equivalent Model(s)
1990-1993	Toyota Corolla	1989-1993	Holden Nova
1989-1993	Holden Barina	1989-1994	Suzuki Swift
1991-1993	Ford Laser	1991-1993	Mazda 323
1988-1994	Mazda 626	1988-1994	Ford Telstar, Mazda MX6
1989-1994	Toyota Camry	1989-1994	Holden Apollo
1991-1995	Mitsubishi Magna	1991-1995	Mitsubishi Verada
1987-1995	Holden Commodore	1989-1995	Toyota Lexcen
1992-1996	Ford Falcon	1992-1996	Ford Fairmont, Ford Futura
1992-1996	Holden Commodore	1992-1996	Holden Berlina, Holden Acclaim, Holden Calais

Frontal Impact Injury Crashes

The safety benefits of design and equipment changes were only calculated for frontal impact injury crashes. Information about the angle of impact in crashes was not available from the Road Injury Database. However, three studies have identified the percentage of injury crashes that were frontal impacts.

1. Ryan and MacKay (1969) conducted a crash investigation study of 408 urban crashes in Adelaide, Australia to which an ambulance was called. 50 to 60 percent of impacts were found to be to the front of the vehicle.

2. Fildes et al. (1991) examined the nature of occupant injuries, vehicle characteristics and crash circumstances in a study of crashes involving post-1981 passenger vehicles that had been in single vehicle collision crashes and at least one person had been admitted to hospital. Frontal impact crashes at 11, 12 and 1 o'clock accounted for 60 percent of crashed vehicles that were inspected.

3. Kloeden et al. (1997) investigated the relationship between free travelling speed and the risk of involvement in a casualty crash for crashes involving passenger vehicles where alcohol was not a factor in 60 kmh^{-1} speed limit zones in the Adelaide metropolitan area. A case control study design was used and pre-crash travelling speeds

were determined by computer-aided accident reconstruction techniques based on physical evidence provided from detailed investigations of each crash site. Of the 151 passenger vehicle crashes that were investigated, 88 percent were frontal impacts.

On the basis of these findings, an assumption was made in this study that 60 percent of the injury crashes in Western Australia involving ANCAP-tested cars and their variants were frontal impacts.

Standard Set of Frontal Impact Injury Crashes

A standard set of crashes was derived from the frontal impact injury crashes in Western Australia in 1997 that involved ANCAP-tested cars and their variants. A simplifying assumption was made that the number of crashes involving vehicles by year of manufacture was equal – in other words, of the total number of frontal impact injury crashes in Western Australia involving ANCAP-tested cars and their variants, one-sixth involved cars manufactured in 1992, one-sixth involved cars manufactured in 1993, and so on. This assumption was not unrealistic since the actual number of crashes in 1997 by year of vehicle manufacture did not vary significantly.

This annual number of crashes by year of manufacture was then apportioned between models on the basis of the proportional share of each model in the total number of frontal impact injury crashes in Western Australia involving ANCAP-tested cars and their variants in 1997.

Impact Velocity

In the ANCAP full frontal test program, vehicles are crashed into a solid wall at 56 kmh^{-1}, with the force of impact spread evenly across the front of the vehicle. To compare the test measurements and the corresponding cost of injuries in ANCAP-tested cars with those in actual ‘real world’ crashes, the impact velocity of ‘real world’ crashes had to be determined.

In their crash investigation study in Adelaide, Ryan and MacKay (1969) examined the impact velocity in each crash and found a mean impact velocity for crashes where at least one person was injured of 34.5 kmh^{-1}.

In the study by Fildes et al. (1991), impact velocity was calculated using the National Highway Traffic Safety Administration CRASH 3 program. The estimated average impact velocity of crashes was estimated to be 45.4 kmh^{-1} with a standard deviation of 23.3 kmh^{-1} and a modal value between 36 kmh^{-1} and 42 kmh^{-1}. Figure 1 shows the impact velocity for the total sample of investigated crashes. From this distribution, the impact velocity in ANCAP tested vehicles (56 kmh^{-1}) was estimated to be in about the 80th percentile range of the impact velocity distribution for crashes resulting in a hospital admission.

