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Regulation Impact Statement for Underrun Protection

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Vehicle Safety Standards Branch
Department of Infrastructure, Transport, Regional Development and Local Government
GPO Box 594
Canberra, ACT 2601</td></tr>
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Department of Transport and Regional Services
GPO Box 594
Canberra ACT 2601</td></tr>
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Abstract

The aim of this Regulation Impact Statement (RIS) is to examine whether there is a need for government intervention, to be directed towards new vehicle construction, in order to reduce the trauma from road crashes involving heavy commercial vehicle underrun. These crashes are often severe, because of the incompatibility in both mass and geometry of heavy vehicles and other road users such as passenger cars, motorcycles, bicycles and pedestrians.

The need for some type of Underrun Protection (UP) was identified. Costs and benefits were estimated for eight possible non-regulatory and regulatory options to introduce UP.

Although self-regulation is very much on the agenda of the road freight transport industry, it was concluded that the level of competition within the industry and the externality of any benefits achieved would not make this an effective option.

It was demonstrated in line with the Council of Australian Governments (COAG) principles for making national standards that there would be a maximum net benefit, within the available administration frameworks, in mandating an Australian Design Rule (ADR) for front UP for new rigid and articulated heavy commercial vehicles (trucks) of NC category (a Gross Vehicle Mass (GVM) greater than 12 tonnes). The ADR would adopt the United Nations Economic Commission for Europe (UNECE) standard R 93. Newly approved models would have to meet the requirements from 1 January 2011 and all models would have to meet the requirements from 1 January 2012.

It was not recommended that either side or rear UP be mandated for any vehicles other than as noted below.

It was recommended that a case for withdrawing the existing rear bumper requirement for semi-trailers in Clause 8 of ADR 42/04 General Safety be examined separately, under a review of ADR 42/04. The examination should include the possibility of accepting UNECE Regulation No. 58 – Rear Underrun Protection as an alternative standard and of adopting state and territory requirements for rear UP for tilt-tray tow trucks into ADR 42/04 or ADR 44/02 Specific Purpose Vehicles.

It is recommended that the state and territory authorities examine whether the steer axle limit should be raised by at least 100 kg for new vehicles certified as having front underrun protection.

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Summary and Recommendations

Summary

The impact that road crashes have on society is significant, costing the Australian economy approximately $15 billion per year. Crashes involving heavy commercial vehicles (a goods carrying vehicle with a Gross Vehicle Mass (GVM) greater than 3.5 tonnes) colliding with passenger cars, motorcycles, bicycles and pedestrians have an increased likelihood of producing a severe injury or fatality. This is mainly due to the incompatibility in mass and geometry between heavy vehicles and other road users.

This RIS addresses a subset of heavy commercial vehicle crashes, referred to as a “heavy vehicle underrun crash”. A heavy vehicle underrun crash occurs when a passenger car, motorcycle, bicycle or pedestrian slides underneath the front, side, or rear end of a heavy commercial vehicle. These collisions have become an increasing cause for concern in the Australian community.

During the period 1988 to 2003, an average of about 35 people were killed annually in Australia in underrun crashes. Around 30 of these fatalities were passenger car occupants, 7 were motorcycle or bicyclists and there may be an additional 5-7 pedestrians. The drivers of the heavy commercial vehicles were rarely killed or injured. Where a fatal underrun crash involved an articulated heavy commercial vehicle, it was more likely to be in a rural area. Rigid vehicles were more evenly balanced between rural and urban. These figures are expected to increase in the future, given an expected doubling of the freight transport task by 2020. The estimated cost (in 2009$) of heavy commercial vehicle underrun trauma was $295 million.

The objective of the Australian Government is to reduce the cost of underrun trauma. To this end, heavy commercial vehicle Underrun Protection (UP) has been investigated since the 1980s in various countries and is now mandatory in the European Union (EU) for commercial vehicles exceeding a GVM of 3.5 tonnes.

While the heavy commercial vehicle manufacturer or operator would bear the cost of fitting UP, the principal beneficiaries would be other road users and the community generally (through the reduction in the severity of injuries). Therefore, existing market arrangements are not likely to respond to the problem and government intervention of a non-regulatory or regulatory type may be needed. Eight options, both non-regulatory (Options 1-5) and regulatory (Options 6-8), were investigated.

The provision of Underrun Protection (UP) by self-regulation (Option 1) could be a low cost option and yet is unlikely to generate the high application rate required for new vehicles if underrun trauma is to reduce significantly. This is due to the competitive nature of the industry and because the costs of the option would be borne in the main by the vehicle manufacturer, and subsequently passed onto the operator and consumer, while a significant portion of the benefits would be received by the wider community. In addition, although there was a case for withdrawing the bumper requirement in ADR 42/04, without mandating replacement rear UP, this was not supported during the public comment period.

The use of a scheme such as the National Heavy Vehicle Accreditation Scheme (NHVAS) or similar, as outlined in Option 2, involved the use of an accreditation scheme to promote

the installation of front UP. However, it is likely to lack the ability to achieve the high application rate that would be required to reduce underrun trauma significantly.

The use of an industry code of practice, as outlined in Option 3, would also be unable to provide the high application rate required for reduction in underrun trauma owing to the reasons outlined for Options 1 and 2.

The use of an Australian Standard, as outlined in Option 4, again faces the same problems as Option 3 in providing the application rate for reducing underrun trauma. In addition, the need to develop a uniquely Australian performance standard does not exist, as there is an international standard available.

The use of state and local government fleet purchasing arrangements, as outlined in Option 5, would suffer in the same way as the other non-regulatory options. In particular, there would be little effect on articulated heavy commercial vehicle numbers as few of these are purchased by government.

The business-as-usual approach, as outlined in Option 6, is not achieving the government objectives as the voluntary fitment of UP is minimal.

Adopting a range of standards from North America, Japan, UNECE, EU and Brazil for UP, as outlined in Option 7, would only add to the complexity of applying and maintaining the different standards and Australia would be unable to participate in the development process. As such, it could find itself in the position of having to choose between accepting unsuitable updated requirements and rejecting the entire standard. In any event, the national standards that were available were for side and rear UP, which was not found to be viable under the economic analysis.

Four scenarios were prepared for estimating the benefits of the application of UP on new rigid and articulated heavy commercial vehicles greater than 4.5 tonnes Gross Vehicle Mass (GVM) (some NB and all NC Australian Design Rule (ADR) category). This was done using a 100 per cent application rate, representing full regulation under Option 8, as well as an estimated 15 per cent application rate, representing self-regulation under Option 1.

A number of assumptions had to be made, including the effectiveness of UP, the discount rate and the expected vehicle life. Because of the assumptions, a range of scenarios and sensitivities were developed, including variations in cost and the effect of carrying additional mass.

Summary of Benefit-Cost Ratios (BCR) and Net Benefits per annum from the provision of UP on new heavy commercial vehicles

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
BCR - Rigid	3.1	1.9	1.1	0.5	0.3	0.1	0.2	0.1	0.1
Net Benefits (2009$m)	15.1	6.5	0.4	-5.4	-7.2	-8.6	-9.6	-10.6	-11.4
BCR - Articulated	15.1	9.3	5.1	1.1	0.6	0.3	0.7	0.4	0.2
Net Benefits (2009$m)	35.1	20.6	10.1	0.4	-2.1	-4.0	-1.4	-2.5	-3.3

Best case - discount rate 4% over 25 years, high effectiveness device.
Likely case - discount rate 7% over 15 years, Most Likely effectiveness device.
Worst case - discount rate 12% over 10 years, low effectiveness device.

Summary of Benefit-Cost Ratios (BCR) and Net Benefits per annum from the provision of UP on new heavy commercial vehicles –Energy Absorbing UP

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
BCR - Rigid	0.15	0.09	0.05	0.03	0.02	0.01	0.01	0.01	0.00
Net Benefits (2009$m)	-136.4	-146.1	-153.0	-155.8	-157.9	-159.4	-280.1	-281.3	-282.1
BCR - Articulated	0.99	0.69	0.43	0.07	0.05	0.03	0.04	0.03	0.02
Net Benefits (2009$m)	-0.6	-13.4	-24.2	-95.4	-97.6	-99.5	-71.6	-72.6	-73.5

Best case - discount rate 4% over 25 years.
Likely case - discount rate 7% over 15 years, Most Likely effectiveness device.
Worst case - discount rate 12% over 10 years.

The benefit-cost analysis found that there was a good case for the provision of front Underrun Protection (UP) for articulated vehicles but marginal Net Benefits from the provision of front UP on rigid vehicles and no Net Benefits for side or rear UP for any vehicle.

Implementing an ADR based on international standard UNECE Regulation 93 for Underrun Protection, as outlined in Option 8, but modified, would be the most cost effective regulatory option available. In modified form this was the provision of front UP for all new rigid and articulated trucks of NC category (a GVM greater than 12 tonnes). The Net Benefits were positive at $24.6m per year and Benefit-Cost Ratios were greater than one. Net Benefits would be $21.5m ($24.6m -$3.1m) per year greater than Option 1.

Industry and regulators alike requested the modification to Option 8, to include rigid vehicles and to only apply the requirements to vehicles above 12 tonnes. This was to allow for practical application of a regulation, as a break point in vehicle categories occurs at 12 tonnes GVM. The modification would still be as (or more) effective at reducing road trauma than compared to an unmodified Option 8 and although it may add a minimal cost burden to industry, would be more than offset by the more efficient implementation of the requirements.

Adopting UNECE requirements for front UP would facilitate market access to efficient and competitive suppliers of the systems. The option would allow transport operators to have a choice of suppliers and access to superior state-of-the-art transport safety technology. The community would be able to reduce the cost of underrun trauma efficiently, while the Australian Government would be able to provide administrative arrangements for compliance at less cost than Option 5 and also participate in a global forum for any future development of UP standards.

Option 8 would also meet the requirements of the COAG Principles for national standards-setting, the WTO's Agreement on Technical Barriers to Trade, and it would enable the Australian Government to implement a key element of the National Heavy Vehicle Safety Strategy 2003-2010.

In the analysis it was noted that the states and territories could, as part of the implementation of an ADR for front UP, raise the state and territory 6 tonne steered axle limit by at least 100 kg. It is important to note that this is not a judgement of what the new axle limits should be, only that the analysis shows the incremental additional allowance was a viable option.

In conclusion, Option 8, modified to apply to all rigid and articulated trucks greater than 12 tonnes GVM (NC category), is the recommended option. The benefits of front UP for all new rigid and articulated trucks of NC category would outweigh the costs, using a discount rate of between 4 and 12 per cent over a 10 to 25 year period. It would reduce the cost of underrun trauma by just under 10 per cent based on an annual cost of underrun trauma of $295m (refer Table 4 and costs of $227m and $68m). Annually it would cost transport operators $6.8m to fit front UP at a marginal cost of $515 per vehicle. It would satisfy the objectives stated in Section 2 and, if looked at purely from a lives saved perspective, would save the equivalent of around 10 lives per year.

Recommendations

The recommended option is Option 8 (modified): An Australian Design Rule (ADR) adopting international standard UNECE R 93 for front Underrun Protection to apply to all rigid and articulated trucks of NC category (greater than 12 tonnes GVM). This would apply to all new vehicles. Newly approved models would have to meet the requirements from 1 January 2011 and all models would have to meet the requirements from 1 January 2012.

It is not recommended that side UP be mandated.

It is not recommended that rear UP be mandated.

It is recommended that the case for withdrawing the existing rear bumper requirement in Clause 8 of ADR 42/04 be examined separately under the review of ADR 42/04, and should include:

- the issue of accepting UNECE Regulation No. 58 – Rear Underrun Protection as an alternative standard; and

- the issue of absorbing state and territory requirements for rear underrun protection of tilt-tray tow trucks into ADR 42/04 or ADR 44/02.

It is recommended that state and territory authorities examine whether the steer axle limit should be raised by at least 100 kg for new vehicles certified as having front underrun protection. However, the outcome is not critical to this analysis.

The development, implementation and review of Australian Design Rules (ADRs) is an established process. If there is broad public agreement to the recommendations, an ADR can be determined under the authority of the Minister for Transport and Regional Services under section 7 of the *Motor Vehicle Standards Act 1989*. After this, further development of the ADR would be considered as part of the normal program of ADR review and revision.

Background

The impact that road crashes have on society is significant. Individuals injured in crashes must deal with pain and suffering, medical costs, wage loss, higher insurance premium rates, and vehicle repair costs. For society as a whole, road crashes result in enormous costs in terms of lost productivity and property damage and costs the Australian economy approximately $18 billion per annum (Australian Transport Council: National Road Safety Action Plan 2007 and 2008). This translates to an average of $840 for every person in Australia.

In terms of traffic safety, issues relating to heavy commercial vehicles have drawn considerable attention from policy makers, road safety engineers and the general public. For the purposes of this Regulatory Impact Statement (RIS), a heavy commercial vehicle is defined as a goods carrying vehicle with a Gross Vehicle Mass (GVM) greater than 3.5 tonnes. Heavy commercial vehicles have many unique operating characteristics that have an effect on crash severity, such as high gross mass, long vehicle length and relatively long stopping distances. Aggregate data and previous research has shown that crashes involving trucks colliding with passenger cars, motorcycles, bicycles and pedestrians have an increased likelihood of producing a severe injury or fatality. This increase is in large part due to the incompatibility between vehicles due to geometric and mass differences. The compatibility of a vehicle is a combination of its crashworthiness and its aggressivity when involved in crashes with vehicles in the fleet. While crashworthiness focuses on the capability of a vehicle to protect its occupants in a collision, aggressivity is measured in terms of the casualties to occupants of the other vehicle involved in the collision. Crashworthiness is sometimes referred to as self-protection while aggressivity is sometimes referred to as partner-protection.

Crash incompatibility is of concern in all vehicle-to-vehicle collisions. Heavy commercial vehicle-to-car collisions are one specific aspect of this problem but another one relates to heavy commercial vehicle-to-vulnerable road user collisions, such as motorcycles, bicycles and non-vehicles (ie pedestrians).

This RIS addresses a particular type of crash event, which is a subset of heavy commercial vehicle crashes and referred to as a “heavy vehicle underrun crash”. A heavy vehicle underrun crash occurs when a passenger car, motorcycle, bicycle or pedestrian slides underneath the front, side, or rear end of a heavy commercial vehicle. Vulnerable road users such as motorcyclists, bicycle riders and pedestrians tend to feature in side underruns with heavy vehicles. Underrun collisions in recent times have become an increasing cause for concern in the Australian community and there have been calls from various sections of the community for addressing the resultant trauma.

Heavy commercial vehicle Underrun Protection (UP) has a long history of investigation. European research organizations as well as heavy commercial vehicle manufacturers have been studying the subject since the 80s, initially commencing with rear and side UP and followed by front UP. Research in Australia, Canada, and the United States commenced in the late 90s and focused mainly on rear underruns, which in Australia contributes to only about 10 per cent of underrun trauma. In recent years, the member countries of the European Union have been instrumental in financing and managing research efforts directed at generating solutions for addressing front underrun trauma, which in Australia accounts for 75 per cent of underrun trauma. Protection for vulnerable road users and passenger car occupants from heavy commercial vehicle underrun is now mandatory in Europe for commercial vehicles exceeding a GVM of 3.5 tonnes. Some member countries of ASEAN and the three most populous and fast growing economies of China, India and Brazil also have some form of UP requirements for heavy commercial vehicles.

Heavy commercial vehicles represent 3.3 percent of all registered vehicles in Australia and account for 7.5 percent of total kilometres driven on public roads (ABS 9309.0: 2001). Appendix 1 describes the various categories of goods vehicles as listed in the Australian Design Rules while Appendix 2 illustrates the 13 types of heavy commercial vehicles operating on Australian roads. For all fatalities resulting from a fatal crash on Australian roads, approximately one in fifteen crashes involves a heavy commercial vehicle engaging with a passenger car and one in forty with a vulnerable road user such as a motorcycle, bicycle or pedestrian (ATSB 2002a). Twenty percent of fatal crashes involve passenger cars and heavy commercial vehicles engaging with each other (ATSB 1997). Sixty-five per cent of these crashes feature collisions with the front ends of both vehicles and less than 10 per cent feature the front end of the passenger car engaging with the rear end of the heavy commercial vehicle.

Table 1 shows the proportions of different types of vehicles and road users that have been involved in fatal underrun crashes with articulated commercial vehicles in the period 1993 to 2002. It shows that the majority (about 82%) of injured persons are passenger car occupants. Only a few percent of the collisions involving trucks result in serious injuries or fatalities to truck occupants. This suggests that UP could be an effective tool to reduce the estimated fifty fatalities each year arising from heavy commercial vehicle underrun collisions.

Table 1: Proportion of road user groups involved in fatal underrun crashes with articulated commercial vehicles, 1993 to 2002

Vehicle occupant	Pedestrian	Motorcyclist	Bicyclist
82%	10%	6%	3%

Source: ATSB, FCD, 1993-2002
Note: Totals do not add to 100 per cent due to rounding of figures

1 Problem

Nature of the Problem

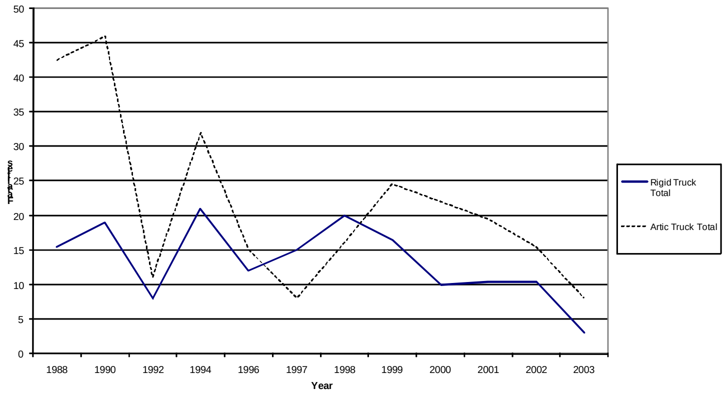
When a heavy commercial vehicle and a passenger car, or vulnerable road user such as a motorcycle, bicycle or pedestrian collide, the results are nearly always more serious for the passenger car occupants or the vulnerable road user than for the heavy commercial vehicle occupants. This is especially true if the front of a smaller vehicle slides under the front or the rear end of a heavy commercial vehicle as happens in a heavy vehicle underrun crash. The high risk of injury to other vehicle occupants from underrun crashes is a result of the lack of compatibility between the colliding vehicles. Vehicle mass, stiffness and geometry affect compatibility. A smaller vehicle under-rides a heavy commercial vehicle to the extent that the heavy commercial vehicle's front or rear extremity enters the occupant compartment or space of the smaller vehicle. Such occupant space intrusion frequently leads to serious injuries or fatalities.

When an underrun crash between vehicles occurs, there are two noticeable outcomes. The first, as described above, is the trauma from the exposure of the smaller vehicle's occupants to impacts with the interior compartment of their vehicle, occupant protection measures in the smaller vehicle being unlikely to engage. The second is the likelihood of further collisions arising from the loss of control of the heavy vehicle. This follows from damage to the steering or braking components of the heavy vehicle by the smaller vehicle.

