Potential benefits of an Australian Design Rule on pedestrian protection

Anderson, R. W. G., Ponte G., Searson, D.
Centre for Automotive Safety Research, University of Adelaide, SOUTH AUSTRALIA, 5005
email: robert@casr.adelaide.edu.au

ABSTRACT

This paper estimates the potential benefits to Australia from the adoption of an Australian Design Rule on pedestrian protection. Previously we compared the sales-weighted performance of the Australian and European new car fleets in relevant pedestrian impact tests, based on test reports from EuroNCAP and ANCAP. The comparison showed that the pedestrian protection of the new car fleet in Australia is inferior to that of the new car fleet in Europe. EuroNCAP and ANCAP use very similar tests to those prescribed by the European Directive on pedestrian safety and a proposed Global Technical Regulation. In the present study, the benefits to Australia of an ADR on pedestrian protection were estimated, based on benefit calculations that were estimated for a second phase of European regulation due in 2011. Expected proportional reductions of fatal, serious and slight casualties were applied to Australian casualty data and the associated crash costs. By examining the current performance of the new car fleet, these benefits were disaggregated into benefits that have already accrued since overseas and international regulations were mooted, and that which is yet to be realised through compliance of the new car fleet with a future regulation. It is estimated that an Australian Design Rule conforming to the proposed Global Technical Regulation with the addition of Brake Assist would reduce fatalities in Australia by approximately 28, serious injuries by 947 and slight injuries by 1248 each year, with associated savings in crash costs of approximately $386million per year. Despite recent improvements in the passive safety performance of the fleet, and the introduction of Brake Assist Systems in around 60% of current new car sales, around half of these benefits are yet to be realised.

Keywords

Vehicle safety, Passive safety, Active safety, Pedestrian, ADR, Crash test, Benefit calculations

INTRODUCTION

In the 10 years up to July 2007, 2595 pedestrians were killed on Australian roads [1]. A significant proportion of the serious and fatal injuries sustained by pedestrians in collisions with vehicles are caused by the interaction between the pedestrian and the vehicle’s frontal structures [2]. It follows, that considerate design of the front of a vehicle should improve a pedestrian's chance of survival and reduce the incidence and severity of injuries in a collision. Design countermeasures will have benefits for other vulnerable road users too, especially pedal cyclists.

Currently in Australia, there are no Australian Design Rules (ADRs) that consider vehicle frontal protection of pedestrians or other vulnerable road users in the event of a collision. Europe and Japan now mandate a minimum level of pedestrian protection in new models of passenger vehicles sold in those jurisdictions, and one by-product of this is that vehicles designed to comply with those pedestrian protection regulations are flowing into the Australian vehicle fleet. Beyond this effect, the Australian new car fleet is improving through the global nature of vehicle research and development, and/or impetus from the European and Australasian New Car Assessment Programs (EuroNCAP and ANCAP).

Since 1 October 2005 (Model Year 2006), new types of passenger vehicles given type-approval in Europe must comply with Phase I (of II) of a European Council Directive, 2003/102/EC, that requires a certain performance level in child headform and full legform impact tests [3]. Existing models of vehicle are not required to comply at this stage. Phase II requirements are more stringent than Phase I, in the number of tests and the performance requirements of the tests; however, the final technical prescriptions of Phase II have not been finalised. The European Council intends to introduce Phase II from Model Year 2011 [4].

Japan has regulated to ensure that new models of passenger cars and their derivatives introduced after 1 September 2005, and all models after 1 September 2010, comply with pedestrian head impact performance requirements. There are no requirements in the Japanese regulation for any legform impact tests [4].

As mentioned above, the EC has not finalised the technical prescriptions of Phase II of the EU Directive. Technical prescriptions are given in 2004/90/EC, but they are still being discussed and amendments are likely [5,6]. The current working document of the EC on the Phase II requirements is aligned with a proposed Global Technical Regulation, with added requirements for Brake Assist Systems [6].

The Australian Government has a policy to align Australian vehicle standards with global regulations [7]. The World Forum for the Harmonization of Vehicle Regulations (UNECE WP.29) is developing a Global Technical Regulation (GTR) on pedestrian protection through its Working Party on Passive Safety (GRSP) [8].

This GTR is relevant as Australia is a signatory to the UNECE 1958 Agreement concerning the Adoption of Uniform Technical Prescriptions for Vehicle Safety and recently became a party to the UNECE 1998 Agreement on Global Technical Regulations (GTRs) [9].

The 1958 agreement allows reciprocal recognition of vehicle standards. Under the 1998 agreement, there is no reciprocal recognition, but instead the agreement provides a forum for the harmonisation of vehicle safety standards [10].

New car assessment programs in Europe, Australia and Japan assess vehicles for pedestrian safety. While manufacturers are not required to design vehicles to do well in these programs, some vehicles have performed well, demonstrating that improvements in vehicle design for pedestrian protection are possible. Consumers' choices are affected by perceptions of safety, including that of pedestrian safety [11], but it is likely that perceptions about pedestrian protection influence consumers' choices less than perceptions about occupant protection. The occupant safety ratings (which are currently separate from the pedestrian safety ratings) of new cars usually comfortably exceed the minimum level required by the relevant ADRs. However, very poor results for pedestrian safety assessments are prevalent. It is probable that vehicle regulation (i.e. the system of ADRs) currently has a more important role to improve levels of pedestrian protection than it has to improve levels of occupant protection.

OBJECTIVES

This paper considers the following questions:

- What changes in the pedestrian and cyclist safety of the vehicle fleet would be elicited from the introduction of a relevant pedestrian regulation in Australia?
- What would the benefits be (reduced death, injury and the associated costs)?