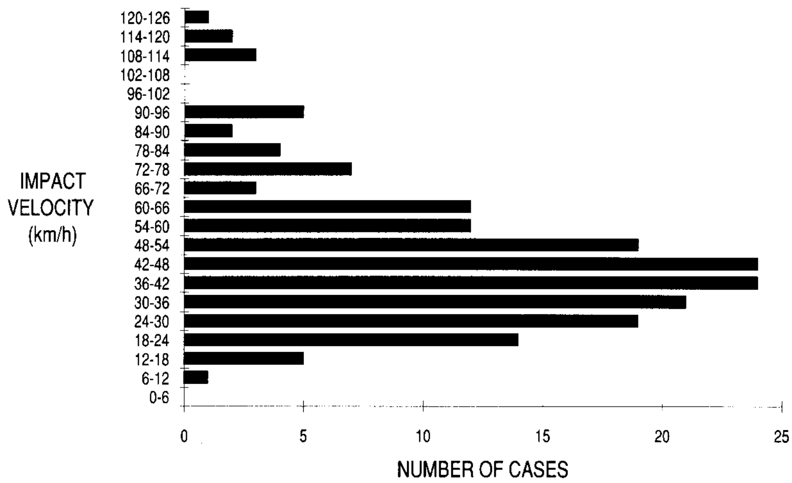

Figure 1.
Distribution of Impact Velocity for a Sample of Single Vehicle Collision Crashes in Victoria

Kloeden et al. (1997) also calculated the impact velocity for crash observations investigated in their study. A skewed distribution of impact velocity was found, with the mean impact velocity being 33 kmh^{-1}, and the mode in the range of 24 kmh^{-1} to 30 kmh^{-1}.

These three studies showed that ‘real world’ crashes occurred at a lower average impact velocity than those in the ANCAP full frontal test program. In order to adjust for this lower impact velocity, and the resultant lower impact energy, an assumption was made that the cost of injury was proportional to the impact energy. The average impact velocity of 34.5 kmh^{-1} calculated by Ryan and Mackay (1969), which was consistent with the findings of Fildes et al. (1991) and Kloeden et al. (1997), was used to determine a multiplier to apply in adjusting costs derived from the ANCAP test measurements to 'real world' crash circumstances.

The multiplier (m) for adjusting to the lower impact velocity in 'real world' crashes was:

$$m = V_1^2 / V_2^2$$
$$= (34.5)^2 / (56.0)^2$$
$$= 0.38$$

where V_1 and V_2 were the velocity of impact at 34.5 kmh^{-1} and 56 kmh^{-1} respectively.

Vehicle Occupancy

ANCAP crash tests involve both driver and front seat passengers. From the Western Australian Road Injury Database, the mean number of injured persons per vehicle involved in an injury crash was found to be 1.3. The expected cost of injuries to drivers and passengers for each ANCAP crash test in Ryan et al. (1998) was adjusted to reflect this level of vehicle occupancy.

The equation used to adjust costs for both impact velocity and vehicle occupancy so as to reflect 'real world' crash circumstances was as follows –

crash costs = 0.38 x (driver cost @ 56kmh^{-1} + (0.3 x passenger cost @56kmh^{-1}))

where driver cost @56 kmh^{-1} and passenger cost @ 56 kmh^{-1} were the cost of injuries calculated for ANCAP crash conditions in Ryan et al. (1998).

Airbags

The take up rate of airbags for ANCAP-tested models manufactured between 1992 and 1997 had to be calculated so that a reasonable estimate of safety benefits from vehicle safety improvements could be made.

Since 1993 more vehicles have been fitted with airbags as a supplementary safety restraint system. Research by the Australian Automobile Association (AAA) (1997) has suggested that 52 percent of the 260 000 Australian–made new cars sold in 1995 were fitted with either driver or twin airbag systems. A small amount of published research has provided estimates on the distribution of driver airbags as standard equipment for specific manufactured models of passenger vehicles in Australia. However, no research was available regarding the proportion of airbags fitted as an optional extra.

Several sources were used as the basis to estimate the percentage of ANCAP-tested cars with driver airbags by make, model and year of manufacture. These are briefly described below. In developing these estimates, some assumptions had to be made and these are also discussed. Further information about the methods and assumptions used to estimate the take up rate of airbags can be found in Hendrie, Lyle and Ryan (2001). No estimates were made regarding the take up of passenger airbags since no reasonable data was available on which to base these estimates.