During the period 1988 to 2003, an average of about 35 people were killed annually in Australia in underrun crashes. Around 30 of these fatalities were passenger car occupants, 7 were motorcycle or bicyclists. (ATSB 2004c). The driver of the heavy commercial vehicle was rarely killed or injured. The number of pedestrians is difficult to estimate as crash databases do not specifically codify pedestrian injury arising from collisions. A very rough estimate would place fatalities of pedestrians in underrun collisions at 5-7 persons annually[i].

Figure 1 shows that there has been a gradual decline in underrun collisions for both articulated truck underrun collisions and rigid truck collisions from a high of 65 fatalities in 1990 to a low of 11 fatalities in 2003. The decline could be attributed to a higher intensity in enforcement by state transport agencies, improvements to roadways and heavy vehicle accreditation programs (operated by private and public sector agencies), which target fatigue, mass limits and vehicle roadworthiness. However, it could be predicted that there will be an increase in the future, due to an expected doubling of the freight transport task by 2020. Indicating that the trend may be moving up again, the latest available figures in 2004 (not shown) indicate an increase from 11 to 18 fatalities. This level was last seen during 1992.

Figure 1: Heavy commercial vehicle underrun fatalities between 1990 and 2003



Source: FCD 1990-2003

Front underrun collisions involving heavy commercial vehicles contribute to around 70-75 per cent of underrun fatalities. In the typical passenger car fatal offset front crash there are high levels of intrusion into the occupant space. European research studies show that in 75 per cent of the cases, the usual occupant protection features built into cars such as seatbelts, airbags, energy absorbing steering columns and crush zones are not engaged. The ability to engage these features is a vital part of the current passenger vehicle standards ADR 69/00 Full Frontal Impact Occupant Protection and ADR 73/00 Offset Frontal Impact Occupant Protection. These ADRs set minimum crash performances to be achieved by light passenger vehicles when striking a barrier that is set at 200 mm or less from the ground.

Side underrun collisions involving heavy commercial vehicles contribute to around 15 per cent of fatalities. The collisions often occur at night but also during the day. In Japan, Europe and some developing economies, because of the immense amount of bicycle and motorcycle traffic, heavy rigid and articulated commercial vehicles must have side Underrun Protection (UP). This type of UP is targeted at protecting vulnerable road users or near parallel collisions with passenger vehicles (an typical example of this is on 4-lane highway where a long heavy commercial vehicle changes lanes while there is a passenger vehicle moving parallel within its blind spot). However, it does not have the structural strength to engage the occupant protection systems of vehicles in a typical "T-bone" side underrun collision.

Rear underrun collisions involving heavy commercial vehicles contribute to around 10 per cent of underrun fatalities. These are a particularly severe crash type for a passenger car because the floor structure of most heavy vehicles is above the bonnet height of the car. The car can run under this structure which may in turn penetrate through the car's 'A' pillars and into the occupant compartment. Again, the usual occupant protection features built into cars such as seatbelts, airbags, energy absorbing steering columns and crush zones are bypassed during these collisions.

The difference in traffic patterns around the world means that the value of fitting UP in Australia cannot be assumed through the actions of other countries. However, it would be justifiable to draw from world research on the effectiveness of UP for particular road user types, and then combine this with Australian crash statistics.

In Australia, insufficient separation between traffic streams in rural areas has been a significant cause for heavy vehicle underruns. Table 2 shows that in case of articulated truck crashes involving underrun, passenger car occupant fatalities are higher in rural areas than urban areas, while for rigid trucks the fatalities are closer to being equally shared.

Table 2: Percentage of underrun fatalities by urban/rural location

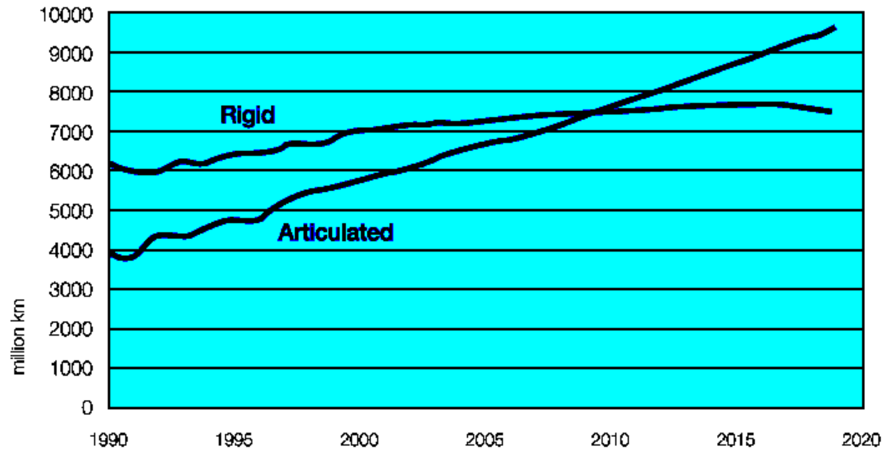
	Rigid Truck		Articulated Truck	
	Passenger Car occupant	Vulnerable Road user	Passenger Car occupant	Vulnerable Road user
Rural	47%	35%	68%	41%
Urban	53%	65%	32%	59%

Source: FCD 1990-1999

Growth in freight transport task:

Fatalities from underrun crashes do not represent a large part of the crash population and are about 3-5 per cent of the total from all types of road user fatalities. However, with the total freight transport task likely to double in the next 20 years, the role of articulated heavy commercial vehicles is likely to expand, as shown in Figure 2. Rigid truck movements are likely to decline gradually, which will have a negative impact on sales of rigid trucks from around 2010.

Figure 2: Vehicle kilometres travelled by commercial vehicles: actual and projected



Source: BTRE Freight Measurement and Modelling

Economic Cost of the Problem

Road crashes generally give rise to spill over costs that are spread across the parties involved in the crash, other road users and owners of public and private property. Fatal injuries arising from crashes present a public health problem to Australian governments, as those involved initially draw scarce medical resources away from other uses, and a significant part of the cost of such resources falls on the public through the taxation system. Those injured may suffer a loss in the quality of life and need access to disability services and facilities, which also pose a burden on the taxation and social welfare systems. Other costs to road users include extended travel time, which increases in heavily congested urban areas, and damage to vehicles and property[ii].

These costs can be even more significant where the road crash involves an underrun type of collision with a heavy commercial vehicle. Fatalities and injuries can be expected to have a greater mean severity due to greater occupant space intrusion by the heavier vehicle, and the reduced (or non-) engagement of the lighter vehicle's energy absorbing structures.

Operators of heavy commercial vehicles also suffer losses through deterioration of perishable product, as heavy commercial vehicles involved in the crash may need to wait for traffic police to investigate the crash. In congested areas, overall heavy commercial vehicle movement may be severely limited leading to increased losses to road freight operators.

The annual economic cost of the problem in terms of heavy commercial vehicle underrun fatalities, serious and minor injuries was estimated for the period 1988-2003[iii]. The Australian Transport Safety Bureau (ATSB), which provided the base data, defines heavy commercial vehicle underrun as *"vehicles running underneath heavy rigid or articulated trucks. In the case of motorcycle and bicycles the rider must still be on the vehicle when it "ran" under the truck".*
Table 3 identifies the number and distribution (ie front, rear or side impact) of underrun crashes using 1990-1996 data and 2002 estimates, which Table 4 then further applies to 1988-2003 detailed data. The result is a summary of the annual cost of fatal, serious and minor injuries from front, rear and side underrun crashes between heavy commercial vehicles with a Gross Vehicle Mass (GVM) greater than 4.5 tonnes, passenger cars, motorcycles and bicycles. Costs for pedestrian trauma due to underrun were not available (note that although heavy commercial vehicles are typically categorised as greater than 3.5 tonnes GVM, crash data was only available for greater than 4.5 tonnes GVM. This mass represents an additional heavy commercial vehicle breakpoint common within regulatory schemes). See *APPENDIX 1: VEHICLE CATEGORIES IN THE AUSTRALIAN DESIGN RULES* on page 64 for details.

The average costs (in 1995 dollars) of a fatal crash, serious crash, minor crash and property damage for passenger vehicle crashes are \$1.7m, \$0.41m, \$0.014m and \$0.006m (BTE 2000). Within this, the costs (in 1995 dollars) for a fatal, serious injury and minor injury for passenger vehicle crashes are \$1.5m, \$0.325m and \$0.012m (BTE 2000).

The difference between these two figures approximates non-trauma related costs such as property damage, heavy commercial vehicle immobility and traffic stoppages. It is equal to around \$0.15, \$0.083m, \$0.002m and \$0.006m (in 1995 dollars). As the non-trauma related costs of heavy vehicle crashes is estimated to be around 1.5 times a passenger car crash, this difference may be multiplied by 1.5 to give \$0.23, \$0.124m, \$0.003m and \$0.009m (in 1995 dollars) respectively in non-trauma costs for each heavy vehicle fatal, serious injury, minor injury as well as property damage suffered.

Assuming a 4 per cent Consumer Price Index, the cost per heavy vehicle injury becomes \$2.6m, \$0.563m and \$0.020m in 2009 dollars for each heavy vehicle fatal, serious injury and minor injury suffered, while resulting in \$0.39, \$0.22m, \$0.006m and \$0.015m respectively in non-trauma costs for each heavy vehicle fatal, serious injury, minor injury as well as property damage suffered. See APPENDIX 6: RESULTS OF BENEFIT-COST ANALYSIS Section 6. for details.

The estimated cost (in 2009 dollars) of heavy commercial vehicle underrun trauma is \$227 million and non-trauma is \$68 million resulting in a total cost of \$295 million. This estimation may be conservative, due to under-estimating and under-reporting of underrun crashes.

Table 3: Estimate of the type of heavy commercial vehicle underrun crashes involving a car, motorcycle or bicycle as a function of injury severity.

	Rigid Heavy Commercial vehicles			
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	10	2	1	13
Serious	69	16	6	91
Minor	158	37	15	208
Total	237	55	22	312
	Articulated Heavy Commercial vehicles			
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	17	3	1	22
Serious	117	22	7	146
Minor	269	50	17	336
Total	403	75	25	504
	All Heavy Commercial vehicles			
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	27	5	2	35
Serious	186	38	13	237
Minor	427	87	22	544
Total	640	130	37	272

Source: FCD 1988-2003
Fatalities from FCD database, Serious injuries estimated from Haworth et al (2002) and NSW, VIC and QLD databases, Minor injuries estimated from Haworth et al (2002)

Table 4: Estimate of the annual cost of heavy commercial vehicle underrun crashes ($2009)

(a) Cost arising from underrun trauma (personal injury only)

Rigid Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$26,485,991	$6,272,998	$2,439,499	$35,198,488
Serious	$38,735,762	$9,174,259	$3,567,768	$51,477,789
Minor	$348,513	$65,346	$21,782	$435,641
All injuries	$65,570,266	$15,512,604	$6,029,049	$87,111,918
Articulated Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$45,023,588	$8,441,923	$2,813,974	$56,279,485
Serious	$65,846,997	$12,346,312	$4,115,437	$82,308,746
Minor	$5,410,658	$1,014,498	$338,166	$1,014,498
All injuries	$116,281,242	$21,802,733	$7,267,578	$139,602,729
All Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$71,509,579	$14,714,921	$5,253,473	$91,477,973
Serious	$104,582,759	$21,520,571	$7,683,205	$133,786,535
Minor	$5,759,170	$1,079,844	$359,948	$1,450,139
All injuries	$181,851,509	$37,315,336	$13,296,626	$226,714,647

Source: FCD, NSW, Victoria and Queensland crash statistics

(b) Cost arising from other than underrun trauma (property damage, heavy commercial vehicle immobility etc only)

Rigid Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$4,052,198	$959,731	$373,229	$5,385,158
Serious	$14,836,989	$3,514,024	$1,952,235	$20,303,248
Minor	$97,476	$18,277	$6,092	$121,845
All injuries	$18,986,663	$4,492,031	$2,331,556	$25,810,250
Articulated Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$6,888,339	$1,291,564	$430,521	$8,610,423
Serious	$25,221,426	$4,729,017	$1,576,339	$31,526,782
Minor	$567,493	$338,166	$1,014,498	$1,920,158
All injuries	$32,677,258	$6,358,747	$3,021,359	$42,057,364
All Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$10,940,537	$2,251,295	$803,750	$13,995,581
Serious	$40,058,415	$8,243,041	$3,528,574	$51,830,030
Minor	$664,970	$356,443	$1,020,591	$2,042,003
All injuries	$51,663,921	$10,850,778	$5,352,915	$67,867,614

Source: FCD, NSW, Victoria and Queensland crash statistics

Types of underrun crashes and policy prescriptions

Underrun Protection (UP) will not prevent crashes but it will allow the crashworthiness features of smaller vehicles to function in the event of an underrun collision. Saving the lives of road users depends on the ΔV (closing speed) of the crash, size of the smaller vehicle and any occupant protection features available in the vehicle. In the case of motorcycles, bicycles and pedestrians, UP may be able to provide a less hostile first point of contact with the heavy vehicle and possibly deflect the smaller vehicle (or the person) away from further danger.

Table 5 illustrates the main types of underrun crashes in Australia, in reality a number of combinations are possible with impact areas on the heavy commercial vehicle ranging from front bumper bars, wheels, rear chassis rails, and side chassis rails. An impact with the chassis rail may result in greater intrusion into the space of a passenger vehicle cabin. In case of offset frontal, the smaller vehicle may tend to rotate away from the heavy commercial vehicle. Table 5 also shows that most OECD countries have some form of mandatory UP, with the European Union leading the table in the mandatory provision for front, side, and rear UP devices for commercial vehicles with a GVM greater than 3.5 tonnes.

Table 5 : Types of underrun crashes and policy responses in some countries

	Effects in terms of Average deceleration			Vehicle based policy prescription recommended	Major countries or regions mandating policy prescriptions
	55 km/h	**70 km/h**	**100 km/h**		
Car or commercial vehicle full frontal head on	20g	35g	45g	Front UP device	EU, Japan,
Car or commercial vehicle offset frontal head on	20g	35g	45g	Front UP device	EU, Japan
Car or commercial vehicle sideswipe impact	12g	15g	20g	Side UP device	EU, Japan
Car to commercial vehicle side impact	8g	12g	NA	Side UP device	EU, Japan
Full rear impact car to commercial vehicle	10g	NA	NA	Rear UP device	EU, US, Japan, Canada China, India, Brazil
Offset rear impact car to commercial vehicle	8g	NA	NA	Rear UP device	EU, US, Japan, Canada China, India, Brazil

Notes: Heavy vehicle GVM/GCM range used in the table is from 20 tonne to 62 tonne. With lower GVMs average decelerations will be lower. In all the above cases cabin intrusion occurs. In crashes where no underrun occurs average deceleration will range from 10g to 15g. The effects have been modelled based on test conditions aligned with ADRs 69 and 73. The EU has 25 member countries and the EU directives enjoy strong following in AGCC and Mercosur countries.

2. Objectives

The objective of the Australian Government is to reduce the cost of underrun trauma. In particular, it is to reduce the aggressive nature of heavy commercial vehicles in collisions with passenger cars, motorcycles, bicycles and pedestrians and thereby reduce the cost of road trauma to the Australian community.

The National Road Safety Strategy for the period 2001-2010 is the Australian government's strategy for reducing road trauma generally. The strategy aims to reduce the number of fatalities per 100,000 people by 40 per cent from 9.3 in 1999 to no more than 5.6 in 2010. This is to be achieved both by maintaining existing measures which are found to be effective, and by introducing new measures based on strategic objectives.

Introducing an Australian Design Rule (ADR) for Underrun Protection (UP) for heavy commercial vehicles is a key measure in both the National Road Safety Action Plan for 2003 to 2004 (although it has not been carried through to the 2005/06 Plan) and the National Heavy Vehicle Safety Strategy 2001 to 2010 (ATC 2003, NTC 2004). The House of Representatives Standing Committee on Transport and Regional Services Inquiry on National Road Safety (Commonwealth Parliament, 2004) also reviewed the issue of underrun trauma and recommended an ADR be developed to mandate installation of UP devices on heavy commercial vehicles.

In case regulatory action is required for providing UP devices on heavy commercial vehicles, the Government needs to ensure that an ADR for UP devices is developed in accordance with the Council of Australian Government (COAG) Principles for National Standards Setting and clause 5 of the Competition Principles Agreement (COAG 2004). The COAG principles require the assessment process for development of standards to be scientifically rigorous, taking into account public health and safety protection. Key features include analysis of the impact on competition, predictability of outcomes, consistency with international standards and practices, impact on international trade, flexibility of standards and adherence to the disciplines of regulation review. Clause 5 of the Competition Principles Agreement requires the Australian Government to demonstrate that proposed regulatory measures provide a net benefit to the community and are necessary to achieve the government's vehicle safety objectives.

The Australian Government's requirements in relation to regulatory action such as the development and application of new ADRs is to ensure that design rules are relevant, cost effective and do not provide a barrier to the entry of safe vehicles and components.

A number of principal requirements guide the Australian government's action when developing and applying new ADRs. These are to ensure that the proposed standard or regulation:

– provides a net benefit to the community

– does not impose excessive requirements on business;

– is cost effective when implemented;

– does not discourage competition in the heavy commercial vehicle assembly and wholesaling sector as well as in the road freight transport industry.

– effectively addresses the community's concerns in relation to impacts on occupant and public safety arising from the introduction of new automotive technology into transport markets;

– is consistent with international standards such as UNECE Regulations.

– does not set unique Australian requirements and standards from other countries are pursued as an exception;

– does not breach WTO requirements and does not pose a technical barrier to trade.

3. Options

Responding to the problem

Underrun crashes present an unusual situation for extracting costs for the provision of Underrun Protection (UP). Heavy commercial vehicle operators in most situations would not derive a great deal of economic benefits from the provision of UP on their vehicles. Other road users, particularly passenger car occupants, would be the principal beneficiaries through reduction in the severity of injuries. It is unlikely that existing market arrangements will be able to correct this externality and influence the provision of UP, as little direct benefits accrue to the provider of such systems. Although European heavy commercial vehicles supplied to the Australian market are provided with UP, this is only because of mandatory requirements in the European Union (EU) countries. While in some cases, the front UP is removed and replaced with a standard bumper-bar, it is uneconomic for other European heavy commercial vehicle wholesalers and importers to offer heavy commercial vehicles without front UP, as it forms part of the front fascia and includes footsteps and other functional devices.

As existing market arrangements are not likely to respond to the problem, government intervention of a non-regulatory or regulatory type may be needed. However, any intervention would have to demonstrate a net benefit to the community.

Currently, Australia only has Australian Design Rule (ADR) 42/04 – General Safety Requirements, Clause 8 Rear Bumpers for Semi-trailers, to respond to the underrun problem. This ADR is relevant to rear underrun crashes between semi-trailers and other road users. This contrasts with the European Union, Japan, United States, some Latin American and Asian countries that have had regulations in place for some time for side and rear UP and more recently for front UP.

In order to reduce fatalities and severity of injuries arising from heavy vehicle underrun crashes, the UP needs to address both *dimensional* and *strength* differences between the colliding vehicles. Properly chosen dimensional requirements restrict underruns while strength requirements prevent the system from deflecting under the impact of forces arising from a collision. This prevents underruns and enables any crash protection features in both vehicles to protect occupants.