BACKGROUND

Passive safety technical prescriptions

Passive safety is defined as the safety features built into a vehicle that protect and reduce injuries to road users during a vehicle collision. In occupant safety, passive safety measures include seat belts, airbags, and structural energy dissipation. In the context of pedestrian safety, passive measures are those that reduce the injury potential of vehicle structures that pedestrians and cyclists often hit in a collision.

All proposed pedestrian regulatory tests are based on tests developed by Working Group 17 of the European Enhanced Vehicle-safety Committee – EEVC [12]. These tests employ sub-system impactors. Other areas of crashworthiness testing use crash test dummies to represent the occupant of a vehicle in a crash, however pedestrian tests use sub-system impactors to represent the head of an adult pedestrian, the head of a child pedestrian, the upper leg/pelvis of an adult pedestrian, and the whole leg of an adult pedestrian (simulating injury mechanisms in the knee and the lower leg).

The European New Car Assessment Program (EuroNCAP) and the Australasian New Car Assessment Program (ANCAP) assess vehicles for pedestrian protection according to EEVC procedures. Variants of the procedure are also specified by the European Directive and the draft GTR. The main differences between head impact tests in each regulatory option and in the current EuroNCAP protocol are summarised in Table 1. Note that 'Original Phase II' describes the technical prescriptions laid out in 2003/102/EC. The final form of Phase II is unlikely to resemble those requirements.

Table 1: Correspondence between alternate proposals for headform impact tests in Phase II of European regulation and the EuroNCAP protocol version 4.1 (adapted from Lawrence et al. (2006) [13])

	EuroNCAP protocol	Original Phase II of the EU Directive	Draft Global Technical Regulation (EC proposal)
Child headform impactor	2.5 kg headform applied to bonnet area bounded by wrap-around distances of 1000 mm and 1500 mm, 40 km/h. HIC < 1000 for full points.	Similar to EuroNCAP, HIC < 1000	3.5 kg headform applied to bonnet area bounded by wrap-around distances of 1000 mm and 1700 mm, 35 km/h*
Adult headform impactor	4.8 kg headform applied to bonnet area bounded by wrap-around distances of 1500 mm and 2100 mm, 40 km/h. HIC < 1000 for full points.	As for EuroNCAP but no points beyond the rear edge of the bonnet are tested. HIC < 1000	4.5 kg headform applied to bonnet area bounded by wrap-around distances of 1700 mm and 2100 mm, 35 km/h*
Bumper test	EEVC WG17 legform impactor, applied across the bumper face, 40 km/h. Knee bending < 15˚, knee shear < 6 mm, tibia acceleration < 150g.	Similar to EuroNCAP, knee bending < 15˚, knee shear < 6 mm, tibia acceleration < 150g	GTR: Flex-PLI legform; EC proposal: EEVC WG17 legform, bending < 19˚, knee shear < 6 mm, tibia acceleration < 170g with a lower protection zone where the tibia acceleration < 250g (no more than 264 mm of the bumper width)
High bumper tests	EEVC WG17 upper legform impactor, 40 km/h, impact force < 5 kN, bending moment < 300 Nm.	Same as EuroNCAP, but manufacturer can choose whether to test with full legform or upper legform.	Similar to EuroNCAP, but choice where bumper height is between 450 and 500 mm. Impact force < 7.5 kN, bending moment < 510 Nm.
Bonnet leading edge test	EEVC WG17 upper legform impactor applied across bonnet leading edge of vehicle, impact force < 5 kN, bending moment < 300 Nm.	Similar to EuroNCAP	GTR: None proposed at this time (EC proposal similar to EuroNCAP Impact force < 7.5 kN, bending moment < 510 Nm)

*2/3 of the tested area to achieve HIC < 1000, all tests to achieve HIC < 1700, at least half 3.5 kg headform test area to achieve HIC < 1000
HIC = Head Injury Criterion

At this stage, the informal group under the Working Party on Passive Safety (GRSP) of UNECE WP.29 have declined to propose an upper legform to leading edge test. It is not clear whether such a test will be proposed in the final form of the GTR. The European Automobile Manufacturers' Association (ACEA) believes that the test has no merit [14].

Active safety technical prescriptions

Brake Assist Systems (BAS) detect emergency braking and maximise braking force as quickly as possible to overcome hesitant or inadequate brake application. It is likely that such systems will have significant benefits for vulnerable road users [13].

In examining pedestrian protection the GRSP are constrained to develop passive safety requirements, although they recognise the potential of active safety systems to help the driver to avoid pedestrian crashes. ACEA first proposed the mandatory use of BAS in Phase II of the European Directive and presumably they therefore consider it a feasible and an effective component of pedestrian protection requirements. Indeed, the European Commission subsequently proposed that it become part of the requirements of Directive 2003/102/EC.

Effectiveness estimates from Lawrence et al. (2006) [13]

Various attempts have been made to estimate the benefits and costs of the implementation of effective pedestrian injury countermeasures in vehicles (13, 15-19). Lawrence et al. (2006) [13] give what is probably the most up to date and comprehensive estimate of benefits and costs.

Lawrence et al. (2006) examined three regulatory options proposed as Phase II of the European Directive (described earlier). To summarise, they estimated a percentage reduction in fatalities and casualties for each option. Their starting point was a vehicle fleet with no pedestrian protection built in. They then estimated fatality and casualty reductions across Europe, the associated monetary benefit and a per-vehicle benefit for each option. The per-vehicle benefit was then used to calculate a benefit-cost ratio, which was favourable. They estimated benefits for pedestrians and pedal-cyclists.