Sources used to calculate the proportion of ANCAP-tested models with airbags were –

1. Each manufacturer of ANCAP-tested vehicles was contacted (except Volvo) to provide an estimate of airbag-equipped vehicles for their models in each year between 1992 and 1997. Estimates were provided by Daihatsu for the Charade, by Honda for the Accord and Civic, and by Subaru for the Liberty and Impreza.

2. Fildes et al. (1996) provided information relating to the proportion of airbag sales as standard equipment for the main manufacturers (but not specific models) in 1995.

3. The *Black and White Data Book* (Glass's Guide, 1998a) and *Auto Complete* (Glass's Guide, 1998b) were used as the basis to determine the ANCAP-tested cars that had driver side airbags as standard, the year of standardisation and the proportion of vehicles with airbags.

Assumptions made in deriving the estimated take up rate of driver airbags were –

1. Unless standard equipment, no airbags were offered as optional extras until 1994.

2. From 1994 onwards, for models that had airbags as an optional extra a conservative 'guesstimate' of five percent was used as the take up rate.

Table 2 shows the estimates of the percentage take up rate of driver airbags for the ANCAP-tested models and their variants by year of manufacture of vehicle. Costs were allocated to each ANCAP-tested model manufactured between 1992 and 1997 on the basis of this estimated percentage take up rate of airbags. For example, if the take up rate of driver airbags for a particular year of manufacture was 47 percent, then 47 percent of crashes involving that particular make and model were allocated injury costs corresponding to those for a vehicle with a driver airbag and the remainder were allocated the cost of injuries corresponding to vehicles with no airbag.

Table 2.
Estimated Percentage (%) of ANCAP-tested Cars with Driver Airbags, 1992 to 1997

Make and Model	Estimated Percentage with Driver Airbags (%)					
	1992	1993	1994	1995	1996	1997
Ford Falcon	0	0	45	100	100	100
Ford Laser	0	0	7	7	5	13
Holden Barina	0	0	38	38	38	64
Holden Commodore	0	37	37	37	37	58
Hyundai Excel	0	0	5	5	5	5
Hyundai Lantra	47	47	47	47	5	5
Mazda 121	0	0	5	5	13	56
Mazda 626	0	0	35	97	100	100
Mitsubshi Lancer	0	0	5	5	5	5
Mitsubishi Magna	0	0	18	18	18	18
Nissan Pulsar	0	0	5	37	37	37
Toyota Camry	0	0	35	35	35	35
Toyota Corolla	0	0	5	5	5	5
Volvo 850	100	100	100	100	100	100
Volvo 940	75	75	100	100	100	100

Vehicle Age

Holgate (1997) estimated that the average age of passenger vehicles in Australia was 10.4 years in 1995. For all Australian vehicles, the Australian Bureau of Statistics (1997) estimated the average vehicle age to be 10.6 years in 1995.

On the basis of an average age of around 10 years, the vehicle life of an ANCAP-tested passenger vehicle in Australia was assumed to be 20 years.

RESULTS

Number of Frontal Impact Injury Crashes by Make, Model and Year of Manufacture

Injury crashes were defined to include those where at least one occupant had the following severity level of injury:

- injury not requiring medical treatment;
- injury requiring medical treatment;
- injury requiring hospital admission; and
- death within 30 days of the accident.

In 1997 there were 2010 injury crashes involving ANCAP-tested cars and their variants in Western Australia. Of these, 1206 (i.e. 60 percent) were assumed to be frontal impact crashes.

On the assumption that the number of frontal impact injury crashes involving ANCAP-tested models and their variants by year of manufacture was equal, 201 (i.e. 1206/6) of the crashes were assumed to have involved cars manufactured in 1992, 201 to have involved cars manufactured in 1993, and so on. These 201 crashes involving ANCAP-tested models and their variants by each year of manufacture were then apportioned between the makes and models on the basis of the proportional share of each model in the total number of injury crashes in Western Australia in 1997 to give the standard set of crashes. This standard set of crashes is shown in Table 3 below.