Any of the United Nations Economic Commission for Europe (UNECE) Regulations and corresponding European Economic Commission (EEC) Directives for front, side or rear UP used in the 25 member countries of the European Union, could potentially be adopted in Australia. As these requirements are mandatory, all European heavy vehicle manufacturers design prime-movers, rigid trucks and trailers to meet them.

The key features of the Australian Design Rule (ADR), UNECE Regulations, EEC Directives, United States Federal Motor Vehicle Safety Standard (FMVSS) [iv]and other standards relevant to underrun are listed below:

A. Front Underrun Protection Standards

1) UNECE Regulation No. 93 – Front Underrun Protection[v]

2) EEC Directive 2000/40//EC – Motor vehicles with trailers – Front underrun protective devices. This directive is aligned with the requirements of UNECE Regulation No. 93[vi]

B. Side Underrun Protection Standards

1) UNECE Regulation No. 73 – Lateral protection of trailers and semi-trailer goods vehicles provides side underrun requirements[vii]

2) EEC Directive 89/297/EEC – Motor vehicles with trailers – Rear Underrun Protection devices. This directive is aligned with the requirements of UNECE Regulation No. 73[viii]

C. Rear Underrun Protection Standards

1) ADR 42/04 – General Safety Requirements, Clause 8 Rear Bumpers for Semi-trailers

2) UNECE Regulation No. 58 – Rear Underrun Protection [ix]

3) EEC Directive 70/221/EEC – Motor vehicles with trailers – Rear underrun protection devices[x]. This directive is aligned with the requirements of UNECE Regulation No. 58

4) FMVSS 223 – Rear impact guards, and FMVSS 224[xi]

5) National Council of Traffic, Brazil, Regulation Number 152, October 2003 – Rear under ride guards for cargo vehicles[xii].

The UNECE Regulation No. 93 (UNECE R 93) ECE requirements for Front Underrun Protection (FUP) can be met through fitment of a Front Underrun Protection Device (FUPD), or by utilising the vehicle structure as a FUPD.

The test that the front UP has to pass for certification consists of three static forces applied one at a time on the centre line of the front UP beam. 80 kN is applied in the centre, 160 kN at a point where the bracket connects the front UP to the chassis beam and finally 80 kN at the corner. Under these forces, there is a limit of 400 mm displacement allowed. The geometry requirements state that the lowermost part of the front UP beam must not exceed 400 mm from the ground and the beam height must not be below 120 mm.

The requirements were originally written with a collision speed of 56 km/h. However crash tests with standard European medium family size passenger car in 60 km/h revealed that the injury values of the car occupants were rather low (below HIC 200 - Head Injury Criteria has a limit value of 1000 for survival). The requirements state that the front UP should be "stiff", but in tests an energy absorption of about 60 kJ in the commercial vehicle front compared to about 110 kJ in the passenger car front was observed in European tests. Crash tests performed on smaller cars at 64 km/h have returned lower energy absorption and somewhat higher HIC values, still below the 1000 mark.

The requirements for rear UP are less than for front UP because it is expected that in a rear underrun scenario the heavy vehicle would be either stationary or moving away from the direction of impact. The requirements for side UP are much less than either front or rear UP, because protection is only expected against sideswiping of smaller vehicles or very low speed direct impact from motorcyclists, bicycles and pedestrians.

Table 6 summarizes the test loads for UNECE / EEC and United States front, side and rear UP.

Table 6: **Test loads for UNECE and US Underrun Standards**

Test Load (kN)		ECE R 93/ 2000/40/EC Front UP	ECE R 73/ 89/297/EEC Side UP	ECE R 58/ 70/221/EEC Rear UP **	USA FMVSS 223/224 Rear Impact Guard
Outer edge	P1	80 kN	1 kN	25 kN	50 kN
Centre	P3	80 kN		25 kN	50 kN
Off centre	P2	160 kN		100 kN	100 kN
Allowed deflection		400 mm	30 mm in front of wheels, 300 mm elsewhere		125 mm
Height		400 mm	550 mm	550 mm	560 mm

Notes: * These test loads apply to vehicles with a GVM >16t, for other vehicles lower values are permitted and are a function of vehicle GVM.

** These test loads apply to vehicles with a GVM >20t, for other vehicles lower values are permitted and are a function of vehicle GVM.

Australian Design Rule (ADR) 42/04 – General Safety Requirements contains dimensional requirements but no test load requirements for rear bumpers for semi-trailers. Instead it requires that the rear cross member has at least the strength of steel tubing of 100 mm diameter and 8 mm wall thickness, and that an equivalent force path is available from the cross member to the main vehicle members.

Eight non-regulatory and regulatory options were evaluated.

Non-Regulatory approaches for Underrun Protection

Option 1: Self-Regulation

Industry may be able to self-regulate the provision of front, side and rear Underrun Protection (UP) on new heavy commercial vehicles greater than 4.5 tonnes Gross Vehicle Mass (GVM). This may include deleting the current regulation of rear UP for semi-trailers in Australian Design Rule 42/04 Rear Bumpers for Semi-trailers.

Option 2: National Heavy Vehicle Accreditation Scheme (NHVAS)

Accreditation Schemes offered by states and territory governments may be useful as an existing mechanism to encourage the introduction of and monitor the use of, front, side and rear Underrun Protection (UP) on new heavy commercial vehicles greater than 4.5 tonnes GVM.

Option 3: Industry Code of Practice

A code of practice could provide voluntary guidance to transport operators on provision of front, side and rear Underrun Protection (UP) on new heavy commercial vehicles greater than 4.5 tonnes GVM.

Option 4: Australian Standard

A voluntary Australian standard could set technical requirements for front, side and rear Underrun Protection (UP) for heavy commercial vehicles on new heavy commercial vehicles greater than 4.5 tonnes GVM.

Option 5: State and Local Government Fleet Purchasing Arrangements

State and local governments could influence the provision of front, side and rear Underrun Protection (UP) on new heavy commercial vehicles greater than 4.5 tonnes GVM, when they purchase the commercial vehicles that provide the services to their rate payers.

Regulatory Approaches for Underrun Protection

Option 6: Business-as-usual

The current regulatory position of only having rear Underrun Protection (UP) for semi-trailers in Australian Design Rule (ADR) 42/04 Rear Bumpers for Semi-trailers, could be maintained.

Option 7: Australian Design Rule adopting front Underrun Protection regulations from Europe, Japan and United States

An ADR could mandate technical requirements for the provision of front, side and rear Underrun Protection (UP) on new heavy commercial vehicles greater than 4.5 tonnes GVM, based on regulations applied in Europe, Japan and the United States.

Option 8: Australian Design Rule adopting international standard UNECE R 93, R73 and R58 for front, side and rear Underrun Protection respectively for rigid and articulated heavy commercial vehicles with a GVM greater than** 4.5 **tonnes

An ADR could mandate technical requirements for the provision of front, side and rear Underrun Protection (UP) on new heavy commercial vehicles greater than 4.5 tonnes GVM, based on international standard UNECE R93, R73 and R58 Front, Side and Rear Underrun Protection respectively. These standards were developed by the Global Forum for Harmonising Automotive Technical Regulations, a forum sponsored by the United Nation's Economic Commission for Europe[xiii] (UNECE).

Options are assessed for application based on their feasibility in the following paragraphs.

Option 1: Self-Regulation

Industry self-regulation can be effective where the heavy commercial vehicle assemblers and wholesalers/importers voluntarily agree to supply Underrun Protection (UP) on heavy commercial vehicles.

The Australian wholesale operations of some European manufacturers have recently commenced promoting commercial vehicles with front UP. This is because of a spill over effect resulting from the imposition of mandatory requirements for UP in Europe. The current volumes sold by the Australian agents of European manufacturers although not large are healthy, and while there may be a slight competitive disadvantage to European wholesalers, it has not reached a point where European wholesalers are likely to import product without front UP. Daimler, a leading supplier of European trucks to the Australian market, supply rigid trucks (ATEGO range) fitted with side UP. Currently, penetration rate for European articulated truck prime movers is around 20 per cent while that for rigid trucks is around 12 per cent.

However, difficulties arise in the provision of safety equipment through self-regulation where a market is small and overcrowded market and where growth is volatile and competition intense. The effectiveness of any option, including self-regulation, depends on the extent to which it achieves the Australian governments' objectives for reducing underrun trauma in the wider community. In such a market, this objective cannot always shared by business where the primary focus must be on improving profitability.

The extent to which self-regulation is effective in simultaneously achieving the objectives of the wider community and business depends on the precise nature and extent of market failure and the general characteristics of the market. In transport markets, the external (social) costs arising from market failure are borne predominantly not by transport equipment firms nor their customers, shareholders or financiers, but by the wider community (and mainly through all the three levels of Australian governments). It is unrealistic to expect business to incur the costs associated with self-regulation, unless they can directly benefit from them.

In a highly competitive market, it is difficult to ensure that the administration and operation of self-regulation is transparent. Even a proposed independent self-regulatory authority would find it difficult to administer self-regulation, let alone impose sanctions on business (its own members) that breach self-regulation requirements.

The road freight transport industry currently does have self-regulation very much on the agenda. This is to be credited and a number of government studies have found that the long distance road transport industry has made a very significant contribution to the national economy, and demonstrated its capacity for competitiveness, innovation and efficiency. However, some aspects of concern to the community remain and they include:

- Road safety issues: including the safety of vehicles, compliance with speed limits, controls on driver fatigue, intimidating driver behaviour, and the safety and security of loads;

- Urban amenity issues, including noise and exhaust emissions and control of heavy commercial vehicle routes;

- Road damage issues: including overloading and the inappropriate use of lightly constructed roads.

Leading on from these concerns, and with pressure from the government, the industry has developed some alternative compliance schemes. Examples include; mass management scheme, maintenance management scheme and national driving hours. No studies are available on the effectiveness of these self-regulated schemes and the legal enforcement initiatives continue to operate through vehicle inspections for mass limits, roadworthiness, fatigue and others. Overall, the industry would not be at the stage of being able to implement self-regulation on the fitment of major safety systems such as those for UP.

The self-regulation option includes the deletion of the current mandatory regulation for rear UP, the Clause 8 ADR 42/04 requirements for rear bumper on semi-trailers. ADR 42/04 prescribes requirements for a rear bumper on semi-trailers. It does not provide any requirements for front or side UP. It is only applicable to semi-trailers and so other types of heavy commercial vehicles are not required to have any similar systems.

It has been claimed that a bumper meeting ADR 42/04 requirements would not effectively protect road users from rear underrun trauma. This is due to both strength and geometric shortcomings. Firstly, the regulation does not specify any test to prove its strength. Many of the rigid barriers on semi-trailers could bend or twist easily if they inadvertently come in to contact with loading docks. Furthermore, in attempting to accommodate loading dock clearances, the geometric requirements may be inadequate for underrun crashes. Having a ground clearance of up to 600 mm results in a bumper that is too high off the ground to engage effectively with occupant protection systems in other vehicles. Being up to 300 mm short of the side of the vehicle the bumper would also allow a vehicle to pass under the corner of a semi-trailer with little or no resistance.

There is a case for withdrawing the bumper requirements in ADR 42/04. To maintain a regulatory requirement for rear UP, which imposes costs on road transport operators without any reduction in rear underrun trauma, may not be justified.

However, a counter argument is that the presence of this basic underrun device provides at least some benefits. This is achieved at a very low cost and using an arrangement that industry is familiar and comfortable with. The rear bumper also serves a dual role in providing for fitting of signage, lamps and registration plates.

Option 2: National Heavy Vehicle Accreditation Scheme (NHVAS)

The National Heavy Vehicle Accreditation Scheme (NHVAS) is a government scheme that attempts to ensure transport operators comply with the law by ensuring that their vehicles are roadworthy and loaded within the relevant mass limits. The scheme is offered in three modules, one for mass management, a second for maintenance management and a third for fatigue management. The scheme requires operators to develop an in-house assurance system and document procedures and produce sets of documents that prove compliance. By complying with the scheme that is voluntary, operators are not subject to frequent stops and checks at the roadside. The scheme operates in all three eastern seaboard states and covers commercial vehicles whose GVM exceeds 4.5 tonnes.

Accreditation schemes can be good substitutes for law enforcement strategies provided that patronage is high, any private agents supervising the scheme are frequently audited for compliance and sanctions are maintained at levels that prevent non-compliance.

To generate high patronage, there must be sufficient incentives available to make it worthwhile for a vehicle operator to want to join the scheme. Since 1999, when the NHVAS scheme was introduced, the concept of it being an “alternative compliance” scheme has expanded out to also include the offer of regulatory benefits or concessions (NTC 2007). This means that the existence of regulation in the first instance still underpins the NHVAS. The scheme in turn offers administrative advantages in enforcement of regulation (eg reduced inspections for roadworthiness) and/or concessions to regulation (eg higher mass limits).

If underrun protection was to be part of the NHVAS, it could not obtain a high fitment rate without requiring a substantial trade-off in some other regulatory area. This is because, as discussed on page 25, the outcome in an underrun crash is inevitably more serious for the smaller vehicle involved. Therefore, the costs associated with underrun trauma are borne more by the wider community than by the transport operators. There would need to be strong incentives for an operator to want to participate.

Nationally, only 3 per cent of heavy vehicle operators are in the NHVAS (NTC 2007). The National Environment Protection Council reported that there are around 31,000 heavy vehicles in the scheme (NEPC 2007). Using the fleet figures on page 79, this represents only around 8 per cent of the heavy vehicle fleet overall. However, it is acknowledged that most of these vehicles are articulated, possibly up to about 35 per cent of articulated vehicles in Australia (NTC 2007). This is still not a majority of the vehicles and serves more to demonstrate that without substantial trade-offs (such as concessions to mass limits which are highly prized to articulated vehicle operators) the patronage of these type of schemes will remain very low (such as in the case of rigid vehicles, which are close to zero per cent).

With low patronage, accreditation schemes are unable to guarantee the high field application rate of a design rule that regulatory arrangements offer. Therefore, they would not be suitable as a replacement for regulation itself, such as a requirement to have underrun protection.

As a final note, the lack of uniform application across the fleet may produce competitive disadvantage to those accredited to a scheme.

Therefore, this option has not been considered any further.

Option 3: Industry Code of Practice

Codes of practice are neither mandatory nor carry the force of the law. A code of practice for Underrun Protection (UP) could set out guidelines on what constitutes industry practice. The code would establish a common standard and expectations between different players. The Truck Safe program managed by the Australian Trucking Association (ATA) is an example of an industry initiated safety accreditation scheme. Industry standards were initially established for four areas: health, vehicle maintenance, management and training. The latest version of Truck Safe, released in August 2008, introduced new speed management standards, as well as a new voluntary module covering mass management. Operators must meet the standards set in these four areas for accreditation and be audited by an external auditor. This is then reviewed by an accreditation council. To date around six hundred transport companies have achieved safe accreditation. The program has been recognised by some as an excellent initiative that has helped operators improve their long-term viability. Others have not taken this view. For example, in 2000, MMI Insurance in their submission to the House of Representatives Standing Committee on Communication, Transport and Arts inquiry into managing fatigue stated that:

"Truck Safe operators are not better risks than any other group of operators; some are in fact the highest risk operators in the industry with the worst accident records to date."

MMI Insurance felt that the key problem was that the Truck Safe audit process did not audit many aspects of road transport law such as driving hours, driver schedules and vehicle compliance. If vehicle compliance could be included in Truck Safe, then it may also be able to include the provision of UP. More recently, the ATA stated that, according to independent statistics, Truck Safe operators are in fact twice as safe as non-accredited operators, resulting in National Transport Insurance offering special insurance benefits to Truck Safe operators.

In general, industry codes of practice are only effective if they are recognized and accepted by all concerned and if there are some rewards for complying and sanctions for non-compliance. Accordingly, industry and government needs to pay close attention to establishing suitable incentives for compliance so as not to diminish the effectiveness of a code of practice. At the time of writing, there are an estimated 47,000 businesses operating in the hire and reward part of the road freight industry, 98.5 per cent of which are in road freight operations and the remainder which are in the road freight forwarding sector. According to NTC estimates, there are 210,000 trucking establishments in existence of which 21 per cent belonged to the hire and reward sector and 79 per cent to the ancillary sector. It appears that Truck Safe coverage of the hire and reward segment of the road freight industry is below 10 per cent, and as such it may not be able to guarantee a high field application rate.

In an effort to reduce collisions between heavy commercial vehicles and motorists resulting from the heavy vehicle not being seen by a motorist, particularly in poor weather conditions or hours of darkness, the ATA introduced a code of practice for improving the visibility of heavy commercial vehicles. The Australian Heavy Vehicle Visibility Code of Practice is voluntary, sets guidelines for operators wishing to take advantage of the added safety of high visibility markings, and provides recommendations for the use of retro reflective graphics. It is based on UNECE Regulation 104 - Uniform Provisions Concerning the approval of Retro Reflective Markings for Heavy Vehicles and their Trailers. As a voluntary code of practice, it cannot guarantee a high field application rate and enforce negative sanctions for non-compliance.

As such, this option, like Option 2 above, would be unable to unable to guarantee the high field application rate of a design rule that regulatory arrangements can offer. Therefore, this option has not been considered any further.

Option 4: Australian Standard

Standards Australia International Ltd (SAI) is a publicly listed company that develops and publishes documents setting out technical specifications or other criteria necessary to ensure that a device will perform as expected. As SAI is a non-government organization, the standards it promulgates are voluntary unless they are specifically incorporated into regulatory frameworks by governments. These standards are usually well-founded and comprehensive and so incorporation is not uncommon. Australian Design Rule 62/02 - Mechanical Connections between Vehicles incorporates a number of Australian Standards that include: AS 2213, AS/NZS 4968.1, AS/NZS 4968.3, AS 4177 and several others. SAI is a member of the International Organization for Standardization (ISO), and contributes to the development of and promotes compliance with international standards developed by the ISO. There are currently about 122,000 Australian Standards in operation.

While there is scope for making use of a voluntary Australian Standard for provision of Underrun Protection (UP) for heavy commercial vehicles, no standard on UP is currently available. Developing Australian Standards with requirements specific for Australia would impose additional costs, especially for European sourced heavy commercial vehicles, as these are already compliant with UNECE R 93. The availability of UNECE regulations for UP makes this option redundant and so this it has not been considered any further.

Option 5: State and Local Government Fleet Purchasing Arrangements

State and local governments purchase a considerable number of commercial vehicles to provide services to their rate payers. As such, they are in a position to influence the configuration of heavy commercial vehicles entering their fleets. By encouraging the installation of Underrun Protection (UP) in their heavy commercial vehicles, governments would be introducing these in to the general fleet through resale, and setting a benchmark for others to follow. Currently, state and local governments purchase around 10 per cent of commercial vehicles and dedicated sub-contractors purchase another 10 per cent. Most of these are rigid vehicles. If government purchasing managers could influence the installation of UP, the uptake of front, rear and side UP could be more rapid than that which could be achieved through vehicle design rules, although what the final proportion in the fleet would be is not clear.