The estimates calculated by Lawrence et al. (2006) were based on detailed in-depth crash data. They assumed that the technical prescriptions would only be effective in a proportion of crashes under 45 km/h and not at all above that speed. They accounted for the proportions of crashes that do not involve vehicle types subject to regulation (vehicles that weigh more than 2500 kg, trucks, and motorcycles). They also accounted for the proportion of injuries caused by passenger vehicle structures not subject to the regulation (A pillars, edges of fenders etc.). Assuming that the general pattern of crashes involving pedestrians and cyclists are similar in Europe and Australia, the percentage reductions estimated by Lawrence et al. (2006) may be expected in Australia as well.

In support of this assumption, data from a) in-depth studies conducted in Adelaide, South Australia and b) fatal pedestrian crashes in South Australia, were compared with data in Lawrence et al. (2006) The data from Adelaide were drawn from references [20] and [21], and comprise, in the first instance, 158 pedestrian crashes investigated at the scene between 1998 and 2005, and in the second instance a review of fatal pedestrian crashes in South Australia from 1991-1997.

One hundred and twenty seven of the 158 crashes from [20] involved a passenger vehicle (80%). Lawrence et al. (2006) determined that 83% of fatal pedestrian crashes and 71% of serious pedestrian crashes in Europe involve vehicles subject to the test regulations.

The direction of impact was not coded explicitly in [20], but was coded for fatal crashes in [21]. Amongst fatal crashes, 84% were with the front of the vehicle (or slightly less if corner impacts are subtracted from the total). If this proportion applies generally, then the proportion of pedestrians in crashes hit by vehicle structures covered by the proposed regulation would be approximately 84% of 80% = 67%. Lawrence estimated that 60% of fatal pedestrian crashes and 56% of serious injury crashes involve the front of a vehicle subject to regulation. This estimate is similar to, but less than, the estimate for Australia, based on data from South Australia.

Based on this limited data, the analysis in this paper will use the assumption that the general pattern of crashes involving pedestrians and cyclists is similar in Europe and Australia. The estimate that regulation in Australia might positively affect a slightly higher proportion of accidents will mean that the results of the analysis will be conservative.

Lawrence et al. (2006) estimated a benefit due to a passive safety component (impact protection) and a component due to active safety (BAS). Their estimates are shown in Table 2.

Table 2: Estimated proportional reduction in pedestrian and pedal cyclist casualties expected from moving from no compliance, to full compliance with proposed regulations on pedestrian protection [13].

Road user type	Benefit component	Original Phase II			GTR + BAS		
		Fatal	Serious	Slight	Fatal	Serious	Slight
Pedestrians	Passive	0.067	0.158	-0.078	0.039	0.118	-0.058
	Active (BAS)				0.077	0.101	0.157
	Total	0.067	0.158	-0.078	0.116	0.219	0.099
Pedal cyclists	Passive	0.024	0.064	-0.019	0.014	0.047	-0.014
	Active (BAS)				0.042	0.057	0.073
	Total	0.067	0.158	-0.078	0.056	0.104	0.059

A decrease in the number of casualties is represented by a positive value in Table 2. It may be noted that Table 2 contains some increase in slight injuries estimated as a result of the regulation. Lawrence et al. (2006) estimated these increased because they assumed that slight injuries (those not requiring hospital admission) are not affected by passive vehicle design changes. Further, the serious casualties (those requiring hospital admission) 'saved' by passive safety improvements would still sustain slight injuries. Therefore, Lawrence et al. (2006) estimated that there would be a net increase in slight injuries, as serious injuries are converted to slight injuries.

Because the increase in the number of slightly injured pedestrians and cyclists offsets the decrease in serious casualties, the proportions in the 'serious' and 'slight' columns of Table 2 imply a specific ratio of crashes between 'serious' and 'slight'. That is, the number of pedestrians represented by the increase in slight pedestrian casualties under the "Original Phase II" (0.078) must be the same number represented by the decrease in serious casualties (0.158). The ratio of slight casualties to serious casualties that produces these figures is about 2.03:1.

Characteristics of the passive safety of the current Australian and overseas new car fleets

Not every passenger vehicle sold in Australia or the EU is assessed by EuroNCAP/ANCAP. However, as the programs target higher selling models, 82% and 90% of the new car fleets in Australia and EU can be assigned assessment scores. Vehicles are assigned points to a maximum of 36 , based on the results of the tests used in the assessment and these are grouped into star-ratings. The EuroNCAP/ANCAP pedestrian star rating system awards one star for the first point gained in a pedestrian assessment, and then an extra star for each additional none points, to a maximum of four stars.

shows the cumulative distribution of performance in EuroNCAP/ANCAP tests of the new passenger vehicle fleet in different European market jurisdictions, and also Australia. These distributions are produced by weighting each model's Euro NCAP/ANCAP performance by its sales volume. The Figure shows, for example, that 0.6 of new car sales in Australia have an ANCAP score of around 9 points or less. Ponte et al. presented this Figure in 2007 [22].

Fifty six percent of new passenger vehicles sold in Australia have a pedestrian safety star rating of less than 2, compared to 32 percent in Europe; this implies that pedestrians struck by new passenger vehicles in Australia are 75 percent more likely to be struck by a 0 or 1 star car than pedestrians in Europe. Note though that most of the differences in the fleet performance occur below 16 points, and so the prevalence of better performing vehicles (pedestrian rating of 3 stars) is similar in each market jurisdiction and relatively small – under 20 percent of the new car fleet.