Table 3.
Standard Set of Frontal Impact Injury Crashes by Make and Model for Each Year of Manufacture

Make and Model	Number of Crashes	Make and Model	Number of Crashes
Daihatsu Charade	7	Mazda 626	3
Ford Falcon	37	Mitsubishi Lancer	9
Ford Laser	12	Mitsubishi Magna	17
Holden Barina	13	Nissan Pulsar	5
Holden Commodore	27	Subaru Impreza	1

Honda Accord	3	Subaru Liberty	1
Honda Civic	3	Toyota Camry	17
Hyundai Excel	20	Toyota Corolla	18
Hyundai Lantra	2	Volvo 850	1
Mazda 121	4	Volvo 940GL	1

Expected Injury Costs in Crashes Involving ANCAP-tested Cars and Variants in 1997

The estimated cost of injuries by make and model that was derived in Ryan et al. (1998) from the ANCAP test measurements, adjusted for impact velocity, vehicle occupancy and the take up rate of driver-side airbags, was multiplied by the standard number of crashes by make and model for each year of manufacture to provide estimates of the expected cost of injuries in crashes involving ANCAP-tested cars and their variants in 1997. Tables 4 and 5 present these costs by model year for small and large-medium cars and for individual makes and models respectively.

Overall, the expected cost of injuries in crashes involving ANCAP-tested cars in Western Australia in 1997 was estimated to be $161.3 million. For models manufactured between 1992 and 1997, the cost of injuries for the standard set of crashes decreased consistently from year to year. These reductions in cost reflected the safety benefits from the design and equipment changes (including take up of airbags) to models manufactured in successive years over the period. Comparing 1992 and 1997 models of ANCAP-tested cars and their variants, the expected cost of injuries sustained in the standard set of crashes declined from $34.0 million to $15.8 million, a fall of 54% .

Approximately half of the injury costs in crashes involving ANCAP-tested cars and their variants in 1997 were attributable to injuries sustained in crashes involving small cars. This percentage varied by year of manufacture of vehicle depending on when vehicle safety improvements were introduced. Comparing models manufactured in 1997 and those manufactured in 1992, the expected cost of injuries in the standard set of crashes decreased by 63 percent for large-medium cars and 42 percent for small cars.

In terms of injury costs for individual ANCAP-tested models and their variants, the models that accounted for the highest share of expected costs across all years of manufacture were the Holden Commodore (16%), the Ford Falcon (15%), the Hyundai Excel (11%), the Ford Laser (11%) and the Toyota Camry (7%). With the exception of the Ford Laser, the other four models had the highest share of crashes in the standard set of crashes – for the Holden Commodore, 13%; the Ford Falcon, 18%; the Hyundai Excel, 10%; and the Toyota Camry, 8%. The Ford Laser, on the other hand, had a relatively high cost of injuries for front seat occupants in earlier models, which resulted in a poor performance with respect to its high share of total costs relative to its share of crashes (i.e. 11% versus 6%).

Some models performed particularly well in terms of the reduction in injury costs for the standard set of crashes in successive models manufactured between 1992 and 1997. Injury costs sustained in the standard set of crashes involving Holden Commodores decreased from $7.6 million for 1992 models to $0.7 million for 1997 models – a considerable decrease of 91 percent (or $257 000 per crash). Other models to have performed well were the Honda Civic with an 87 percent decrease in the cost of injuries for the standard set of crashes, the Subaru Liberty (76%), the Nissan Pulsar (73%), the Honda Accord (70%), the Ford Laser (69%) and the Toyota Corolla (66%). The only model for which the expected cost of injuries for the standard set of crashes increased in successive models was the Holden Barina, which resulted from its worse performance in later ANCAP crash tests than in an earlier test.

Table 4.
Expected Cost of Injuries in Crashes Involving ANCAP-tested Cars and their Variants by Year of Manufacture and Size of Vehicle, 1997

Vehicle Size	**Cost of Injuries by Year of Manufacture ($000)**						
	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**Total**
Small cars	15 866.1	15 857.1	17 246.2	16 311.2	9 886.7	9 218.5	84 385.8
Large-medium cars	18 111.6	14 701.2	13 149.2	12 515.7	11 816.6	6 619.8	76 914.1
Total	33 977.7	30 558.3	30 395.3	28 826.9	21 703.4	15 805.2	161 266.8

Table 5.
Expected Cost of Injuries in Crashes Involving ANCAP-tested Cars and their Variants by Year of Manufacture and Model, 1997