This Option has a good potential for partly achieving the objectives set out in the National Road Safety Strategy as state and local governments acquire over 20 per cent of heavy commercial vehicles registered annually. As state and local governments retire their vehicles once in three years, the net benefit could rise as relatively recent vehicles retired from government fleets replace older heavy commercial vehicles in the national fleet. However, there are very few prime movers purchased by governments so this benefit would only apply to rigid trucks.

The risk of losing, or not getting, government contracts could motivate assemblers and importers to provide UP on their rigid trucks. However, there would be little effect in the prime mover market.

Option 6: Business-as-usual

The current situation would remain unchanged and so there would not be any new regulations introduced nor any existing regulations removed. The only regulated Underrun Protection (UP) would be a rear bumper for semi-trailers as currently required by Clause 8 of Australian Design Rule (ADR) 42/04 General Safety Requirements.

Option 7: Australian Design Rule adopting Underrun Protection regulations from Europe, Japan and United States

Until recently, only the European Union and the UNECE had regulations for front Underrun Protection (UP). Japan, a signatory to the 1958 Agreement, applied UNECE R 93 in April of 2007. The United States do not have any specific requirements for front UP. Japan, United States and Canada mandate the provision of side and rear UP.

Adopting a range of standards from North America, Japan, UNECE, EU and Brazil for UP would only add to the complexity of applying and maintaining the different standards. This would raise the costs of administering regulation, as compared with a single international and globally accepted standard. Perhaps more importantly, when standards from various countries were revised, Australia would be unable to participate in the development process. As such, it could find itself in the position of having to choose between accepting unsuitable updated requirements and rejecting the entire standard. This would lead to a less than optimal suite of standards, create uncertainty for business and become an increased administrative burden. It is an indication of the inefficiency of such a system that many of the major vehicle producing countries, such as in the European Union but also Japan, have signed up or are considering signing up to the internationally based United Nations (UNECE) regulatory system. The globally integrated automotive industry members in Australia have in turn expressed their support for adopting UNECE regulations to address road safety issues.

Option 8: Australian Design Rule adopting international standards UNECE R 93, R73 and R58 for front, side and rear Underrun Protection respectively for rigid and articulated heavy commercial vehicles with a GVM greater than 4.5 tonnes

UNECE R 93, R73 and R58 front, side and rear Underrun Protection (UP) regulations, are the relevant regulations for application to front underrun crashes involving heavy commercial vehicles. The regulations are annexed as a part of the 1958 Agreement and their requirements are available for application as Australian Design Rules. This option meets the Australian government's objective of adopting international standards for the construction of motor vehicles and trailers. The regulations apply to commercial vehicles with a GVM greater than 3.5 tonnes.

Summary

The remaining options that were examined for impact analysis are Options, 1, 5, 6, 7, and 8. Options 2, 3, 4 were rejected as discussed above.

4. Impact Analysis

Background to the Heavy Commercial Vehicle Industry

The heavy commercial vehicle industry in Australia is made up of heavy commercial vehicle assemblers, importers, and sub-assembly suppliers. Industry revenue for 2003-04 was nearly $15 billion, while for trailers it is estimated at $2 billion. This equates to $18 billion and $2.5 billion in 2009 dollars.

Locally built heavy commercial vehicles account for around 18 per cent of the total number retailed in 2008 with the remainder mainly from Japan and Europe. The European Union is a key supplier of prime movers along with Australian made heavy commercial vehicles such as Kenworth, Mack, Iveco, and Volvo. The industry displays a high level of globalization. However, trailers from Japan, Europe and the USA are rarely supplied to the Australian market.

In Australia, there are five main operating classes of heavy commercial vehicles. These are:

- Rigid commercial vehicles
- Rigid commercial vehicles with trailers
- Semi-trailers
- B-Doubles
- Road trains

More detailed information regarding the industry and types of vehicles can be found at *APPENDIX 2: THE HEAVY COMMERCIAL VEHICLE ASSEMBLY AND WHOLESALING INDUSTRY IN AUSTRALIA.*

The Affected Parties

Parties directly affected by the proposed standard are:

(a) Rigid and articulated heavy commercial vehicle manufacturers and importers; trailer manufacturers;

(b) Sub-contractors designing and supplying components used in the manufacture of rigid heavy commercial vehicles, prime movers and trailers;

(c) Consultants providing vehicle certification and compliance services to heavy commercial vehicle manufacturers, trailer manufacturers and road freight operators;

(d) State and territory transport agencies performing a regulatory, review or oversight function; and

(e) Road freight operators;

A detailed table listing all affected parties is provided in Appendix 7. Several interest groups represent the affected parties and these include:

– Heavy commercial vehicle assemblers and importers are represented by the Truck Industry Council The sector comprises heavy vehicle assemblers, heavy vehicle importers and component manufacturers/importers;

– Suppliers of trailer components are represented by the Australian Road Transport Suppliers Association;

– Suppliers of vehicle certification, design and testing services are represented by the Commercial Vehicle Industry Association of Australia;

– Heavy commercial vehicle distributors are represented by the Motor Traders Association of Australia ;

– Motorist clubs (membership drawn from passenger car owners) are represented by the Australian Automobile Association;

– Heavy commercial vehicle owners/operators are represented by the Australian Trucking Association;

- Motorcycle owners are represented by the Australian Motorcycle Council;
- Bicycle owners are represented by the Bicycle Federation of Australia;
- Pedestrians are represented by the Pedestrian Council of Australia;
- Insurance providers are represented by the Australian Transport Insurers Association;
- Other interest groups operating largely in the after-market are represented by the Australian Automobile After-market Association.

Impact on Existing Regulations

The only current requirement in the Australian Design Rules for heavy commercial vehicles is for a rear Underrun Protection (UP) for semi-trailers in Clause 8 of Australian Design Rule 42/04 Rear Bumpers for Semi-trailers. The retention of this standard is discussed later in this RIS.

The introduction of any effective UP requirements would only serve to increase the effectiveness of the current crashworthiness regulations for other vehicles.

Economic Aspects of Underrun Protection: Benefit-Cost Analysis

A Benefit-Cost Analysis was performed to examine the case for 100 per cent fitment of front, side and rear UP to new vehicles above 4.5 tonnes Gross Vehicle Mass (GVM).

This represented Option 7: Australian Design Rule adopting Underrun Protection regulations from Europe, Japan and United States and Option 8: Australian Design Rule adopting international standard UNECE R 93, R73 and R58 for front, side and rear Underrun Protection respectively for rigid and articulated heavy commercial vehicles with a GVM greater than 4.5 tonnes.

This was then re-calculated to examine the case for 15 per cent per cent fitment of front, side and rear UP to new vehicles above 4.5 tonnes Gross Vehicle Mass (GVM). This represented Option 1: Self Regulation, Option 5: State and Local Government Fleet Purchasing Arrangements and Option 6: Business-as-usual. Refer to Table 12 for an explanation of the assumed fitment rate.

It is difficult to estimate many of the economic costs that Underrun Protection (UP) would impose on the construction, operation and maintenance of heavy commercial vehicles. A number of different factors have to be taken into account and their influence is complex to analyse.

In an earlier Communiqué from the Council of Australian Governments, it was suggested that estimation tools such as the costing model provided by the Commonwealth Office of Small Business could assist with estimating business costs for any proposed regulatory activity. The Australian Government has since mandated the IT-based Business Cost Calculator (BCC) as the standard tool to assess the business compliance cost of any regulatory proposal.

The extended initial consultation and public comment period for the issue of underrun protection (up until February 2007) has overlapped the introduction of the BCC. Therefore, the costing model categories of Education (training with the requirements of new standards), Purchase (purchase of test equipment and hire/purchase of test facilities), Record Keeping (test data recording and compiling), Procedural (test procedures) and Publications (purchase/obtaining of new standards) have not been individually assessed. However, this would not affect the outcome of the RIS, as the estimates were originally provided directly by a number of sources from industry and were accepted throughout the public comment stage.

The extended consultation period has also meant that the RIS monetary values vary as to when they were collected. All values have been normalised to 2009 dollars using a Consumer Price Index (CPI) of four per cent.

Costs for provision of Underrun Protection

<u>*Front Underrun Protection*</u>

General

The design of typical rigid front Underrun Protection (UP), including that designed to meet UNECE R93, is of traditional “brackets and beam” construction. Such a system is primarily connected to the chassis beams, but also to foot-steps and lamp brackets. Despite the range of available chassis heights, the front UP height should not deviate beyond certain limits. This in turn necessitates a flexible production system with a modular arrangement for the brackets. The product development phase would need a few person-years of work input, during which it would be necessary to test the front UP according to the legislative requirement.

Generally, manufacturers need between 20 and 50 tests to develop a conforming prototype. Additionally, in the product/assembly verification phase, further testing would be needed. An estimate is that this entire activity would cost no more than $4 million. This would be amortized over 100,000 to 250,000 heavy commercial vehicles until a front end redesign was undertaken for the updated model. Over and above development and engineering costs is the marginal production cost, which is more difficult to estimate. Material prices and manufacturing cost may range from $300 to $400 for each UP device. Aggregating development, material and production costs, the cost for rigid front UP, fitted to a new heavy commercial vehicle and complying with UNECE R 93, has been estimated at $440 per vehicle. When normalised to 2009 dollars, this becomes $514.74 (See *APPENDIX 6: RESULTS OF BENEFIT-COST ANALYSIS* Part 2. for details). Other estimates have previously put this cost at from a low of $100-150 (Haworth 2002) to a high of $1000-4000 (NTC 2005). Although the former appears to represent manufacturing costs only, and the latter covers the costs of retrofitting to all vehicles, it would be prudent to include a sensitivity analysis on front UP cost as part of any benefit-cost analysis.

Cost due to added mass

The materials used in typical rigid front UP include a steel front UP beam and steel brackets, all of which is covered with styled plastics. This is the standard look for today's heavy commercial vehicles. A number of metal alloys may be used, adapted to the strength requirements and production methods. The added mass of the front UP can be 50-80 kg, depending on factors such as the chassis height and construction details.

This mass may be located three quarters of a metre in front of the front axle(s) for a typical bonneted vehicle and between a metre and a metre and a half for a typical cab-over vehicle. The cantilever effect of this mass about the front axle(s) could then give a total effect of up to 110 kg added to the front axle(s) (with a corresponding 30 kg reduction from the rear axle(s)). This total effect is based on a worst case of a cab-over design with wheelbase of about 4 metres and front overhang of about one and a half metres[1]. For the purposes of estimation, an average estimate of 100 kg would be suitable to use as a compromise between the mass effect of a short wheelbase cab-over articulated as compared to a bonneted articulated truck or other longer wheelbase rigid trucks.

One potential issue with this additional load on the front axle(s) follows on from the state and territory 6 tonne steered axle limit. In Europe, steered axle limits vary with the most observed limit 7.1 tonnes. The added mass on a vehicle's front axle(s) from front UP, as well as increases in mass in meeting the latest engine emission standard (Euro 4), may become a problem for European heavy commercial vehicle makers supplying in to Australia.

The National Transport Commission (NTC) have estimated that raising the steered axle limit by 500 kg (to 6.5 tonnes) would more than offset such effects, while still allowing for improvements in cabin strength. Whether the limit would or should be raised is beyond the scope of this RIS. However, the potential loss in productivity and higher running and maintenance costs due to the additional mass of UP should be considered as part of any benefit-cost analysis. An indicative assessment of this has been made later in this RIS.

Future developments in other safety devices, such as UP with energy absorbing systems and deflection zones, would likely lead to further increases in the mass of existing UP, Consideration of this is again beyond the scope of this RIS. Any future proposal to fit advanced UP would be assessed on its merits at the time.

Cost due to added length

Unless part of the vehicle structure, energy absorbing UP typically increases the length of a vehicle. Rigid UP typically does not. The rigid UP covered by UNECE R93 allows for a *maximum* longitudinal distortion of 400mm. This distortion may occur without involving the remainder of the front of the vehicle and so rigid UP may be mounted almost flush with the front of the vehicle. Therefore, there is no need to estimate a cost relating to legally available lengths of heavy commercial vehicles. An exception to this may be where a vehicle structure has not been originally built to accept UP and it has to be added on to the front in a similar way as a bull bar. Vehicle or bull bar manufacturers were asked to comment on this by way of the feedback forms at the start of this RIS. No concerns were raised during the public consultation period.

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[1] This is calculated by balancing the moments about the rear axle(s) for an 80kg load ie 80kg x 5.5m/4m.

Side Underrun Protection

The costs for rigid side Underrun Protection (UP) for a range of rigid heavy commercial vehicles and articulated heavy commercial vehicles depend on the vehicle length and so are variable. These are presented in Table 7 (See *APPENDIX 6: RESULTS OF BENEFIT-COST ANALYSIS*, Part 3. for details). For rough purposes only, if the relative number of the different vehicle lengths in the fleet is taken in to account, an average cost of $847 would result (a more sophisticated calculation was used for the benefit-cost analysis). When adjusted to 2009 dollars, this becomes $1,158. The material used for construction of the systems is generally aluminium, although steel may also be used.

Table 7: Cost of rigid side UP for rigid heavy commercial vehicles and articulated heavy commercial vehicles

Vehicle Type	Cost (2005$) Side UP
3 axle semi-trailer	$872
5 axle semi-trailer	$872
6 axle semi-trailer	$872
7 axle B-Double	$1,147
8 axle B-Double	$1,147
9 axle B-Double	$1,147
Double Road Train	$1,675
Triple Road Train	$2,455
2 axle rigid commercial vehicle	$574
3 axle rigid commercial vehicle	$574
4 axle Twin-Steer rigid commercial vehicle	$574
2 axle rigid commercial vehicle with 2 axle dog trailer	$872
3 axle rigid commercial vehicle with 3 axle dog trailer	$872
Fleet average	$847
Adjusted to 2009$	$1158

Source: VBG (component supplier), Sweden and Scania, Sweden

Rear Underrun Protection

Systems for rear Underrun Protection (UP) are available in simple, foldable and removable types. The cost of the simple type has been estimated at $904 per vehicle (See *APPENDIX 6: RESULTS OF BENEFIT-COST ANALYSIS*, Part 4. for details). The cost for foldable and removable types is high and the foldable versions can be twice that of a simple system. Some alternative estimates for side and rear UP are shown in Table 8. The estimates include the variation in costs arising from the use of steel and aluminium and foldable and detachable types of rear UP. This table has been included to again demonstrate the importance of including a sensitivity analysis on protection system cost as part of any benefit-cost analysis. However, it was not subsequently used towards the calculations in the analysis.

Table 8: Cost for rigid type UP to UNECE regulations or EEC Directives (2005$)

Front UP* (incremental cost over normal bumper bar)	$440
Side UP** (for a 3 axle semi-trailer)	$1600
Rear UP** (Aluminium beam)	$310#
Rear UP** (Steel beam)	$450#
Rear UP** (Mounting assembly fixed type)	$470
Rear UP** (Mounting assembly detachable type)	$650
Rear UP** (Mounting assembly foldable type)	$2300

*Supplied by commercial vehicle maker,
**Supplied by specialist manufacturer, adjusted for c.i.f. prices and industry profitability

Costs and Benefits from installing UP under a variety of scenarios

Four scenarios were prepared for estimating the benefits from UP, which meet UNECE Regulations. Table 9 describes the various types of scenarios in terms of device effectiveness rates used for estimating benefits (See *APPENDIX 6: RESULTS OF BENEFIT-COST ANALYSIS*, Part 5. for details). As an example of how the table should be read, for front UP under Scenario A, 25 per cent of fatal injuries are converted to serious injuries and 35 per cent of serious injuries are converted to minor injuries. There are no benefits estimated for the conversion of minor injuries to no injuries and so the scenarios may be slightly conservative.

Benefit estimates include trauma and non-trauma related items such as reduced level of property damage, mobility of the heavy commercial vehicle after the underrun crash.

Table 9: UP device effectiveness rates for various scenarios

Scenario A - Low	**Front**	**Side**	**Rear**
Fatal injury	25%	20%	35%
Serious injury	35%	30%	45%
Scenario B - Most Likely	**Front**	**Side**	**Rear**
Fatal injury	30%	25%	39%
Serious injury	39%	36%	50%
Scenario C - High	**Front**	**Side**	**Rear**
Fatal injury	35%	30%	44%
Serious injury	44%	41%	55%
Scenario D – Energy Absorbing	**Front**	**Side**	**Rear**
Fatal injury	39%	35%	49%
Serious injury	49%	46%	60%

Source: Haworth (2002), Rechnitzer (1993), VC-COMPAT studies, Elvik.

Table 10 provides an estimate of the potential annual benefits available if UP were fitted to all heavy commercial vehicles in the fleet (See *APPENDIX 6: RESULTS OF BENEFIT-COST ANALYSIS*, Part 7. On page 93for details). The table suggests potential savings of up to $126 m [(36+62) + (8+11) + (4+5)] for energy absorbing systems (Scenario D).

Table 10: Expected annual benefits from provision of UP for various scenarios (if fitted to entire fleet)

	Front Rigid Systems (2009$ million)						Energy Absorbing Systems (2009$ million)	
	Low (A)		Most Likely (B)		High (C)		(D)	
	Rigid	Artic	Rigid	Artic	Rigid	Artic	Rigid	Artic
	25	42	29	48	32	55	36	62

	Side Rigid Systems (2009$ million)						Energy Absorbing Systems (2009$ million)	
	Low (A)		Most Likely (B)		High (C)		(D)	
	Rigid	Artic	Rigid	Artic	Rigid	Artic	Rigid	Artic
	5	7	6	8	7	9	8	11

	Rear Rigid Systems (2009$ million)						Energy Absorbing Systems (2009$ million)	
	Low (A)		Most Likely (B)		High (C)		(D)	
	Rigid	Artic	Rigid	Artic	Rigid	Artic	Rigid	Artic
	3	3	4	4	4	4	4	5

In balancing these benefits with the costs of fitting UP, the timing of both benefits and costs becomes important. Fitting of safety devices to vehicles usually requires an initial outlay that then leads to a benefit over a period in the future. Further, if the safety devices are fitted only to new vehicles, this initial outlay is staggered. This RIS is concerned with fitment to new vehicles only. Therefore, the initial outlay for installation would see the benefits occur after a period and they would increase as more of the fleet is fitted with the device. This is covered in more detail in *APPENDIX 5: METHODOLOGY OF BENEFIT-COST ANALYSIS*, which describes the methodology used for the benefit-cost analysis. *APPENDIX 6: RESULTS OF BENEFIT-COST ANALYSIS* lists outputs from the four scenarios assumed for estimating benefits from UP.

Results

The end of *APPENDIX 6: RESULTS OF BENEFIT-COST ANALYSIS* includes a summary of the outputs from the benefit-cost analysis. The summary lists Best Case, Likely Case and Worst Case scenarios for each device's effectiveness (the effectiveness is represented by Scenario A to D). It was constructed by using the longest payback period (vehicle life) and lowest discount rate of 4 per cent for the Best Case, with the shortest payback period and highest discount rate of 12 per cent for the Worst Case. The Likely Case used a 15 year payback period with a 7 per cent discount rate.

The summary was further reduced by grouping Scenarios A, B and C together and D separately (as D represents a different type of UP device – energy absorbing). Table 11 below shows the results of this.