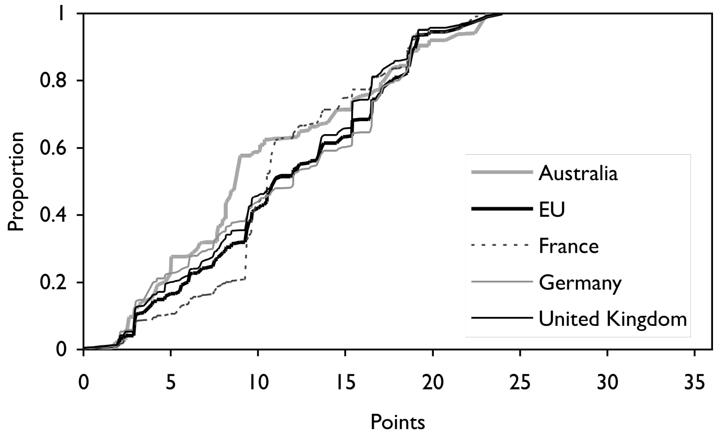

Figure 1: Cumulative performance of the new car fleet in Australia, France and the United Kingdom, for models assessed by EuroNCAP/ANCAP

Figure 2 shows a breakdown of the cumulative distribution of the performance of the Australian new car fleet according to the year that each model was released. It shows clearly the improvement in the performance of more recently released models into the Australian market.

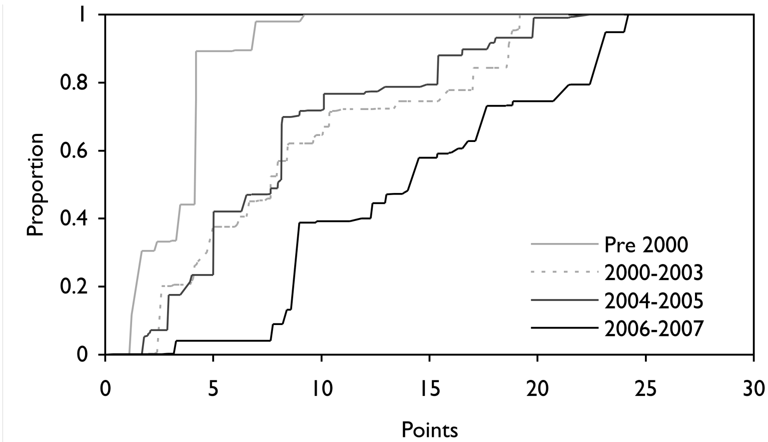

Figure 2: Cumulative Australian new car fleet performance by model release year. Sales volumes from July 2006 to June 2007 are used to define the new car fleet. The legend refers to the model year.

However, the new-car fleet performance of models assessed in 2006-2007 in Europe shows much greater improvement over previous periods than the improvement of the equivalent segment of the Australian fleet. Figure 3 shows the new car fleet performance of vehicle models released in Model Years 2006 and 2007, by market jurisdiction. While 60% of the passenger vehicles sold in Australia released in MY2006 and MY2007 are rated at 2 stars or greater, vehicles of the same performance constitute almost all passenger vehicles sold in Europe released in MY2006 and MY2007. More 06-07 vehicles in Europe are rated at 3 stars (more than 18.5 points) than in Australia. It is clear from these data that the performance in pedestrian tests of the recently released vehicle fleet in Australia is lower, on average, than the equivalent segment of the new car fleet in Europe.

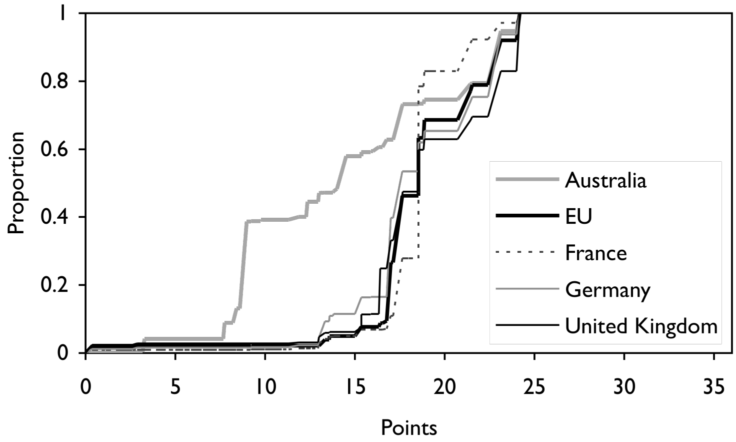

Figure 3: New car fleet performance of models released in MY2006 and MY2007 in Australia and Europe (2006 sales for Europe and 06/07 sales for Australia).

Deployment of BAS into the current Australian new car fleets

BAS is becoming more common in new cars. To determine the prevalence of BAS in the new car vehicle fleet for this study, a survey was undertaken. The technical specifications of the models comprising the top 80% of sales were checked. In this survey the specification of either "Brake Assist System" or "Electronic Brake Assist" was used to indicate a system of BAS that would deliver the benefits provided in Table 2.

Sales data used to construct the list were for the 12 months from July 1st, 2006 to June 30, 2007 [23]. Information on the technology used came from websites and brochures of the current specifications (as at 25th June 2008) of the vehicles in the list. Therefore, the analysis is of current models, but based on sales data to the end of June 2007. The prevalence of BAS was weighted by the model's sales.

The result of the survey was that, of 80% of all new car sales, 63% are equipped with BAS and 37% have no BAS. These proportions are estimates of the proportions of all new cars with and without BAS.