Make and Model	Cost of Injuries by Year of Manufacture ($000)						
	1992	1993	1994	1995	1996	1997	Total
Daihatsu Charade	659.8	659.8	647.3	647.3	435.7	333.9	3 383.9
Ford Falcon	5 113.7	5 113.7	4 162.9	3 117.1	3 117.1	3 117.1	23 741.8
Ford Laser	3 683.7	3683.7	3 585.7	3,585.7	1 221.4	1 150.5	16 910.7
Holden Barina	1 141.6	1 141.6	2 467.4	2 467.4	2 554.2	2 260.3	12 032.4
Holden Commodore	7 666.4	4 256.0	4 256.0	4 256.0	4 344.2	729.8	25 508.5
Honda Accord	604.0	604.0	562.6	379.0	267.6	178.7	2 95.9
Honda Civic	534.2	525.2	506.3	358.9	67.0	69.4	2 061.1
Hyundai Excel	2 693.4	2 693.4	4 243.8	4 243.8	1 778.2	1 778.2	17 430.8
Hyundai Lantra	346.8	346.8	346.8	285.9	233.3	233.3	1 792.8
Mazda 121	765.2	765.2	741.5	741.5	703.6	499.5	4 216.6
Mazda 626	311.9	311.9	270.4	196.9	193.4	193.4	1 477.7
Mitsubishi Lancer	1 306.0	1 306.0	1 281.2	1 281.2	1 281.2	1 281.2	7 736.8
Mitsubishi Magna	2 371.4	2 371.4	2 209.2	2 209.2	1 531.8	1 531.8	12 224.8
Nissan Pulsar	1 030.2	1 030.2	1 010.6	283.8	283.8	283.8	3 922.4
Subaru Impreza	93.2	93.2	91.5	91.5	91.5	91.5	552.4
Subaru Liberty	199.1	199.1	84.1	78.1	84.5	48.8	693.6
Toyota Camry	1 813.7	1 813.7	1 572.5	2 248.7	2 248.7	757.7	10 455.0
Toyota Corolla	3 611.9	3 611.9	2 324.1	2 324.1	1 236.9	1 236.9	14 346.0
Volvo 850	15.5	15.5	15.5	15.5	15.5	15.5	93.0
Volvo 940	15.9	15.9	15.9	15.1	13.8	13.8	90.6
Totals	33 977.7	30 558.3	30 395.3	28 826.9	21 703.4	15 805.2	161 266.8

Safety Benefits of Design and Equipment Changes to ANCAP-tested Cars and their Variants in 1997

The expected cost of injuries in 1997 sustained in crashes involving successive models of ANCAP-tested cars and their variants can be used to determine the safety benefits of the vehicle design and equipment changes made over this period.

Table 6 presents these safety benefits for 1997 by year of manufacture of the ANCAP-tested cars and their variants. Column 1 denotes the model year. Column 2 is taken directly from Table 4 and is the expected cost of injuries in 1997 for ANCAP-tested cars and their variants involved in the standard set of crashes. Column 3 shows the hypothetical cost of injuries sustained in crashes in 1997 involving ANCAP-tested cars and their variants on the assumption that no design and equipment changes occurred in these vehicles between 1992 and 1997. Under this assumption, the cost of injuries for each year of manufacture would have been the same as that for 1992 models, namely $33 977 700. In Column 5 the difference between the expected and hypothetical cost of injuries by year of manufacture was calculated. This difference reflected the safety benefits in 1997 of vehicle safety improvements in successive models of ANCAP-tested cars and their variants manufactured between 1992 and 1997.

The safety benefits in successive models manufactured between 1992 and 1997 increased from $3.4 million for 1993 models to $18.2 million for 1997 models. For all years of manufacture, the total safety benefits in Western Australia in 1997 from the lower cost of injuries sustained in later models amounted to $42.6 million.