Regarding rigid UP devices, Table 11 (a) demonstrates that there is a very strong case for the provision of front UP for articulated heavy commercial vehicles greater than 4.5 tonnes Gross Vehicle Mass (GVM), with Net Benefits of $10.1-35.1m per year (and a Benefit-Cost Ratio (BCR) well in excess of one for all cases). There is less of a case for front UP for rigid heavy commercial vehicles greater than 4.5 tonnes GVM, with Net Benefits of $0.4-15.1m per year (and a BCR in excess of one but to a lesser degree).

Also, Table 11 (a) demonstrates that there is no case for the provision of side or rear UP for rigid or articulated heavy commercial vehicles greater than 4.5 tonnes Gross Vehicle Mass (GVM). Net Benefits were at best $0.4m per year and at worst -$11.4m per year (and BCRs below one in all cases but one).

Regarding energy absorbing UP devices, Table 11 (b) demonstrates that there is no case for the provision of front, side or rear energy absorbing UP for rigid or articulated heavy commercial vehicles greater than 4.5 tonnes Gross Vehicle Mass (GVM). Net Benefits were at best -$0.6m per year and at worst -$282.1m per year (and BCRs below one in all cases).

Table 11 (a): Summary of Benefit-Cost Ratios (BCR) and Net Benefits per annum from the provision of UP on new heavy commercial vehicles – Scenarios A, B and C combined

	Front			**Side**			**Rear**		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
BCR - Rigid	3.1	1.9	1.1	0.5	0.3	0.1	0.2	0.1	0.1
Net Benefits (2009$m)	15.1	6.5	0.4	-5.4	-7.2	-8.6	-9.6	-10.6	-11.4
BCR - Articulated	15.1	9.3	5.1	1.1	0.6	0.3	0.7	0.4	0.2
Net Benefits (2009$m)	35.1	20.6	10.1	0.4	-2.1	-4.0	-1.4	-2.5	-3.3

Best case - discount rate 4% over 25 years, high effectiveness device.
Likely case - discount rate 7% over 15 years, Most Likely effectiveness device.
Worst case - discount rate 12% over 10 years, low effectiveness device.

Table 11 (b): Summary of Benefit-Cost Ratios (BCR) and Net Benefits per annum from the provision of UP on new heavy commercial vehicles – Scenario D (Energy Absorbing UP)

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
BCR - Rigid	0.15	0.09	0.05	0.03	0.02	0.01	0.01	0.01	0.00
Net Benefits (2009$m)	-136.4	-146.1	-153.0	-155.8	-157.9	-159.4	-280.1	-281.3	-282.1
BCR - Articulated	0.99	0.69	0.43	0.07	0.05	0.03	0.04	0.03	0.02
Net Benefits (2009$m)	-0.6	-13.4	-24.2	-95.4	-97.6	-99.5	-71.6	-72.6	-73.5

Best case - discount rate 4% over 25 years.
Likely case - discount rate 7% over 15 years, Most Likely effectiveness device.
Worst case - discount rate 12% over 10 years.

Discussion

The benefit-cost analysis found that there was a very strong case for the provision of rigid (ie not the energy absorbing type) front Underrun Protection (UP) for articulated heavy commercial vehicles greater than 4.5 tonnes Gross Vehicle Mass (GVM) (NB1, NB2 and all NC Australian Design Rule (ADR) category). This option produced positive Net Benefits in all cases. However, there was no case for the energy absorbing type of UP as this option produced negative Net Benefits in all cases.

It also found that there was only a marginal case for front UP for rigid vehicles greater than 4.5 tonnes GVM. This option produced positive Net Benefits in all cases but these were of low value in the Worst Case.

Finally, it found that there was no case for the provision of side or rear UP for any vehicle category. This option produced negative Net Benefits in nearly all cases.

The analysis was based on about 35 fatalities per year due to underrun with a heavy commercial vehicle (from a total of about 200 fatalities per year from all types of heavy commercial vehicle crashes). There were about 750 crashes per year involving underrun with heavy commercial vehicle causing some sort of injury or fatality. The number of serious and minor injuries were estimated to be similarly proportioned to the fatalities for front, rear and side underrun. Of the 750 crashes, around 550 were with the front of the heavy commercial vehicle, 130 with the side and 50 with the rear. Although there are varying estimates, the cost of front UP per vehicle was roughly 30 per cent less than that of rear UP and side UP was the highest at about 10 per cent greater than rear UP (although the cost of side UP dropped below rear UP for shorter vehicles).

These figures combined to give a front UP Benefit-Cost Ratio around ten times greater than rear UP and at least five times greater than side UP. Within this, UP for articulated vehicles was around six times that for rigid vehicles.

Assumptions

A number of assumptions have had to be made in the benefit-cost Analysis. To keep it relevant, a broad range of scenarios and sensitivities were included.

The potential benefits were based on the identified cost of a passenger car crash and a fatality. An inquiry that found that heavy vehicle crashes cost 50% more than passenger car crashes was used to extend the non-trauma part of the crash cost by 50%.

The effectiveness of the devices under the various scenarios was based on a number of studies in England and Germany. The Likely Case was based directly on the studies while the alternatives were estimated assuming a variation of +/- 5%. Refer *APPENDIX 5: METHODOLOGY OF BENEFIT-COST ANALYSIS*.

A range of discount rates and payback periods were used. The discount rate for the Most Likely case was 7%, in line with similar studies. However, a rate of 4% (representing a low risk government rate) to 12% (representing the auto finance rate) was used for the alternatives. Also, the expected life of a commercial vehicle was estimated at 15 years but included a range from 10 years to 25 years. Refer *APPENDIX 5: METHODOLOGY OF BENEFIT-COST ANALYSIS*.

There were no benefits estimated for the conversion of minor injuries to no injuries and so the scenarios may be slightly conservative. However, such conversions would be too difficult to estimate with any accuracy. It has been noted that other recent reports on underrun have not included such estimates.

Only the effectiveness of the side UP devices under the various scenarios included protection of vulnerable road users, as the information for other types of UP was not available. Although motorcyclists and bicyclists were not subsequently extracted from the road crash data for other types of UP (pedestrians were not reported), they represented a small proportion only of the total and so would have a limited affect on the results.

A fleet profile was used to adjust the contribution that each vehicle fitted with a safety device would provide towards the total benefit. This contribution was based on both the proportion of vehicles in the fleet of any particular age, and the tendency for vehicles of a particular age to be involved in road crashes. The assumption was made that the heavy commercial vehicle profile would not be different to the general fleet profile.

The number of new heavy commercial vehicles being registered each year was reduced by 20 per cent to exclude European sourced vehicles. No cost for fitting UP has been assumed for these vehicles. Since 2003, European built heavy commercial vehicles supplied to the Australian market have been fitted with front UP. A small number of heavy commercial vehicles imported from Europe are fitted with side UP. For the purposes of this Regulation Impact Statement, it has been assumed that all European heavy commercial vehicles are fitted with front UP as there is a mandatory requirement in the European Union for front UP. While some of these systems may have been removed prior to supply to the Australian market, it has been assumed that they would be retained if Australia introduced a similar regulation. Therefore, no cost for fitting UP has been assumed for these vehicles.

Sensitivity to cost estimates

The cost of underrun systems was highlighted earlier on as showing some variation, depending on the source of the estimation. Therefore, the Net Benefits and Benefit-Cost Ratios (BCRs) were tested for sensitivity to changes in these estimates. The sensitivity tables near the end of *APPENDIX 6: RESULTS OF BENEFIT-COST ANALYSIS* showed that in the case of front UP, a cost increase of up to 20 per cent for rigid or articulated vehicles could easily be tolerated without materially affecting the results. However, the Net Benefits became negative for rigid vehicles in the Worst Case.

Front UP on articulated vehicles was the only system remaining comfortably within a range of positive Net Benefits. Front UP on rigid vehicles was marginal to begin with and became more so with the cost variations. Both side and rear UP were even more marginal and would not be tolerant to changes in the estimates.

Sensitivity of extra load on the axle(s)

As discussed earlier in this RIS, the 6 tonne steered axle limit may limit the payload carried by a vehicle fitted with the added mass of a front UP.

The cost of this added mass is not simple to estimate, as it may also lead to more running and maintenance costs. On the other hand, it is unlikely that the front axle(s) of all heavy commercial vehicles, particularly rigid, would always be at this 6 tonne limit when laden. This being the case, the addition of another 100 kg or so may not be an issue for some vehicles. Only articulated vehicles tend to be loaded to the state and territory axle load limits, this being supported by the findings of the Truck Industry Council (Truck Industry Council 2004) who reported that "only a small proportion of rigid trucks are fully loaded to legal mass limits". Because of this, the analysis has been limited to articulated vehicles only. In addition, the estimation was used to further test the case for front UP only, as side and rear UP already had insufficient margin in their Net Benefits and Benefit-Cost Ratios to be viable options.

An estimation was made of this cost (refer to the sensitivity tables near the end of *APPENDIX 6: RESULTS OF BENEFIT-COST ANALYSIS*). The Truck Industry Council (Truck Industry Council 2004) estimated that a 3.0 to 3.8 per cent reduction in payload for a truck (through meeting a number of safety and emission initiatives) would equate to $200-250 m cost per year in productivity. This is a $67 m cost for a one per cent reduction, which in turn equates to a $17.4 m cost per year for the 100 kg UP device (based on 100 kg being the equivalent of 0.26 per cent payload on a typical 38 tonne payload truck/trailer combination). It is a figure that is independent of the location of the additional mass as it represents lost payload to a vehicle that is on the legal mass limit for all axles. The $17.4 m was adjusted to $21.2 m for 2009$, or $1.23 m based on annual registrations. In terms of annual Net Benefits, in the case of front UP, this loss of productivity of articulated vehicles could be tolerated without materially affecting the results.

An alternative possibility was then checked for articulated vehicles using the assumption that the 6 tonne limit would be raised by at least 100 kg. The cost to road wear when an axle is incrementally loaded has been estimated by the NTC for a steer axle loaded at 6 tonnes and above, in their report concerning a package to accelerate safety initiatives in heavy vehicles. The NTC advise (using figures from ARRB research) a cost of $0.0039 per kilometre, which is the value directly calculable from Table 4 for a 100 kg increase of a rigid axle truck (NTC 2006). This value is also comparable to linear interpolation (over a smaller range of masses) of both the typical B-double vehicle at $0.0038 per km (Table 2 of that report) and articulated vehicle $0.0038 per km (Table 3 of that report). The 0.0038 per km figure was adjusted to 0.0046 per km for 2009$. This loss equated to $1.28 m annually. Again, this increase in road wear of articulated vehicles could be tolerated without materially affecting the results.

There remains the option to transfer the cost of a reduction in payload (productivity loss) into an increase of road wear, through the increase of the axle load limits. This decision is one for the state and territory authorities. For the purposes of this RIS, both options have been costed, both give similar results and both still show positive Net Benefits and a Benefit-Cost Ratio greater than one. This means the case for underrun devices can be shown regardless of the axle load limits.

Summary

Given the results of the Benefit-Cost analysis above, there was a strong case for Underrun Protection (UP) for articulated vehicles but the case for rigid vehicles was marginal. There was no case for side or rear UP.

This led to a further refining of the remaining options. Option 5 was rejected (State and Local Government Fleet Purchasing Arrangements) as it relied mainly on influencing the sale of rigid vehicles fitted with UP, yet there was only a marginal case for rigid vehicles. This meant that while there may be some merit in the option, it could not be fully justified in its own right. Option 6 was rejected (Business-as-usual) as it was similar to Option 1 but included maintaining rear UP, which it was subsequently shown that there was no case for. Option 7 was rejected (Australian Design Rule adopting Underrun Protection regulations from Europe, Japan and United States), as it was mainly concerned with side and rear UP which it was subsequently shown that there was no case for.

This left the remaining options as Option 1 (Self-Regulation) and Option 8 (Australian Design Rule adopting international standard UNECE R 93, R73 and R58 for front, side and rear Underrun Protection respectively for rigid and articulated heavy commercial vehicles with a GVM greater than 4.5 tonnes). For the purposes of analysing the impacts of the options, Options 1 and 8 were limited to front UP only, as it was shown that there was no case for side and rear UP.

Impact of the options

The impact of the options on *Business*, *Road Users* and *Governments* was determined. *Business* includes the manufacturers of heavy commercial vehicles; *Road Users* include road transport operators, car, 4WD, motorcycle and bicycle users (and those in the wider community who may be affected by road trauma). *Government* includes state/territory/local governments as well as the Australian Government.

Option 1: Self-Regulation of front Underrun Protection

Likely Benefits

Governments

Australian

In removing the current mandatory requirement in ADR 42/04 for fitting a rear bumper for semi-trailers (rear Underrun Protection (UP)), there would be a small benefit in no longer having to administer it. This benefit has not been estimated.

State/Territory/Local

By encouraging the fitment of front UP devices through self-regulation, the costs of medical treatment and hospitalizations are likely to reduce following a decrease in underrun trauma. The estimated savings are approximately $3.1m per year, based on an assumed 15 per cent voluntary take up of UP.

Business

By encouraging the fitment of front UP through self-regulation, European manufacturers may find that they have a competitive advantage over manufacturers from other countries. This is because they would have had experience in designing and manufacturing UP. However, because Australia relies on overseas heavy commercial vehicle manufacturers for over 90 per cent of its transport equipment requirements, self-regulation may also introduce varying requirements across the fleet with some standards (including in-house) being less effective or untried. If this were to happen, all heavy commercial vehicle makers may find it difficult to sell product in to a confused or sceptical market. This benefit has not been estimated.

In case of trailers, local manufacturers are able to satisfy demand and so overseas manufacturers do not have any presence in the Australian market. In removing the requirements in ADR 42/04 for fitting a rear bumper for semi-trailers, there would be a small benefit to manufacturers in no longer having to design, manufacture and certify the bumpers. This benefit has not been estimated.

Road Users

Installation of front UP would on average reduce downtime and liabilities for heavy commercial vehicle operators (through less trauma from road crashes). There would also be reductions in road trauma that may lead to reductions in insurance premiums for all road users. This benefit has not been directly estimated but would form part of the benefit attributed to State/Territory and Local government.

Likely Costs

Governments

Australian/State/Territory/Local

In removing the requirements in ADR 42/04 for fitting a rear bumper for semi-trailers, there may be cost (in terms of a loss of a benefit) to road trauma reduction. This follows on from the argument earlier that this basic underrun device provides at least some benefits. However these benefits are not able to be estimated.

The Australian government may need to work with industry to identify appropriate voluntary specifications for underrun systems. This would assist in achieving the government's objective of reducing the cost of heavy vehicle underrun trauma. The government may also have to put systems in place to monitor the take-up of these voluntary specifications. The cost to do this has not been estimated.

Costs may accrue to states and territories as part of the effort towards monitoring the take-up of UP for heavy commercial vehicles as well as underrun trauma costs. These costs have not been estimated.

Business/ Road Users

In encouraging the fitment of front UP through self-regulation, manufacturers who are not European may find that they have a competitive disadvantage against manufacturers from Europe. These costs have not been estimated.

There would be additional costs to heavy commercial vehicle suppliers and manufacturers for designing, manufacturing and installing front UP. These costs may be passed on to the consumer. The estimated costs are approximately $0.4m per year, based on an assumed 15 per cent voluntary take up of UP. These may be passed on to road transport operators.

Distributional Effects

The benefits from Option 1 would be gained by the community in the reduction of road trauma and road transport operators in the reduction of downtime and liabilities. Industry and government may gain slightly on reduced certification costs and some parts of industry may gain some competitive advantage in being able to supply UP more efficiently that their competitors.

The costs from Option 1 would be incurred by business in the increase costs of supplying UP. These costs may be passed on the consumer. Industry and government may also incur some costs on facilitating and monitoring any voluntary arrangements.

Discussion and Conclusion for Option 1

Option 1 estimated that were industry is encouraged to install front UP through self-regulation, the Net Benefits would be about $3.1m per year with a Benefit-Cost Ratio greater than one.

However, this option would be unlikely to achieve fully the government's primary objective of reducing costs from road trauma, and particularly those of the National Road Safety and the National Heavy Vehicle Safety Strategies. Although the benefits and costs were calculated on an assumed take up rate of 15 percent, the option would be voluntary and so in fact there would be no guarantee that UP would be fitted to any heavy commercial vehicles.

This is partly due to an environment where profits are shrinking (profit margins are around 4 per cent), competition is increasing, growth of road freight is slowing and more commercial vehicles are running empty. Operators would be looking for savings to sustain their businesses and in the main would only install equipment that is essential for meeting regulatory requirements. In addition, provision of front UP may add some extra mass to the vehicle and this may impact on operator revenue. This impact may be limited but in a highly competitive industry it may have some negative effect. These are key factors that would determine the field effectiveness of self-regulation as a measure for providing UP.

The response of heavy commercial vehicle makers who are facing shrinking profits may be to discontinue the provision of UP. The supply of heavy commercial vehicles complying with a (say) code of practice would be a cost to road freight transport operators if their trade association or consignors insist on operating heavy commercial vehicles with UP. Although it is expected that on average there would be a reduction of downtime and liabilities for heavy commercial vehicle operators (through less trauma from road crashes) to offset this cost, this benefit would not be obvious to freight transport operators in the short term.

The case for withdrawing the bumper requirements in ADR 42/04 was not supported by public comment. The respondents were generally of the view, as outlined previously, that the presence of this basic underrun device provides at least some benefits. These are achieved at a very low cost and using an arrangement that industry is familiar and comfortable with. The rear bumper also serves a dual role in providing for fitting of signage, lamps and registration plates.

Therefore, the case should be left to be examined separately under the review of ADR 42/04. The following two related aspects arose during the consultation period and so should also be included in this examination:

Firstly, if the rear bumper requirement in Clause 8 of ADR 42/04 were to be retained, it should also accept UNECE Regulation No. 58 – Rear Underrun Protection as an alternative. This would allow manufacturers already building to this regulation for other markets to supply what is acknowledged as a superior arrangement.

Secondly, Clause 11.1.2 of ADR 42/04 requires any protrusion that is technically essential to the use of the vehicle to be minimised for the risk of bodily injury. During the consultation phase of this RIS, the states and territories raised the issue of rear underrun with tilt tray tow trucks. The tray on a tilt-tray tow truck contains a sharp rear horizontal edge that is likely to exacerbate the effects of any rear impact. The states and territories already have in place local requirements to minimise this effect. Therefore, it may be appropriate to absorb these into either ADR 42/04 or ADR 44/02.

Table 12 provides a summary of the benefits and costs of Option 1.