METHODOLOGY FOR CALCULATING BENEFITS OF IMPROVED PEDESTRIAN PROTECTION

The methodology used to estimate the potential benefit of the implementation of an ADR on pedestrian protection in Australia is based on the benefit estimates made by Lawrence et al. (2006) [13] and the current performance of the Australian new car fleet described in the previous section. The method relies on an estimate of the correspondence between a vehicle's EuroNCAP/ANCAP rating and the potential benefit of replacing that vehicle with one that complies with a proposed ADR on pedestrian protection. An assumption must also be made about how a complying vehicle would fare in a EuroNCAP/ANCAP assessment.

Correspondence between EuroNCAP tests and the passive component of regulatory proposals

In assessing any potential benefit to vulnerable road users in Australia, it should be recognised that, since European and Japanese regulation in the area was mooted, new vehicles have demonstrated improved pedestrian protection. The estimates of benefit in Lawrence et al. (2006) assume a 'standing start' (i.e. a fleet with no built-in pedestrian protection). However, such an assumption may no longer be appropriate. The Australian fleet has been improving, probably in response to regulatory activity overseas and consumer testing programs. Fortunately, EuroNCAP/ANCAP assessments provide some quantification regarding the performance of vehicles in tests similar to those prescribed by regulations in Europe and Japan. It is therefore useful, when estimating future benefits, to estimate the correspondence between EuroNCAP/ANCAP performance and proposed regulation, and use this estimate to examine benefits already accruing, and those yet to be realised.

Based on an examination of the three assessment protocols – EuroNCAP, the original Phase II proposal, and the proposed GTR – the following observations can be made:

- In the original Phase II proposal, approximately the rear half of the adult headform test area specified by EuroNCAP would not be tested on most vehicles, and the base of the windscreen would not be tested. Hence, at minimum, a vehicle complying with the original Phase II regulation would score half of the available points for the adult headform tests under EuroNCAP.
- In all other respects, a vehicle complying with the original Phase II proposal would approximately comply with EuroNCAP requirements for full points.
- Under the GTR and EC proposal, headform impact severities would be less than when tested under the EuroNCAP protocol because of the heavier child headform and the lower impact speed. Moreover, only two-thirds of the headform tests would have to satisfy EuroNCAP criteria (HIC < 1000) to pass the regulation. Such a vehicle would receive approximately 12 points in the EuroNCAP head impact assessment (i.e. half of the headform impacts would pass).
- An upper leg test is currently proposed by the European Commission [5] but not for the GTR. As such, a vehicle could fail the EuroNCAP assessment but still pass the draft GTR. Also, given the misgivings of the automotive industry [24] it is not clear that this test will survive in the final version of Phase II of the EU Directive, or whether it will be included in the final draft of the GTR.
- Even though slightly different requirements are specified for the bumper tests, it will be assumed that a vehicle complying with the GTR would also satisfy EC and EuroNCAP requirements.

An estimate of the number of points that a complying vehicle might need, in a EuroNCAP/ANCAP assessment, to comply with each regulatory proposal, is given in Table 3. Conservative estimates of EuroNCAP/ANCAP performance of complying vehicles in Table 3 will also produce conservative estimates of the benefit of moving the current new passenger vehicle fleet to a minimum level of compliance with candidate regulations.

Table 3: Estimated equivalent EuroNCAP/ANCAP pedestrian assessment performance for regulatory options for pedestrian protection

	EuroNCAP/ANCAP – full points	Original Phase II compliance	GTR/Current EC proposal
Adult head	12	6	6
Child head	12	12	6
Upper leg	6	6	0
Full leg	6	6	6
Total	36	30	18

Estimating the benefits of a compliant new car fleet

The performance in pedestrian impact tests has been gradually improving, notwithstanding the gap between the Australian new car fleet and those of Europe. Hence, any benefit estimate of a new ADR needs to take account of the benefit already accrued. Improvements to date have not occurred as a result of an ADR in Australia. One might not choose, therefore, to assign benefits from improvements to-date to future benefits arising from an ADR on pedestrian protection.

What kind of EuroNCAP performance would a vehicle designed with little or no pedestrian protection built in have? Figure 2 showed that the new car fleet consisting of pre-2000 released vehicles has a EuroNCAP score of around 4 points or less. This might be considered the 'standing start' from which the benefit calculations of Lawrence et al. (2006) apply. Table 3 suggests the minimum EuroNCAP performance of vehicles that might comply with each alternate proposal for Phase II of the European Directive. These levels of performance correspond to the level at which benefits cut out. (Although further benefits would accrue with further improvements in safety, such improvements are not required under either proposed regulation and do not form part of the benefit estimates made by Lawrence et al. (2006))

For the passive component of the original Phase II requirements, benefits would be maximised if a vehicle scoring around 30 EuroNCAP points replaces a vehicle scoring around 4 EuroNCAP points. But, if a car that complies with regulation replaces a car that already has some level of performance in the tests, the benefit will not be as great. For the purposes of the present analysis, this 'sliding' benefit was approximated by a linear function. Such a function is illustrated in Figure 4: the benefit of complying with the original Phase II of the Directive is shown by the line labelled 'A'. The line 'B' indicates the benefit arising from the passive component of the GTR and current EC proposal. Here the benefit is not as great and a complying car is estimated to score 18 EuroNCAP points.

The potential benefit of replacing any model of vehicle sold in Australia with a vehicle complying with passive safety standards can be estimated by applying the functions shown in Figure 4 to that model's EuroNCAP/ANCAP score. This benefit can then be weighted by the model's sales volume. In this way, the benefit of making the entire new car fleet compliant with passive safety standards can be estimated. An assumption will be that the overall performance of vehicles for which no rating exists is represented by the overall performance of the vehicles used to make the estimate of benefit.