Table 6.
Safety Benefits of Design and Equipment Changes to ANCAP-tested Models and their Variants by Year of Manufacture, 1997

Year of Manufacture (1)	Expected Injury Costs by Year of Manufacture ($000) (2)	Hypothetical Injury Costs by Year of Manufacture ($000) (3)	Safety Benefits by Year of Manufacture ($000) (4)
1992	33 977.7	33 977.7	0.0
1993	30 558.3	33 977.7	3 419.4
1994	30 395.3	33 977.7	3 582.4
1995	28 826.9	33 977.7	5 150.8
1996	21 703.4	33 977.7	12 274.3
1997	15 805.2	33 977.7	18 172.5
Total	161 266.8	203 866.2	42 599.4

Safety Benefits of Design and Equipment Changes to ANCAP-tested Cars and their Variants over the Lifetime of the Vehicles

The safety benefits attained in 1997 were projected over the lifetime of the ANCAP-tested cars manufactured between 1992 and 1997 assuming that the standard set of crashes occurring in Western Australia in 1997 also occurred in other years. The average vehicle life of a car was assumed to be 20 years, which implied that a 1992 model would be on the road until 2011, a 1993 model would be on the road until 2012, and so on. A discount factor of 5 percent was used to express all safety benefits in 1997 monetary values.

On the basis of these assumptions, Table 7 presents the estimates of the safety benefits from the design and equipment changes in successive models of ANCAP-tested cars and their over the estimated life of these vehicles. These safety benefits, expressed in 1997 dollar values, amounted to $91.0 million for 1993 models, and increased consistently in successive models to $330.7 million for 1997m models. For all ANCAP-tested models manufactured between 1992 and 1997, the safety benefits in Western Australia derived from design and equipment changes over the lifetime of the vehicles was $890.0 million.

Table 7.
Safety Benefits of Design and Equipment Changes to ANCAP-tested Models and their Variants by Year of Manufacture over the 20-Year Lifetime of the Vehicles

Year of Manufacture (1)	Expected Injury Costs by Year of Manufacture ($000) (2)	Hypothetical Injury Costs by Year of Manufacture ($000) (3)	Safety Benefits by Year of Manufacture ($000) (4)
1992	555 254.8	555 254.8	0.0
1993	464 159.3	555 254.8	91 095.5
1994	447 859.9	555 254.8	107 394.9
1995	441 502.5	555 254.8	113 752.3
1996	308 167.5	555 254.8	247 087.3
1997	224 583.6	555 254.8	330 671.2
Total	2 441 527.5	3 331 528.8	890 001.3

DISCUSSION

The purpose of this study was to estimate the safety benefits of successive design and equipment changes in cars entering the passenger vehicle fleet in Western Australia since the introduction of the ANCAP crash test program. These safety benefits were calculated for ANCAP-tested cars manufactured between 1992 and 1997. In 1997 the safety benefits achieved from vehicle safety improvements through the reduction in the cost of injuries sustained in crashes involving these vehicles was estimated as $42.6 million, with higher safety benefits being achieved in later models. Over the assumed lifetime of these vehicles of 20 years, the safety benefits from design and equipment changes introduced in successive models was estimated to be $890.0 million.

These safety benefits can be extrapolated nationally based on the proportion of injury crashes occurring in Western Australia relative to these crashes occurring Australia-wide. Of an estimated 21 526 injury crashes requiring hospitalisation in Australia in 1997, 13.5 percent were in Western Australia (Federal Office of Road Safety, 1999). This suggests an estimate of $316 million for the safety benefits in 1997 from design and equipment changes in cars entering the Australian passenger vehicle fleet between 1992 and 1997. Over the lifetime of these vehicles, the safety benefits in Australia from design and equipment changes can be estimated to be $6593 million.

Several assumptions were made and a range of data sources used in arriving at these estimated safety benefits from improvements in vehicle safety design. The estimates were based on the most plausible assumptions and the best data available at the time of conducting the study. Research is currently underway revising the costing of road injuries in the Road Injury Cost Database. These revised costs will be used to improve the estimates of the cost of injuries to front seat occupants involved in the ANCAP crash tests. Better estimates of the costs derived from the test measurements will in turn improve the accuracy of the expected injury costs and safety benefits from vehicle safety improvements that were calculated in this study.

In the case of the other data used in the study, no better data is likely to become available to improve the accuracy of the estimated safety benefits. A limitation of this study is that no sensitivity analysis was conducted to test how robust the estimated safety benefits were to changes in the assumptions made or the data used in the calculations. This limitation will be addressed in further work examining the safety benefits to the community of improvements in the design of new vehicles.

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