Table 12: Costs and Benefits : Option 1- Self –Regulation of front Underrun Protection (UP) for rigid and articulated heavy commercial vehicles with a GVM greater than 4.5 tonnes

	NET BENEFITS (2009$)		COSTS (2009$)	
	Description	**Estimate**	**Description**	**Estimate**
Business	Increased competitive advantage for some (15%) heavy commercial vehicle manufacturers meeting market demand for UP	unable to estimate	Decreased competitive advantage for some (85%) heavy commercial vehicle manufacturers not meeting market demand for UP	unable to estimate
	Reduced design, manufacturing and certification costs for trailer manufacturers not required to fit ADR compliant rear bumpers for semi-trailers (deletion of requirement in ADR 42/04)	unable to estimate		
Road Users	Reduced road trauma for all road users [3]	$3.1m	Increased design, material and manufacturing costs for some Australian, Japanese manufacturers for choosing to meet market demand for UP [2]. These may be passed on to road transport operators	$0.4m
	Reduced insurance premiums for all road users			
	Reduced downtime and liabilities for heavy commercial vehicle operators			
Governments	Reduced need for public resources such as emergency services etc	unable to estimate	Increased costs to assist industry with voluntary specifications for UP and monitoring application rates.	unable to estimate
	Reduced certification costs for not administering the approval and maintenance of ADR compliant rear bumpers for semi-trailers [4]			

[2] For Australia an application rate of 15 per cent is assumed (See Note 4). Cost was calculated by applying the 0.15 rate to the cost results at the end of Appendix 6 for front underrun systems only, combined rigid and articulated. Likely case - discount rate 7% over 15 years, Most Likely effectiveness device.

[3] Under-run trauma will reduce if a high field application rate can be achieved. Overseas studies in Norway and Sweden advise that field effectiveness for self-regulation can be between 25 to 35 per cent. This rate needs to be adjusted for Australia as Swedish and Norway businesses voluntarily offer a number of safety initiatives of motor vehicles. For Australia an application rate of 15 per cent is assumed, relating mainly to the presence of European manufacturers. Note that this does not take in to account any variation in the performance of the underrun systems themselves. The benefit was calculated by applying the 0.15 rate to the costs and benefit results in Appendix 6 for front underrun systems only, combined rigid and articulated. Likely case - discount rate 7% over 15 years, Most Likely effectiveness device. The 0.15 rate was applied through the Benefit-Cost model but it can equally be determined by inspection that the BCR ratios would remain the same as for mandatory fitment, with the Net Benefits reducing by 85 per cent.

[4] As the Australian certification system is based on a cost recovery model, any benefits from reduced certification costs should more correctly be allocated to business and may in turn be passed on to transport operators

Option 8: Australian Design Rule adopting international standard UNECE R 93 for front Underrun Protection for rigid and articulated heavy commercial vehicles with a GVM greater than 4.5 tonnes

Likely Benefits

Governments

Australian

None.

State/Territory/Local

By mandating the fitment of front Underrun Protection (UP) to new articulated heavy commercial vehicles with a GVM greater than 4.5 tonnes, the costs of medical treatment and hospitalizations would be likely to reduce following a decrease in underrun trauma. The estimated savings were approximately $20.6m per year.

Business

None.

Road Users

Installation of front UP would on average reduce downtime and liabilities for heavy commercial vehicle operators (through less trauma from road crashes). There would also be reductions in road trauma that may lead to reductions in insurance premiums for all road users. This benefit has not been directly estimated but would form part of the benefit attributed to State/Territory and Local government.

Likely Costs

Government

Australian

The Australian Government operates and maintains the road vehicle certification system, which is used to ensure that vehicles first supplied to the market comply with the Australian Design Rules. There are costs incurred in operating this service. A cost recovery model is used and so these costs are recovered from business. There would be costs attributed to the addition of a new design rule for UP to the current certification system. These costs have not been estimated.

State/Territory/Local

Costs may accrue to states and territories as part of the effort towards monitoring the continued compliance of front UP for heavy commercial vehicles to in-service requirements. These costs have not been estimated.

Business

Large enterprises

There would be adjustment costs to heavy commercial vehicle suppliers for installing front UP devices. While European heavy commercial vehicle makers may enjoy some commercial advantage, non-European heavy commercial vehicle makers, including three domestic firms, would need time to design, test and manufacture front UP. The cost of heavy commercial vehicles manufactured by non-European and domestic firms would need to include a premium to cover the cost of product development and testing to the mandatory standard. These costs have been estimated at $2.5m per year. These may be passed on to road transport operators.

Small and medium enterprises

The segment of the industry that manufactures bull bars for new (and possibly in-service) heavy commercial vehicles would need to modify their designs and carry out testing to the new vehicle requirements for front UP. UNECE R93, the proposed regulation, allows for the design and testing of devices as distinct components of heavy commercial vehicles. Potential changes to bull bar manufacturing would likely be an important issue to those involved. These costs have not been estimated. This segment of the industry in particular was invited during the consultation period to provide any costs. However, no concerns were subsequently raised.

Road Users

Industry may pass on the costs of front UP devices to road transport operators. However, this would not be a certainty given the low relative percentage of a typical vehicle cost (around 0.5 per cent) and the intensity of competition.

Distributional effects

The benefits from Option 8 would be gained by the community in the reduction of road trauma and road transport operators in the reduction of downtime and liabilities.

The costs from Option 8 would be incurred by business in the increase costs of supplying front UP. These costs may be passed on the consumer. Government would also incur some costs on administering the regulations, although these would be recovered from business because of the cost recovery model being used.

Discussion and Conclusion on Option 8:

Option 8 estimates that if industry is required to fit front UP to new heavy commercial vehicles with a GVM greater than 4.5 tonnes, the Net Benefits would be about $20.6m per year with a Benefit-Cost Ratio greater than one. This is about $17m greater than Option 1.

This option would enable the Australian government to implement a key element of the National Heavy Vehicle Safety Action Plan 2005-2007 and the National Heavy Vehicle Safety Strategy 2003-2010.

Adopting UNECE requirements for front UP would facilitate market access to efficient and competitive suppliers of front UP. The option would allow transport operators to have a choice of suppliers and access to superior state-of-the-art transport safety technology. The community would be able to reduce the cost of underrun trauma efficiently while the Australian government would be able to provide administrative arrangements for compliance assurance and also participate in a global forum for any future development of UP standards.

Table 13 provides a summary of the benefits and costs of Option 8.

Summary of Impact Analysis

The impacts of Options 1 and 8 on affected parties have been discussed above.

The impact analysis indicated that Option 8 would be the most efficient and effective option, that is to mandate the provision of front UP for articulated trucks with a GVM greater than 4.5 tonnes by applying an international standard.

The majority of costs are borne by the vehicle manufacturers, which may then be passed on to the operator and the consumer. The majority of benefits would be received by the community in terms of reduced road trauma.

Option 1 benefits would not reach their full potential, due to the high element of uncertainty in generating sufficient field effectiveness. This arises out of the fragmented nature of the road freight industry. Option 8 would allow the benefits to reach their maximum potential (for new vehicles) and so meet the Australian and state governments' objectives to reduce underrun trauma. Therefore, Option 8 was the recommended option.

Table 13: Benefits and Costs: Option 8- Australian Design Rule adopting international standard UNECE R 93 for front Underrun Protection (UP) for rigid and articulated heavy commercial vehicles with a GVM greater than 4.5 tonnes

	NET BENEFITS (2009$)		COSTS (2009$)	
	Description	**Estimate**	**Description**	**Estimate**
Business	None		Increased design, material and manufacturing costs for (80%) Australian, Japanese manufacturers previously not building heavy commercial vehicles meeting front UP regulations [5]. These may be passed on to road transport operators	$2.5m
Road Users	Reduced road trauma for all road users [6] Reduced insurance premiums for all road users Reduced downtime and liabilities for heavy commercial vehicle operators	$20.6m	Increased design, material and manufacturing costs for those involved in bull-bar manufacture These may be passed on to road transport operators	unable to estimate
Governments	Reduced need for public resources such as emergency services etc		Increased costs to administer mandatory [7] regulations for front UP	unable to estimate

[5] Cost was calculated from the Scenario B cost results in Appendix 6 for front articulated underrun systems only. Likely case - discount rate 7% over 15 years, Most Likely effectiveness device.

[6] Benefit was calculated from the Scenario B benefit results in Appendix 6 for front articulated underrun systems only. Likely case - discount rate 7% over 15 years, Most Likely effectiveness device.

[7] As the Australian certification system is based on a cost recovery model, any benefits from reduced certification costs should more correctly be allocated to business and may in turn be passed on to transport operators.

5. Consultation

The Department has consulted with the Technical Liaison Group (this is the main consultative committee for development of the Australian Design Rules (ADRs) and members include representatives of peak industry associations, state and territory governments and motoring clubs: refer to Appendix 8: Technical Liaison Group), prior to seeking public comment. The Department undertakes public consultation on behalf of the Minister for Transport and Regional Services. Under Part 2, section 8 of the Motor Vehicle Standards Act 1989 the Minister may consult with state and territory agencies responsible for road safety, organizations and persons involved in the road vehicle industry and organizations representing road vehicle users before determining a design rule.

Public consultation

The issue of an exposure Draft for public consultation is an integral part of the Department's due process for developing new vehicle design rules as it initiates the most extensive and interactive phase of making national standards. Publication of the proposal provides an opportunity for business and road user communities, as well as all other interested parties to respond to the proposal by writing or otherwise submitting their comments to the Department. Providing proposals with a RIS assists all stakeholders to identify more precisely the impacts of the proposals and enables more informed debate on the issues.

The proposal was issued for public comment in March 2007 for a two month period. All responses were collated and considered and revisions to the proposal were made. A discussion of the points raised by respondents and the Department's response to those points has been included in Appendix 9: Public Comment, along with the Department's analysis. The analysis includes reference to any revisions made to the proposal.

A critical revision was to update the crash data that had been made available since the original draft of the RIS had been written. The revision changed the outcome of the economic analysis. It did this by narrowing the scope of application of the proposal from front Underrun Protection (UP) for both rigid and articulated vehicles with greater than 7.5 tonne GVM (the original RIS was written for higher mass vehicles), to front UP for articulated vehicles only, and only those greater than 4.5 tonne GVM. The RIS was not sent for a further public comment period as neither the method of analysis nor the source of the crash statistics changed – other than being updated. Any earlier public comment relating to the method of analysis or choice of crash statistics was addressed in Appendix 9.

A draft Australian Design Rule (ADR) and complementary Administrator's Circular were developed following the public consultation.

In December 2007, the Technical Liaison Group (TLG) met and considered the contents of the revised RIS. The group generally agreed with the proposal and moved to form a Single Issue Working Group (SIWG) to continue work on the technical requirements of the draft ADR and Administrator's Circular. It was also noted that a final implementation date and any changes to state and territory axle load limits were still to be discussed and agreed to at TLG level.

In April 2008 the SIWG was formed and worked through the details of the ADR and Circular. It was subsequently agreed at TLG that the implementation date for the ADR would be 1 January 2011 for new model vehicles and 1 January 2012 for all vehicles; and that the states and territories would review the question of axle load limits as a separate issue.

As it was not critical that an Administrator's Circular be issued before the ADR was in place, it was also agreed to finalise the existing draft circular at a later time and in response to any implementation issues that arise.

Scope of the proposed ADR

At the time of the initial public consultation, the RIS recommended that the scope of the proposed ADR cover front UP for articulated vehicles greater than 7.5 tonne GVM. However, the RIS was subsequently updated to use crash data for vehicles greater than 4.5 tonnes. The term "articulated vehicle" refers to a "prime mover" that can be coupled to a semitrailer.

During subsequent deliberations at the SIWG and TLG level, both the states and territories and the industry raised concerns about its application only to articulated vehicles, even though "prime mover" is a defined term under the regulations of the *Motor Vehicle Standards Act 1989*.

From the perspective of the vehicle manufacturers, the problem was one of identifying which vehicles were destined to become prime movers (articulated) at the time of production and type approval certification to the ADRs. From the perspective of the state and territories, a similar problem would arise at the point of registration, as some vehicles are registered as "cab-chassis" vehicles that while complete enough for registration, may still be converted to either a bodied vehicle or a prime mover immediately afterwards. The states and territories were also concerned about conversions of in-service vehicles, which could occur a number of times in a vehicle's life. This lead to the same difficulty of identifying the point when a vehicle becomes a prime mover. It also causes a further problem of how to monitor and control the reasonably rigorous test requirements for UP in an in-service environment.

Industry's proposal was for the Australian Government to mandate front UP for all rigid and articulated NC category vehicles (a GVM of greater than 12 tonnes), which would be an across the board application but only to the heavier end of the truck market. This solution was unanimously supported by all parties at TLG as making the regulations practical to implement.

In terms of road safety there would be a benefit as well. While the case for mandating front UP to rigid vehicles could not be fully justified in its own right (as some scenarios within the analysis had become marginal), there were benefits potentially available. With regard to only applying the ADR to vehicles above 12 tonnes GVM, the reality is that there are extremely few articulated vehicles below this mass, and all crash activity for articulated vehicles was at these higher masses. Refer to the crash contribution table on page 88 which note that "Note: All articulated trucks involved in fatal under-run crashes weighed in excess of 20t GVM.

The breakpoints in the heavy vehicle categories are NB1 from 3.5t, NB2 from 4.5t and NC from 12t (Refer *APPENDIX 1: VEHICLE CATEGORIES IN THE AUSTRALIAN DESIGN RULES*). The NC category is the heaviest definable category and the overwhelming majority of prime movers sit within it. By mandating the NC category for both rigid and articulated, the bulk of the crash activity in the prime mover area will be addressed while the heavier rigid area will also be addressed. The regulation would also be practical to implement. The conclusion was therefore that this arrangement would not only be a good outcome administratively, but in terms of road safety as well.

In terms of Net Benefits and Benefit-Cost Ratios, the combination of articulated vehicles and rigid vehicles above 12 tonnes GVM was calculated. Firstly, the loss of any possible contribution from vehicles less than 12 tonnes GVM was calculated using the crash contribution table on page 88.

For articulated vehicles there was no loss, as all were above 12 tonnes GVM. For rigid vehicles, those above 12 tonnes GVM represented 63 per cent of all the known fatal crashes of vehicles above 4.5 tonnes (2.3+1.6+1.8) / (3.4+2.3+1.6+1.8). Therefore, the benefits for rigid vehicles above 12 tonnes GVM were reduced to this amount. Using the benefits and costs reported in Scenario B analysis on page 98:

$\text{Net Benefits}_{\text{combined rigid \& artic}}$ = Gross Benefits – Costs

Gross Benefits = $\{(6.5+7.0)_{\text{rigid}} \times 63\%\} + (20.5+2.4)_{\text{artic}} = \$31.4\text{m}$

Costs = $\{7.0_{\text{rigid}} \times 63\%\} + (2.4)_{\text{artic}} = \$6.8\text{m}$

$\text{Net Benefits}_{\text{combined rigid \& artic}} = 31.4 – 6.8 = \$24.6\text{m}$ per year

and;

$\text{BCR}_{\text{combined rigid \& artic}}$ = Gross Benefits / Costs

$$\text{BCR}_{\text{combined rigid \& artic}} = \frac{31.4}{6.8} = 4.6$$

This approach would still result in positive Net Benefits and a Benefit-Cost Ratio greater than one and in at $24.6m per year this would result in higher Net Benefits than the recommended option (Option 8) in the Impact Analysis ($20.6m per year) for the Most Likely case. This is due to the addition of 63 per cent of the $6.5m Net Benefits potentially available to rigid vehicles, due to front UP (refer Table 11(a)).

The reason that the inclusion of rigid vehicles in the regulation option was not justified in its own right was because for the Worst Case scenario, the Net Benefits were slightly negative. In this case, the overall Net Benefits could reduce by $0.4m per year (refer Table 11(a)).

This potential reduction is entirely due to the costs, as the gross benefits in reduced road trauma would always be greater by including rigid vehicles. This cost (if it eventuates) would be borne by the manufacturers. This is acceptable as they are supportive of the initiative because it will save them administrative effort and time.

Therefore, it is a recommended that the above modification of Option 8 be adopted, that being to regulate for the fitment of front UP on all NC category vehicles.

A final initiative that was agreed at TLG was to optionally allow manufacturers of new vehicles with a GVM greater than 3.5 tonnes to certify to the ADR. There are a number of state and territory based schemes that are or may require the fitment of front UP in order to receive other benefits. This would allow participants to use the Australian Government's certification arrangements when taking advantage of such schemes with new vehicles. This would not affect the analysis in this RIS as it would be an optional feature of the ADR.

6. Conclusion and Recommended Option

The provision of Underrun Protection (UP) by self-regulation, as outlined in Option 1, could be a low cost option and yet unlikely to generate the high application rate required for new vehicles if underrun trauma is to reduce significantly. The difficulty in achieving a high penetration rate with self-regulation is three-fold. Firstly, there is a high level of competition in the industry. The low profit margins means that operators are forced to cut costs continuously to service debt and other operating costs that keep rising (eg fuel). Secondly, the market power of consignors is considerable, and this also forces operators to operate at these very low margins. These factors have led to financial distress for some operators, with constant consolidation of the industry. This stress may play a part in reports of repeated violations of regulatory arrangements by a very small section of the industry. Thirdly, while the costs of the option would be borne in the main by the vehicle manufacturer, and subsequently passed on the operator and consumer, a significant portion of the benefits would be received by the wider community instead.

Given the environment in which the road transport freight industry operates, heavy commercial vehicle and trailer suppliers are likely to succumb to commercial pressures in a self-regulated environment.

In addition, although there was a case for withdrawing the bumper requirement in ADR 42/04, without mandating replacement rear UP, this was not supported during the public comment period. Therefore, while it will be recommended not to mandate a new rear underrun requirement, the case of withdrawing the existing rear bumper requirement in Clause 8 of ADR 42/04 will be left to be examined separately under the review of ADR 42/04. This should also include the issue of accepting UNECE Regulation No. 58 – Rear Underrun Protection as an alternative standard and possibly the absorption of state and territory requirements for rear underrun protection of tilt-tray tow trucks in to ADR 42/04 or ADR 44/02.

The use of an such as the National Heavy Vehicle Accreditation Scheme (NHVAS) or similar, as outlined in Option 2, involved the use of an accreditation scheme to promote the installation of front UP. As the patronage of the NHVAS is very low among heavy vehicle operators, it is likely to lack the ability to have the high application rate that would be required to reduce underrun trauma significantly.

The use of an industry code of practice, as outlined in Option 3, would also be unable to provide the high application rate required for reduction in underrun trauma owing to the reasons outlined for Options 1 and 2.

The use of an Australian Standard, as outlined in Option 4, again faces the same problems as Option 3 in providing the application rate for reducing underrun trauma. In addition, the need to develop a uniquely Australian performance standard does not exist, as there is an international standard available. This standard could be applied to Australian conditions, although there may have to be some adjustments to account for bull bar fitment and the greater use of bonneted vehicles as compared to vehicles in European countries.

The use of State and local government fleet purchasing arrangements, as outlined in Option 5, would suffer in the same way as the other non-regulatory options. However, it may be able to achieve an application rate into the fleet of 10 to 15 per cent, which over a period is likely to ramp up to a higher level. Unfortunately, there would be little effect on articulated heavy commercial vehicle numbers as few of these are purchased by government.

The business-as-usual approach, as outlined in Option 6, is not achieving the government objectives as the voluntary fitment of UP is minimal.

Adopting a range of standards from North America, Japan, UNECE, EU and Brazil for UP, as outlined in Option 7, would only add to the complexity of applying and maintaining the different standards and Australia would be unable to participate in the development process. As such, it could find itself in the position of having to choose between accepting unsuitable updated requirements and rejecting the entire standard. In any event, the national standards that were available were for side and rear UP, which was not found to be viable under the economic analysis.