As detailed earlier, the EC proposal includes the mandatory use of BAS. As this component is independent of the passive component of the EC proposed regulation, an alternative approach is needed to estimate benefits of further improvements to the new car fleet: When assessing benefits yet to accrue, the benefits listed in Table 2 are applied only to vehicle sales for which there is no BAS; that is, 37% of new car sales.

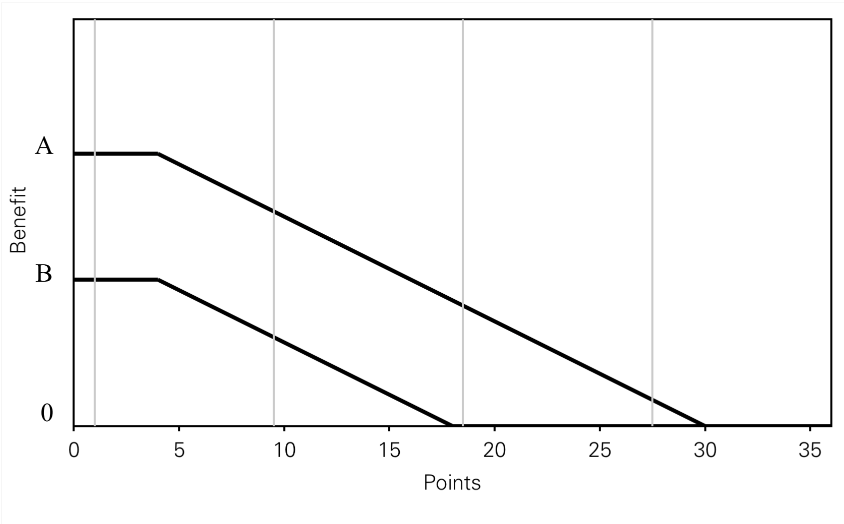

Figure 4: Benefit as a function of EuroNCAP/ANCAP performance, applied to the new car fleet to estimate benefit arising from improvements in pedestrian safety. "A" is the maximum benefit of implementing European Directive Phase II protection, "B" is the benefit of the passive safety component of the GTR/EC recommendation.

Pedestrian and cyclist injury in Australia

The benefit calculation described above will produce an estimate of the proportion of deaths and casualties saved by the introduction of an ADR on pedestrian protection. To estimate benefits in absolute terms, the benefits must be applied to the number of pedestrians killed and injured on Australian roads. In doing so, it is important to remember that such an estimate will rely on an assumption that the pattern of pedestrian and pedal cycle injuries are broadly similar in Europe and Australia. That is, the proportions of casualties hit by the fronts of passenger vehicles at certain speeds are similar in Europe and Australia.

The number of pedestrians and cyclists killed and an estimate of the number injured (hospitalised) is given in Table 4. Fatality data are taken from the ATSB fatality database [1] and serious injury data are based on hospital separation data from the National Hospital Morbidity Database of the Australian Institutes for Health and Welfare [25].

Slight injury data are more difficult to estimate. Minor pedal cycle and pedestrian injuries are probably grossly underreported in traffic accident statistics. Data in Watson and Cameron [26] give an indication of this. They collated traffic accident statistics from four states in Australia (Victoria, Queensland, Western Australia and South Australia) for the 5 years 2000-2004. Over this period, 12,471 injury crashes involving a cyclist and a motor vehicle were reported to police, including 3,362 crashes in which the rider was hospitalised or killed. From the data in Watson and Cameron, it is possible to estimate national figures for reported crashes by recognising that the four states examined account for 62% of the Australian population [27]. This produces a national estimate of 1080 reported pedal cycle crashes annually, in which the rider was hospitalised or killed. Comparing this to hospital separation data in Table 4 indicates that around 2/3 of pedal cycle serious casualties are missing from police reported data

Slight injury data are not collected by the National Hospital Morbidity Database. The South Australian Traffic Accident Reporting System indicates that slightly injured pedestrians are about three times as common as seriously injured pedestrians. Similarly, slightly injured pedal cyclists are about six times as common as seriously injured pedal cyclists. However, as Lawrence et al. (2006) note, under-reporting in police crash data is unlikely to be uniform by crash severity: some serious injuries are mistakenly coded as slight. Anderson [15] also found indications that this coding error might also occur commonly in South Australia. Estimates of the ratio of slight to serious casualties in Europe are 2.03:1 for pedestrians and 3.36:1 for pedal cyclists (see previous discussion). These ratios are consistent with TARS data for South Australia, allowing for potential unevenness in under-reporting rates by severity, and so will be used in this report in the absence of reliable Australian data.

Table 4: Fatality [1] and estimated injury [25] numbers used to represent pedestrian and cyclist injuries in Australia

Road user type	Fatalities (Jan-Dec 2006)	Serious Injuries (Jul 2003 - Jun 04)	Slight Injuries
Pedestrians	227	2,578	5,245*
Cyclists	40	3,676	12,340*

*Estimates from serious casualty numbers scaled by ratios inferred from Lawrence et al. (2006)

Costs of death and injury in Australian road crashes

Baldock and McLean [28] examined the economic costs of road crashes in Australia. Their estimates were based on costs estimated by the Bureau of Transport Economics (BTE) [29] updated using CPI figures to costs in 2004. It should therefore be noted that the costs were current at the time of publication of Baldock and McLean. The costs associated with avoiding a single road traffic casualty (from Baldock and McLean) are given in Table 5. These figures will be used to represent costs for Australian casualties.

A further point should be made about these costs: The BTE estimates are based on the value of human capital, rather than a "willingness to pay" method. The results are therefore conservative. Willingness to pay methods can produce an estimate of crash costs that is 25% to 60% higher than the valuation of human capital [28].