Implementing an ADR based on international standard UNECE Regulation 93 for Underrun Protection, as outlined in Option 8, and modified as discussed on page 54, would be the most cost effective regulatory option available. This was the provision of front UP for all new rigid and articulated trucks of NC category (a GVM greater than 12 tonnes). The Net Benefits were $24.6m per year and the Benefit-Cost Ratio was greater than one. This would be $21.5m ($24.6m -$3.1m) per year greater than Option 1. Industry and regulators alike requested the modification to Option 8, to allow for practical application of the requirements. The modification would reduce road trauma and although it may add a minimal cost burden to industry, would be more than offset by the more efficient implementation.

Adopting UNECE requirements for front UP would facilitate market access to efficient and competitive suppliers of the systems. The option would allow transport operators to have a choice of suppliers and access to superior state-of-the-art transport safety technology. The community would be able to reduce the cost of underrun trauma efficiently, while the Australian Government would be able to provide administrative arrangements for compliance at less cost than Option 5 and also participate in a global forum for any future development of UP standards.

The above recommended option would also meet the requirements of the COAG Principles for national standards-setting, the WTO's Agreement on Technical Barriers to Trade, and it would enable the Australian Government to implement a key element of the National Heavy Vehicle Safety Strategy 2003-2010.

In the analysis it was noted that the states and territories could, as part of the implementation of an ADR for front UP, raise the state and territory 6 tonne steered axle limit by at least 100 kg. It is important to note that this is not a judgement of what the new axle limits should be, only that the analysis shows the incremental additional allowance was a viable option.

When productivity loss - or road wear, as determined on pages 41 and 107 is taken into account with front UP for articulated vehicles, the Net Benefits and Benefit-Cost Ratios remain positive and greater than one respectively. This means that mandating of front UP is independent of whether steered axle limits are increased by the states and territories. Increasing the limits (in this case an average value of 100 kg was calculated for) remains the prerogative of the state and territories.

In conclusion, Option 8, modified to apply to all rigid and articulated trucks greater than 12 tonnes GVM (NC category), is the recommended option. The benefits of front UP for all new rigid and articulated trucks of NC category would outweigh the costs, using a discount rate of between 4 and 12 per cent over a 10 to 25 year period. It would reduce the cost of underrun trauma by just under 10 per cent based on an annual cost of underrun trauma of $295m (refer Table 4 and costs of $227m and $68m). Annually it would cost transport operators $6.8m to fit front UP at a marginal cost of $515 per vehicle. It would satisfy the objectives stated in Section 2 and, if looked at purely from a lives saved perspective, would save the equivalent of around 10 lives per year (based on a cost of a fatality of $2.6m as calculated in *APPENDIX 6: RESULTS OF BENEFIT-COST ANALYSIS* on page 90).

Recommended Option

The recommended option is Option 8 (modified): An Australian Design Rule (ADR) adopting international standard UNECE R 93 for front Underrun Protection to apply to all rigid and articulated trucks of NC category (greater than 12 tonnes GVM). This would apply to all new vehicles.

It is not recommended that side UP be mandated.

It is not recommended that rear UP be mandated.

It is recommended that the case of withdrawing the existing rear bumper requirement in Clause 8 of ADR 42/04 be examined separately under the review of ADR 42/04, and should include:

- the issue of accepting UNECE Regulation No. 58 – Rear Underrun Protection as an alternative standard; and
- the issue of absorbing state and territory requirements for rear underrun protection of tilt-tray tow trucks in to ADR 42/04 or ADR 44/02.

It is recommended to the state and territory authorities examine whether the steer axle limit should be raised by at least 100 kg for new vehicles certified as having front underrun protection. However, the outcome is not critical to this analysis.

7. Implementation and Review

The development, implementation and review of Australian Design Rules (ADRs) is an established process. The public comment exposure indicated broad agreement to the recommendations, and an ADR has now been fully developed that is suitable for determination under the authority of the Minister for Infrastructure, Transport, Regional Development and Local Government under section 7 of the *Motor Vehicle Standards Act 1989*. The details of the ADR have been reviewed and revised through the Technical Liasion Group. This has ensured that it is workable and practical and that any incorporated standards reference the latest versions.

After determination, any further changes to the ADR would be considered as part of the normal program of ADR review and revision. This program includes monitoring overseas developments and regular consultation with the Department's key stakeholders to identify implementation issues or changes in factors affecting existing ADRs.

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Abbreviations

ADR	Australian Design Rule
ACA	Australian Communications Authority
ACCC	Australian Consumer and Competition Commission
AGCC	Arab Gulf Cooperation Council
ANCAP	Australian New Car Assessment Program
ARSTA	Australian Road Transport Suppliers Association
ATA	Australian Commercial vehicle Association
ATSB	Australian Transport Safety Bureau
AVSR	Australian Vehicle Standards Regulations
COAG	Council of Australian Governments
Cth	Commonwealth
DOTARS	Department of Transport and Regional Services
ECE	Economic Commission for Europe
EEC	European Economic Community (also EC or EU)
EEVC	European Enhanced Vehicle-safety Committee
EU	European Union (also EC or EEC)
FAPM	Federation of Automotive Product Manufacturers
FCAI	Federal Chamber of Automotive Industries
FMVSS	Federal Motor Vehicle Safety Standards
FORS	Federal Office of Road Safety
GVM	Gross Vehicle Mass
IRTAD	International Road Traffic and Accident Database
MTAA	Motor Traders Association of Australia
MUARC	Monash University Accident Research Centre
MVSA	Motor Vehicle Standards Act
NA category vehicle	Goods vehicle with GVM not exceeding 3.5 tonnes
NB category vehicle	Goods vehicle with GVM exceeding 3.5 tonnes
NC category vehicle	but not exceeding 12 tonnes
NTC	National Transport Commission
OECD	Organisation for Economic Cooperation and Development
RTA	Roads and Traffic Authority
TIC	Commercial vehicle Industry Council
TPA	Trade Practices Act
TC category trailer	A trailer with GTM exceeding 3.5 tonnes but not exceeding 10 tonnes
TD category trailer	A trailer with GTM exceeding 10 tonnes
UNECE	United Nations Economic Commission for Europe
VicRoads	Organisation providing roads and road safety administration in Victoria

Glossary

Administrative cost	Cost incurred by DOTARS for administering an ADR
Aggressively	Aggresivity as a safety performance concept is the risk of injury that a vehicle poses to other road users with which it impacts, including other vehicle occupants and vulnerable road users such as motorcylists, bicyclists and pedestrians.
Articulated vehicle	A combination of a prime mover and semi-trailer
B-Double	A combination of vehicles consisting of a prime mover towing 2 semi-trailers
Combination vehicle	Either a combination of a rigid goods vehicle and one trailer (other than a semi-trailer); or an articulated vehicle
Heavy commercial Vehicle	Vehicles exceeding a GVM of 3.5 tonnes
Compliance cost	Cost incurred by vehicle manufacturers in preparing vehicles to comply with an ADR.
Crashworthiness	Crashworthiness as a safety performance concept is the relative safety of a vehicle in protecting its occupants in the event of a crash. It is a measure of the risk of death or serious injury to a driver or vehicle occupant when the vehicle is involved in a crash.
Δ (Delta) V	The closing velocity between two objects that collide.
Gross Profit Margin	The gross profit margin is defined as: 100 * *income Operating tax before profits Operating.* The average profit margin is slightly over-estimated because the operating profit before tax for non-employing businesses includes the returns to labour of working proprietors. The average gross profit margin for all industries in 1999/2000 was 7.0 per cent (ABS 2001c).
GCM	The mass specified for a vehicle by the manufacturer as being the maximum of the sum of the gross vehicle mass of the drawing vehicle plus the sum of the axle loads of any vehicle capable of being drawn as a trailer
GVM	The maximum laden mass of a vehicle as specified by the manufacturer of the completed vehicle
Laden mass	The mass of a vehicle and its load borne on the surface on which it is standing or-running.
Mercosur	The Southern Common Market created in 1991 by Argentina, Brazil, Paraguay and Uruguay.
Prime mover	A motor vehicle with no significant load carrying area and which is built to tow a semi-trailer
Rigid vehicle	A motor vehicle that has a significant load carrying area. It may also be equipped with a tow bar or other coupling on the rear of the vehicle
Road train	A combination of vehicles other than a B-Double consisting of a motor vehicle towing at least 2 trail
Semi-trailer	A trailer that has one axle group or single axle towards the rear and a means of attachment to a Prime mover that would result in some of the load being imposed on the prime mover
Total combination mass	The combined mass of the laden or unladen trailer and the towing vehicle
Underrun collision	An underrun collision occurs when a passenger car or motorcycle slides underneath the front, side, o rear end of a heavy commercial vehicle.
Vehicle compatibility	Vehicle mass, stiffness and geometry affect compatibility. Incompatibility is greatest between a passenger car and articulated heavy commercial vehicle

APPENDIX 1: VEHICLE CATEGORIES IN THE AUSTRALIAN DESIGN RULES

DETAILS OF HEAVY VEHICLE CATEGORIES

GOODS VEHICLES
A motor vehicle constructed primarily for the carriage of goods and having at least 4 wheels or 3 wheels and a '*Gross Vehicle Mass*' exceeding 1.0 tonne.

A vehicle constructed for both the carriage of persons and the carriage of goods shall be considered to be primarily for the carriage of goods if the number of seating positions times 68 kg is less than 50 percent of the difference between the '*Gross Vehicle Mass*' and the '*Unladen Mass*'. The equipment and installations carried on certain special-purpose vehicles not designed for the carriage of passengers (crane vehicles, workshop vehicles, publicity vehicles, etc.) are regarded as being equivalent to goods for the purposes of this definition. A goods vehicle comprising 2 or more non-separable but articulated units shall be considered as a single vehicle.

LIGHT GOODS VEHICLE (NA)
A goods vehicle with a '*Gross Vehicle Mass*' not exceeding 3.5 tonnes.

MEDIUM GOODS VEHICLE (NB)
A goods vehicle with a '*Gross Vehicle Mass*'; exceeding 3.5 tonnes but not exceeding 12.0 tonnes.

NB1 over 3.5 tonnes, up to 4.5 tonnes '*Gross Vehicle Mass*'
NB2 over 4.5 tonnes, up to 12 tonnes '*Gross Vehicle Mass*'

HEAVY GOODS VEHICLE (NC)
A goods vehicle with a '*Gross Vehicle Mass*' exceeding 12.0 tonnes.

TRAILERS
A vehicle without motive power constructed to be drawn behind a motor vehicle.

VERY LIGHT TRAILER (TA)
A single-axle trailer with a '*Gross Trailer Mass*' not exceeding 0.75 tonne.

LIGHT TRAILER (TB)
A trailer with a '*Gross Trailer Mass*' not exceeding 3.5 tonnes, other than a trailer of Category TA.

MEDIUM TRAILER (TC)
A trailer with a '*Gross Trailer Mass*' exceeding 3.5 tonnes but not exceeding 10 tonnes.

HEAVY TRAILER (TD)
A trailer with a '*Gross Trailer Mass*' exceeding 10 tonnes.

APPENDIX 2: THE HEAVY COMMERCIAL VEHICLE ASSEMBLY AND WHOLESALING INDUSTRY IN AUSTRALIA

Background

The heavy commercial vehicle assembly and wholesaling segment of the motor vehicle manufacturing industry in Australia comprises of three sub segments: the first being heavy commercial vehicle assemblers, the second category comprising of importers, the third category comprises of suppliers of engines, transmissions, braking systems, trailers and suspension assemblies that are used in the assembly of a heavy commercial vehicle. Industry revenue for 2003-04 was $14.94 billion. The size of the trailer market for freight trailers is estimated at $2 billion annually with numerous small businesses operating in the market. These revenues equate to $18 billion and $2.5 billion in 2009 dollars.

Annual Sales Volume

The heavy commercial vehicle market in terms of annual sales is very small compared to other OECD countries and many developing economies. Sales for 2002 and 2003 are shown in Table 14.

Table 14 : Annual sales for heavy commercial vehicles exceeding 7 tonnes GVM

Heavy commercial vehicle type	2001	2002	2003	2004
Rigid commercial vehicle,	8721	10,010	12,507	N/A
Prime mover	1620	2041	2556	
Trailer	N/A	N/A	N/A	N/A

Source: VFACTS

A number of vehicles are supplied from the plants of European, North American and Japanese manufacturers. Table 15 shows the sales distribution for 2003 based on country of manufacture and demonstrates that the European Union is a key supplier of prime movers along with Australian made trucks such as Kenworth, Mack and Iveco. Locally built heavy commercial vehicles accounted for an estimated 16 per cent of the total number retailed in 2003 with the remainder 85 per cent imported mainly from Japan and Europe. This trend has remained to the present day. All local assemblers and wholesalers are foreign owned and vehicles are sourced from all over the world. As such, the industry displays a high level of globalization.

Table 15: Number of new heavy commercial vehicles sold during 2003

Country of manufacture	Rigid commercial vehicles	Prime movers	Trailers	Total Rigid + Prime movers
Australia	1377	2800	N/A	4177
European Union	1552	1866	Nil*	3418
Japan	8900	240	Nil*	9140
USA	300	1044	Nil*	1344
Total	12,129	5950		18,079

Source: VFACTS
*Trailers from Japan, Europe and the USA are rarely supplied to the Australian market.

Types of Vehicles

Rigid heavy commercial vehicles offer a load carrying area and may be equipped with a tow bar or other coupling on the rear of the vehicle. Articulated heavy commercial vehicles consist of a prime mover (towing vehicle) which has no significant load carrying area but linked with a turntable device to a semi-trailer. In all thirteen types of vehicles are normally registered across Australian states and territories.

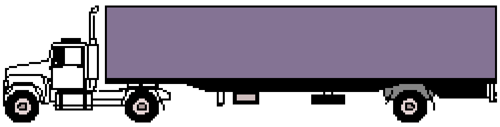
The various types of heavy commercial vehicles operating in Australia are detailed below. In summary, there are five main operating classes of heavy commercial vehicles. These are:

- Rigid commercial vehicles
- Rigid commercial vehicles with trailers
- Semi-trailers
- B-Doubles
- Road trains

A B-Double combination consists of a prime mover towing two semi-trailers. The first trailer includes a turntable, which links to the second trailer, rather than using a dolly to link the trailers as in road train configurations. A road train comprises of a prime mover hauling two or more trailers and employing a dolly or a rigid heavy commercial vehicle hauling two or more trailers. Such a classification of the heavy commercial vehicle market is useful for costing heavy commercial vehicle UP devices.

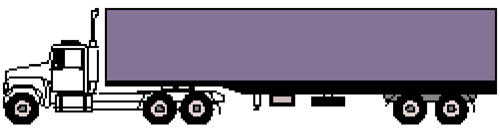
ARTICULATED HEAVY TRUCKS

1. THREE AXLE SEMI-TRAILER



Maximum Mass Limit (tonnes) **24** (no increase permitted)
Width=**2.5m**
Height=**4.3m**
Length=**19m**

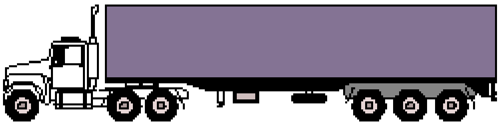
2. FIVE AXLE SEMI-TRAILER



Maximum Mass Limit (tonnes) **39.0 (40.0)**
Width=**2.5m**

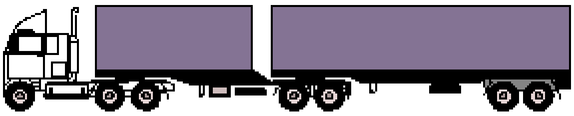
Height=**4.3m**
Length=**19m**

3. Six Axle Semi-Trailer



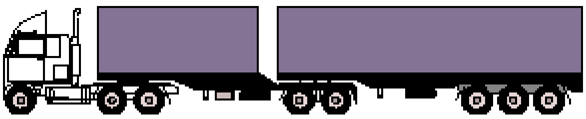
Maximum Mass Limit (tonnes) **42.5 (45.5)**
Width=**2.5m**
Height=**4.3m**
Length=**19m**

4. Seven Axle B-Double



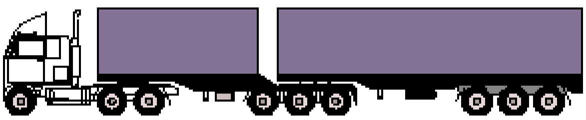
Maximum Mass Limit (tonnes) **55.5 (57)**
Width=**2.5m**
Height=**4.3m**
Length=**25m**

5. Eight Axle B-Double



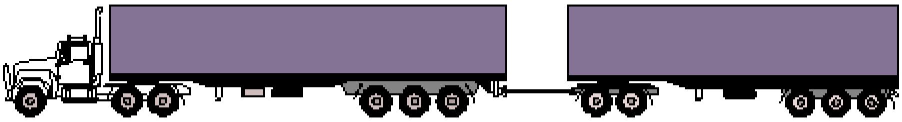
Maximum Mass Limit (tonnes) **59.0 (62.5)**
Width=**2.5m**
Height=**4.3m**
Length=**25m**

6. Nine Axle B-Double



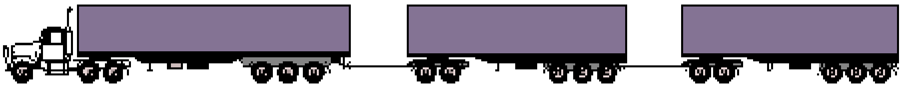
Maximum Mass Limit (tonnes) **62.5 (68)**
Width=**2.5m**
Height=**4.3m**
Length=**25m**

7. Double Road Train



Maximum Mass Limit (tonnes) **79.0 (85.7)**
Width=**2.5m**
Height=**4.3m**
Length=**36.5m**

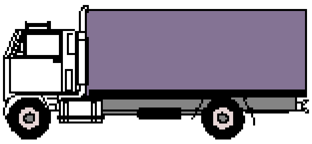
8. VEHICLE: TRIPLE ROAD TRAIN



Maximum Mass Limit (tonnes) **115.5 (125.2)**
Width=**2.5m**
Height=**4.3m**
Length=**53.5m**

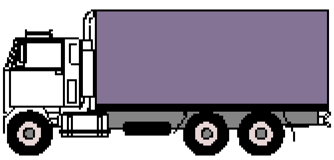
RIGID TRUCKS

9. TWO AXLE RIGID COMMERCIAL VEHICLE



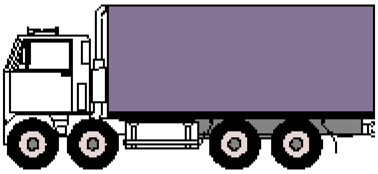
Maximum Mass Limit (tonnes): **15** (no increase permitted)
Width=**2.5m**
Height=**4.3m**
Length=**12.5m**

10. THREE AXLE RIGID COMMERCIAL VEHICLE



Maximum Mass Limit (tonnes): **22.5 (23)**
Width=**2.5m**
Height=**4.3m**
Length=**12.5m**

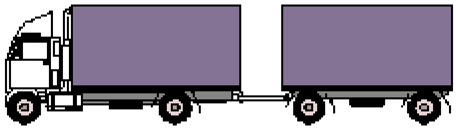
11. FOUR AXLE TWIN-STEER RIGID COMMERCIAL VEHICLE



Maximum Mass Limit (tonnes): **26.5* (27)**
Width=**2.5m**
Height=**4.3m**
Length=**12.5m**

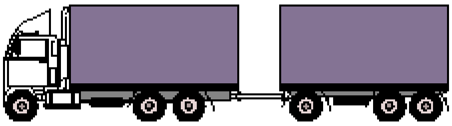
* If load-sharing twin-steer, mass is 27.5t (28)

12. TWO AXLE RIGID COMMERCIAL VEHICLE WITH TWO AXLE DOG TRAILER



Maximum Mass Limit (tonnes): **30.0** (no increase permitted)
Width=**2.5m**
Height=**4.3m**
Length=**19m**

13. THREE AXLE RIGID COMMERCIAL VEHICLE WITH THREE AXLE DOG TRAILER



Maximum Mass Limit (tonnes): **42.5*** (no increase permitted)
Annual Charge ($);
Width=**2.5m**
Height=**4.3m**
Length=**19m**

Source: National Transport Commission, Melbourne

APPENDIX 3: SOURCES OF DATA COLLECTION

Several types of data collection sources have been used for estimating the cost of underrun trauma, underrun exposure rate, underrun fatality rate and injury severity. They include:

- ATSB National Fatal Road Crash Database
- ATSB Monthly Road Fatality Database;
- State crash databases;
- Exposure data; and
- Special Reports and Journal Articles

These databases are described below:

DATABASES FOR ROAD CRASHES

ATSB NATIONAL FATAL ROAD CRASH DATABASE

The Australian Transport Safety Bureau (ATSB) Monthly Road Fatality Database and the National Fatal Road Crash Database (FCD) combine information from crash databases and coronial records for all fatal crashes. The FCD is available for a range of years (for example 1992, 1994, 1996, 1997) but is generally not available for several years after the occurrence of the crash. <u>Thus, it is a source of detailed but not timely data on a relatively small sample of crashes</u>.