Table 5: Savings in road crash costs (AUD) in South Australia associated with reductions of a single fatality, a single serious injury (hospital admission) and a single slight injury (non-hospital admission), separately for each crash injury level

Fatality	Serious injury	Slight injury
$1,747,522	$331,107	$16,965

RESULTS

Benefits from a 'standing start'

Benefits from a 'standing start' are an estimate of all pedestrian protection arising from conformance of the fleet to regulation, both realised and unrealised. Table 6 shows the estimated annual reduction to pedestrian and pedal cyclist injuries that would result from a passenger vehicle fleet that complied with either the current Phase II of the EU Directive, or the GTR. These figures were produced by multiplying the expected reductions estimated by Lawrence et al. (2006) by the estimate of current Australian pedestrian and pedal cyclist injuries in Table 4. Lawrence et. al.'s (2006) estimates are reproduced in Table 2.

Table 6: Estimated total reduction in Australian pedestrian and bicycle casualties due to pedestrian protection measures according to alternate regulatory proposals

Road user type	Benefit component	Original Phase II			GTR + BAS		
		Fatal	Serious	Slight	Fatal	Serious	Slight
Pedestrians	Passive	15	407	-407	9	304	-304
	Active				17	260	823
	Subtotal	15	407	-407	26	565	519
Pedal cyclists	Passive	1	235	-235	0.6	173	-173
	Active				1.7	210	901
	Subtotal	1	235	-235	2	382	728
Total		16	642	-642	28	947	1247

By multiplying these casualty reductions by the costs associated with road crash casualties estimated by Baldock and McLean (Table 5), the monetary benefit associated with crash reductions can be estimated (Table 7).

Table 7: Estimated total reduction in Australian pedestrian and bicycle casualty costs due to pedestrian protection measures according to alternate regulatory proposals (millions of dollars). Figures in parentheses indicate negative values.

Road user type	Benefit component	Original Phase II				GTR + BAS			
		Fatal	Serious	Slight	Total	Fatal	Serious	Slight	Total
Pedestrians	Passive	$27	$135	$(7)	$155	$15	$101	$(5)	$111
	Active					$31	$86	$14	$131
	Subtotal	$27	$135	$(7)	$155	$46	$187	$9	$242
Pedal cyclists	Passive	$2	$78	$(4)	$76	$1	$57	$(3)	$55
	Active					$3	$69	$16	$88
	Subtotal	$2	$78	$(4)	$76	$4	$126	$13	$143
Total		$29	$213	$(11)	$231	$50	$313	$22	$385

The figures in Tables 6 and 7 can be interpreted in two ways. They can be considered the annual benefit of moving the entire passenger car fleet from total non-compliance to compliance with the proposed regulations. Alternatively, assuming a steady state in the number of pedestrian collisions, they can be thought of as the lifetime benefit (ie. the potential benefit for the life-span of the vehicle) of the new passenger vehicle sales from one year in which all such vehicles comply.

In summary, with fleet compliance to the current GTR proposal with the addition of mandatory BAS, Australia will benefit from the regulation by an estimated 28 fatalities, 947 serious casualties and 1247 slight casualties per year, compared with a car fleet represented by models released prior to the year 2000. This represents a saving of $385million annually in crash related costs.

Benefits already accrued and those remaining to be realised

As mentioned previously, despite no pedestrian protection regulation in Australia, the performance of the passenger car fleet has been improving, as indicated by EuroNCAP/ANCAP ratings. Although better performing cars are making up a larger proportion of the new car fleet, they still represent a minority of the total registered passenger vehicle fleet [30]. Hence, the benefits that have already been accrued refer to the lifetime benefit of the current level of protection offered by new passenger vehicles sold in 2006/2007. The benefits yet to be realised are the lifetime benefits of improving the new car fleet to the point of compliance with a candidate regulation. With this interpretation in mind, benefits already accrued are actually benefits that will be felt more as time goes on, as current models supersede the existing older models in the vehicle fleet.

Further improvements in the pedestrian protection performance of the new car fleet, in the absence of an ADR, are likely given the trend in performance of cars in EuroNCAP/ANCAP tests. Therefore an estimate of the benefits yet to be realised may overstate the benefits of any ADR; the following analysis will assume a steady new passenger vehicle fleet performance in the absence of an ADR. This performance is characterised by vehicle sales from 2006/07.

The benefit function described in Figure 4 was applied to models of passenger cars sold in 2006/07, based on each model's EuroNCAP/ANCAP pedestrian test score. Models that had not been rated were assumed to be represented by the models for which there was a rating. The potential benefit of replacing each model with one that complied with the regulation was multiplied by the sales volume of the model, and summed over all models for which a EuroNCAP/ANCAP pedestrian test score exists. This sum was divided by total sales of all models considered. The resulting number is an estimate of the benefit of replacing the current new car fleet with one that complies with each candidate regulation.

For the active safety component, it was assumed that 37% of all new vehicles are yet to be equipped with BAS. It was also assumed that for those vehicles that currently do have BAS, the benefit is fully realised (that is, no additional benefit would be realised from these vehicle sales from the inclusion of BAS in the ADR). The results of these calculations for each of the proposed regulations are given in Tables 8 and 9.

Table 8: Estimated reduction in Australian pedestrian and bicycle casualties from pedestrian protection measures yet to be realised according to alternate regulatory proposals

Road user type	Benefit component	Original Phase II			GTR + BAS (current EC proposal)		
		Fatal	Serious	Slight	Fatal	Serious	Slight
Pedestrians	Passive	11	297	-297	5	164	-164
	Active				6	96	299
	Subtotal	11	297	-297	11	260	135
Pedal cyclists	Passive	0.7	172	-172	0.3	93	-93
	Active				0.6	78	338
	Subtotal	0.7	172	-172	1	171	245
Total		12	469	-469	12	431	380

Table 9: Estimated reduction in Australian pedestrian and bicycle casualty costs from pedestrian protection measures yet to be realised according to alternate regulatory proposals (millions). Figures in parentheses indicate negative values.

Road user type	Benefit component	Original Phase II				GTR + BAS (current EC proposal)			
		Fatal	Serious	Slight	Total	Fatal	Serious	Slight	Total
Pedestrians	Passive	$19	$98	$(5)	$112	$8	$54	$(3)	$59
	Active					$11	$32	$5	$48
	Subtotal	$19	$98	$(5)	$112	$19	$86	$2	$107
Pedal cyclists	Passive	$1	$57	$(3)	$55	$0.5	$31	$(1.6)	$30
	Active					$1	$26	$6	$33
	Subtotal	$1	$57	$(3)	$55	$1.5	$57	$4.4	$63
Total		$20	$155	$(8)	$167	$21	$143	$6	$170

By comparing Tables 8 and 9 with Tables 6 and 7 it can be seen that just under half of the benefits of either of the regulatory options will result from future improvements in the new car fleet. An estimated 12 of the 28 fatalities to be saved over the lifetime of one year's new car sales would come from future improvements of the new car fleet. This is in line with the proposed GTR plus BAS, with an estimated 16 of 28 fatalities already being saved due to the improved performance of the new car fleet. Potentially, $170 million of $386 million in crash cost savings would similarly come from future improvements. This result is a consequence of the widespread deployment of BAS in the existing new car fleet (approximately 63% of all new vehicle sales). Over half of the benefit of the passive safety technical prescriptions of the GTR are still to be realised in the Australian new car fleet.

DISCUSSION

The most likely form of an ADR on pedestrian protection will be a GTR adopted under the UNECE 1998 Agreement. Although GRSP are currently restricted to the consideration of passive safety measures, BAS may still form part of the GTR, given that it is likely to be included in Phase II of the European Directive.

It appears that the improvement in pedestrian protection in the Australian new car fleet to date is only around half of what might be achieved under a future ADR consisting of the proposed GTR plus BAS. The potential benefits of pedestrian protection in terms of reduced death and injury are significant: pedestrian protection to the proposed GTR with BAS on all vehicles should eventually bring with it an estimated reduction of 28 fatalities and around 950 serious casualties per year, and concomitant savings in crash related costs of around 385 million dollars per year. A willingness to pay approach to estimating crash costs would produce a higher estimate of related savings. Around half of these benefits are already in the pipeline, based on the performance of the newest models on the market.

Note that most of the accrued benefit of existing pedestrian protection is still to be realised in the whole passenger car fleet – the median age of registered vehicles in Australia is 9.7 years [30]. Therefore, although the new car fleet displays some level of performance in the results of pedestrian impact tests, the overall performance of the registered passenger car fleet will be considerably worse. Improved performance is 'in the pipeline' as new vehicles gradually replace older vehicles in the fleet. Note that, because the predicted reduction in casualties due to regulation is not large (Table 2), an estimate of the total benefit of pedestrian protection that is based on current crash numbers will not be greatly affected by any benefits that have already been realised.

The benefit estimates made in this report are not without limitations. Limitations include the applicability of the estimated reductions in European fatal and casualty pedestrian crashes to Australia, as well as the limitations of the estimated reductions themselves. This paper gives some limited evidence that the proportions of crashes in Australia affected by a future ADR are similar to the proportions likely to be affected by equivalent regulation in Europe. As for the limitations in the estimates of fatality and casualty reductions for Europe, Lawrence et al, (2006) discuss these in their report [13]. It should be noted here that their own conclusions were that their reduction estimates were neither unduly conservative nor generous, and were arrived at after considerable consultation, and with the use of data received from several research agencies and car manufacturers in Europe.

This paper's estimate of the reduction in the number of fatal and casualty crashes in Australia assumes that Australian pedestrian and cyclist fatality and casualty numbers are constant, when in fact they have been declining [1, 20]. The estimate of the absolute benefits is subject to trends and other sources of variation in the numbers of crashes.

The mechanism of introducing a new ADR is complex [7] and the position of the Australian Government is not to consider revisions to the Australian Design Rules outside of international considerations. The Australian Government has also stated that, "regulatory intervention is balanced against the extent to which the market is able to drive the desired safety objective" [31]. There is no evidence that the market will 'drive the desired safety objective' in the area of pedestrian protection – the new car fleet passive safety performance of Australian passenger cars is currently inferior to the new car fleets of Europe.

Pedestrian safety may not be effectively promoted through the same market mechanisms that have produced levels of performance that exceed minimum standards in the area of occupant safety. To date, a minority of vehicle sales would satisfy an ADR on pedestrian protection, whereas many of these vehicles comfortably exceed the minimum benchmark standards for occupant protection. As such, an ADR would provide an important mechanism for manufacturers to improve safety levels provided by vehicles to vulnerable road users.

The proposed GTR on pedestrian and vulnerable road user protection will not necessarily produce the highest level of protection that is feasible. The passive safety component of the GTR corresponds to around 18 EuroNCAP/ANCAP points, and already there have been vehicles that offer better protection; ANCAP recently reported on its first assessment of a 4-star car, awarding it more than 27.5 points [32]. ANCAP and EuroNCAP may provide additional impetus for safety conscious manufacturers to exceed the minimum requirements of an ADR.

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