STATE CRASH DATABASES

Each state and territory operates and manages a database of information about road crashes occurring within their jurisdiction. The databases are compiled from Police report forms with some enhancement by the state road authorities. The categories of crashes covered by the crash databases differ. All of the databases include crashes resulting in injury but some jurisdictions do not include non-injury crashes (for example Victoria). Other jurisdictions include non-injury crashes where the extent of property damage is above a certain threshold or a vehicle needs to be towed away. There is some concern about under reporting of minor crashes.

EXPOSURE DATA

Exposure data describes the amount and type of use of vehicles. Thus, they provide denominator data in the calculation of crash rates. The most commonly used source of information for vehicle exposure is the Australian Bureau of Statistics' *Survey of Motor Vehicle Use.* The Survey provides information on the number and types of vehicles registered in each state and territory and how far they have travelled in the 12 months of the Survey period.

SPECIAL REPORTS AND JOURNAL ARTICLES

A number of special reports and journal articles have been published that provide information about commercial vehicle underrun crashes, occupants killed and strategies for mitigating the risk of injuries from underrun collisions. These are included in the bibliography.

QUALITY OF UNDERRUN CRASH DATA

The quality of statistics should be judged with their ability to satisfy users' information needs. Statistics on vehicle occupants killed or hospitalised in terms of underrun collisions should provide an accurate and timely measure of the crash events to which they relate. They need to be:

- Relevant, that is record the wearing status of the occupants and the circumstances under which the fatalities or hospitalisations occurred;
- Accurate and reliable, that is not be subject to large number of unknowns, errors or revisions;
- Timely, this is available after a year of occurrence of crashes;
- Comprehensive in coverage;
- Easily accessible

APPENDIX 4: REVIEW OF SELECTED STUDIES ON UNDERRUN PROTECTION DEVICES

Review of Literature

Frontal Underrun Collisions

Swedish Studies:

Swedish laboratory tests have shown that Underrun Protection (UP) devices significantly reduce the risk of injury, especially combined with the use of seatbelts in passenger cars (Hogstrom et al, 1974). However, it is not possible, on the basis of these tests, to state any exact figures for the effect on the severity of injury of equipping all heavy commercial vehicles with UP devices.

Hogstrom et al (1974) of Volvo analyzed 187 collisions that occurred in the period 1970- 72 between cars and heavy commercial vehicles and found that 28 per cent were frontal impacts from the side or from the rear. In another study Fosser (1979) analyzed the distribution of points of impacts in 581 collisions in Sweden and found that in 44 per cent of crashes, other road users (passenger cars, motorcycles and pedestrians) hit the heavy commercial vehicle between the wheels on the side or from the rear. In continuing research, Hogstrom et al (1986) reviewed Fosser's (1979) findings by studying over 1000 heavy commercial vehicle crashes in Sweden and noticed that the front of the heavy commercial vehicle is involved in some 77 per cent of fatal crashes.

Netherlands Studies

Goudsward et al (1991) studied commercial vehicle-passenger car crashes across Europe and found that 65 per cent of the fatally injured were passenger car occupants numbering in excess of 7000 people and 60 per cent (4200 people) of these fatally injured passenger car occupants were killed in commercial vehicle front to car front collisions. The average relative speed in case of frontal crash injury cases (Δ v for the car) was estimated by Goudsward to be 55 km per hour with 25 per cent of collisions taking place with the sides of the commercial vehicle and 15 per cent with the rear of the commercial vehicle.

German Studies

In the late seventies Danner and Langweider (1981) studied 1559 multiple vehicle crashes involving cars and heavy commercial vehicles and found that the high mass of the commercial vehicle was not the sole factor in the severity of car-commercial vehicle crashes but frontal aggressivity of the commercial vehicle contributed significantly to serious injuries. They suggested that aggresivity could be reduced by engineering means. Danner et al also estimated impact speeds and found that in 50 per cent of the frontal crashes the impact speed was 50 km per hour. In commercial vehicles crashing into the sides of cars 70 per cent of crashes took place at speeds less than 30 km per hour. In case of cars crashing into the rear of commercial vehicles, 70 per cent of the crashes were at 40 km per hour.

British Studies:

Distribution of impact positions in 226 car-commercial vehicle crashes across Britain was analyzed by Mackay and Walton (1984). They found that 63 per cent of the crashes were with the front of the commercial vehicle, 11 per cent with the sides of the commercial vehicle and 18 per cent with the rear of the commercial vehicle.

Gloyns and Rattenbury (1989) found a higher proportion of frontal crashes than Mackay and Walton. According to Gloyns et al (1989) 75 per cent of passenger car fatalities involved the front of the heavy commercial vehicle. Of these 2/3 were frontal crashes of the head-on and offset type while 1/3 were heavy commercial vehicle into the side of the car. The Gloyns study produced some important information on frontal underrun crashes. The typical fatal frontal crash is offset with high levels of intrusion in majority of cases. In 70 per cent of the cases intrusion extended into the passenger compartment of the car with occupants suffering severe head and chest injuries. Gloyns estimated that front and rear UP devices would reduce fatalities by 17 per cent.

In a review of a sample of police reports on fatal crashes involving heavy commercial vehicles Thomas and Clift 91988) found that underrun was involved in some 88 per cent of their sample, and in 75 per cent of the cases the energy absorbing capacity of the car's main chassis members was not utilized. They found that high levels of intrusion were common in frontal collisions, and in 58 per cent of the cases the A pillar was contacted.

Robinson and Riley (1991) studied 111 fatal crashes occurring in 1976 where cars drove under heavy commercial vehicles and concluded that UP devices at the front of the heavy commercial vehicle could certainly have prevented 11 deaths, probably have prevented 32 deaths and possibly have prevented 59 deaths. Unlike the Gloyns study it can be concluded that a mid point estimate of 32 per cent (32 fatalities prevented out of 111 fatalities) is the best estimate of the effects of UP devices.

<u>Side and Rear Underrun Collisions</u>

Australian Studies
Mc Lean (1966) in a study of 59 crashes involving heavy commercial vehicles in Adelaide suggested fitting rear and side UP devices for heavy commercial vehicles to reduce the injury potential for underrun collisions.

Swedish Studies
Hogstrom et al (1986) in a previously discussed study involving 100 commercial vehicles in Sweden suggested that side UP devices would have an injury reducing potential in 35 per cent of crashes involving vulnerable road users.

British Studies
The Riley et al (1981) 1976 study in Britain reviewed 740 fatal crashes and found 300 fatalities involved vulnerable road users. Two thirds of these fatalities (100 persons) involved vulnerable road users impacting with the sides of heavy commercial vehicles with 98 persons run over by the rear wheels of the heavy commercial vehicle. Riley et al estimated that side UP devices would save 40 motor cyclists/cyclists and 14 pedestrians.

German Studies
A significant number of side impacts were observed by Langweider and Danner (1987) in 1559 commercial vehicle involved crashes. They described these side impacts as "swiping" and noted that such impacts could take place during overtaking manoeuvres. The injury causing mechanism is not the speed but the danger of the subsequent fall into the space between the front and rear axle, resulting in being run over by the commercial vehicle's

wheels. They found that side UP devices would influence around 50 per cent of serious and fatal injury cases to motorcyclists and cyclists. In particular, these guards would totally avoid the falls between the wheels. They recommended that side panels should be designed with flat surfaces covering the whole area. This contrasts with other designs that employ side rails with gaps between the upper and lower rails, which can present their own hazards as people can still be caught between the rails.

In a continuing study, Langweider and Danner examined 110 commercial vehicle crashes with pedestrians and found that 42 per cent were with the front of the commercial vehicle while 33 per cent were with the side. They recommended that the design of the front and sides should present flat surfaces, without protruding edges, and particularly noted the need for this between the commercial vehicle's cabin and the load tray. They also noted that two-thirds of commercial vehicle crashes are at speeds less than 30 km per hour and that the suggested measures of incorporating front and side UP devices would be effective.

APPENDIX 5: METHODOLOGY OF BENEFIT-COST ANALYSIS

Benefit-cost analysis is a useful tool for evaluating the feasibility of implementing new technology, but it does not replace the decision process itself. Net Benefits and Benefit-Cost Ratios show whether the returns (benefits) on a project outweigh the resources outlaid (cost) and what this difference is. Although positive Net Benefits and a Benefit-Cost Ratio greater than one suggest that a project should be pursued, there may be other factors to consider. The goal of benefit-cost analysis is to provide information to assist with the decision.

When benefits and costs are spread over a period of time (for example the initial investment and maintenance necessary in the following years or the number of fatalities prevented following implementation of an initial investment) they have to be compared to one another in an objective manner. Although several methods exist, the method used in this analysis is the Net Present Value (NPV) method. Using this method, the flow of benefits and costs are reduced to one specific moment in time (this moment is the moment of initial investment), and both benefits and costs are discounted. The time period that the benefits are assumed to be generated over is the life of the vehicle. Although the expected heavy commercial vehicle life was assumed as being 15 years, a range from 10 to 25 years was used in the calculations.

Choosing the discount rate is important: the higher the discount rate the lower the impact of future benefits and costs when the projects are appraised. 7 per cent was used as a base discount rate. This was typical of similar studies on Underrun Protection (UP) devices in the Australian context.

However, a range of discount rates was established beginning with the view that the discount rate should be the interest rate of the ten-year Commonwealth Treasury bond. When discount rates are adjusted to fall in with inflation and taxes, they are a good indicator for the compensation consumers ask for postponing their own consumption. If this view is followed a discount rate of 4 per cent (real rate) should be used. This was the lower value of the established range.

An alternative view is that discount rates of about 12-14 per cent should be used for calculating net benefit, as consumers rather than governments finance the installation of safety devices in their vehicles. The auto finance rate in the country depends on the credit risk of a consumer, tenure of the loan and varies from 10.5 per cent to 15 per cent.

To obtain an inter temporal comparison of benefits and costs, discount rates of 4 per cent, 5 per cent, 6 per cent, 7 per cent and 12 per cent were applied for the analysis.

The methodology that was used to calculate the benefits and costs for the options presented is outlined below:

1. <u>Estimate the number of (rigid and articulated) trucks in the fleet in the next year;</u>
    - Note the number of underrun protected (UP) and non UP vehicles in fleet the last year,
    - Reduce these by a 3% assumed fleet attrition rate,
    - Note the number of vehicles that were registered in the last year,
    - Multiply this by 0.8 to remove the influence of European vehicles assumed to be already fitted with; and

- Add this to the last year's reduced UP fleet to get the size of the UP fleet and the total fleet for the next year.

2. Estimate the unit cost of front UP.

3. Estimate the unit cost of rear UP.

4. Estimate the unit cost of side UP;
    - Note the proportion of each type (rigid and articulated) and length of trucks in the fleet this year'
    - Estimate the unit cost of side UP per vehicle metre,
    - Multiply this by the length of different types of truck and trailers,
    - Calculate a weighted average unit cost (rigid and articulated) by proportioning this out by the relative numbers of different trucks and trailers in the fleet.

5. Estimate the effectiveness of the different UP types;
    - Note the reported effectiveness of UP under studies at various speeds to reduce fatal, serious and minor injuries,
    - Average the effectiveness at various speeds,
    - Both increase and decrease the effectiveness to give a number of alternative scenarios (A,B,C,) for sensitivity analysis,
    - Add an extra scenario to represent energy absorbing UP (D).

6. Estimate the overall cost of underrun crashes per year;
    - Summarise the 1988-03 FCD data and other estimates, for underrun crashes with rigid and articulated heavy commercial vehicles over 4.5 tonnes, in to the number of fatal, serious and minor injuries,
    - Proportion injuries relating to front, side or rear underrun using State crash databases,
    - Note the cost of a single fatality, serious injury and minor injury for passenger vehicles and splitting this in to trauma cost (injuries) and non-trauma cost (property),
    - Multiply the non-trauma cost by 1.5 for the cost of a single heavy vehicle fatality,
    - Convert this to 2009 dollars,
    - Multiply this by the summarised injury data on numbers to get an overall cost.

7. Calculate the possible overall yearly benefit from installing UP devices to the whole fleet;
    - Multiply the yearly injury numbers and types (fatal, serious, minor) by the effectiveness of the underrun devices for each effectiveness scenario,
    - Cascade any reduction in injury down to the next level ie fatal injuries saved become serious injuries, serious injuries saved become minor injuries (note that minor injuries are not cascaded to injury free),
    - Take the reduced injury numbers away from the original injury numbers to get the net reduction in injuries.

8. Calculate the Net-Benefits and Benefit-Cost Ratios for installing UP progressively to the whole fleet through new registrations for each UP effectiveness scenario.

Fleet registration and crash profile
This method calculates the cost to fit UP to new vehicles registered within a year, and compares this to the accumulation of benefits that these new vehicles then generate over their life. The benefits are discounted back to the starting year for comparison. The Net Benefits and Benefit-Cost Ratios represent a steady state in the fleet. This steady state is achieved once the initial group of vehicles have moved through their life (having provided all their benefits) and are beginning to exit the fleet. At this point, the costs become equivalent to the yearly cost to fit UP to new vehicles. The benefits become equivalent to the yearly benefits flowing from all vehicles in the fleet, at various stages in their lives, that are fitted with UP.

Note: this method was taken from Fildes (2002). It has been extended by assuming that the heavy commercial vehicle fleet has the same or similar registration and crash profile as the remainder of the fleet and by calculating additional multipliers representing different discount rates. The safety device in this case is UP. It is the main method used. A detailed explanation of the method can be found in the above reference and has not been repeated here. However, a summary table of the multipliers used is shown below, followed by a general description.

Multipliers

	Discount Rate (%)				
Discount Period (yrs)	4	5	6	7	12
10	0.4190	0.4000	0.3823	0.3659	0.2988
15	0.5769	0.5396	0.5059	0.4755	0.3600
20	0.6593	0.6093	0.5649	0.5255	0.3825
25	0.6829	0.6283	0.5803	0.5380	0.3870

- Establish a general profile of the vehicle fleet made up of, for any given year of vehicle age up to 20 years old, the number of new registrations as a proportion of the cumulative fleet over the entire period, divided in to the number of fatal or injury crashes as a proportion of the cumulative number of fatal or injury crashes over the same period,
- For any given year after year zero (first registration), reduce the proportions by the generic time discount factor of $(1 + d)^n$,
- Add the proportions up for each year that the safety device of interest has been fitted,
- Multiply the final result by the estimated net saving in injuries established at point 7,
- Calculate the cost to fit the safety device of interest to newly registered vehicles,
- Calculate the Net Present Values of the benefits and costs.
- Calculate the Net Benefits and Benefit-Cost Ratios.

A starting point is summarising the Fatal Crash Database (FCD) data by the number of persons involved in road crashes between 1988-2003. A dataset for fatalities arising from heavy commercial vehicle (greater than 4.5 tonnes GVM) underrun collisions was composed from the FCD. The number of persons involved in serious and minor injuries were obtained from New South Wales and Queensland road crash databases and statistical reports published by state road safety agencies.

There are a number of on-going studies as well as past studies on the effectiveness of UP in preventing fatalities and serious injuries. Appendix 4 provides a review of these studies but some key features of these studies are in Table 16.

Table 16: Studies on heavy commercial vehicle underruns and effectiveness of UP devices

Study	Type of UP device	Effectiveness in fatal crashes	Effectiveness ir serious injury crashes
Mclean (1966)	Rear and side UP to be fitted	Considerably reduces injuries	
Riley (1983)	Rear UP	35%	
Hogstrom and Svensson (1986)	Side UP would have positive effect on 35% of crashes involving cyclists and motor cyclists	35%	
Langweider and Danner	Side UP would prevent 50% of serious and	50%	

(1987)	fatal injuries to riders of motorcycles		
Robinson and Riley (1991)	Energy absorbing front UP device	36%	
Rechnitzer and Foong (1993)	Rear UP and improved rear-end visibility	40%	
Rechnitzer (1993)	Front and side UP	15% front (car-commercial vehicle) 20% side (pedestrian-commercial vehicle) 20% side (motorcycle-commercial vehicle)	30% front (car-commercial vehicle) 30% side (pedestrian-commercial vehicle) 30% side (motorcycle-commercial vehicle)

According to Rechnitzer (1993), rigid rear underrun systems are highly effective for speeds up to 60 kilometres per hour since they then engage the car's safety systems. Rear UP of the energy absorbing type is effective in collisions at speeds up to 90 kilometres per hour when occupants are restrained occupants and in airbag-equipped cars.

As the effectiveness of UP depends on ΔV, structural characteristics of the front ends of the passenger car and the heavy commercial vehicle to absorb energy, heavy vehicle height, overlap area of car-commercial vehicle, mass of heavy commercial vehicle, angle of impact, a number of effectiveness rates have to be used. To estimate the benefits from the provision of UP, effectiveness rates based on, past studies, current research on heavy commercial vehicle-car compatibility, modelling results and judgement are used as shown in Table 17.

Table 17: Effectiveness rates of UP used in estimating benefits

Type of impact	**Type of UP**	**Road user protected**	**Speed range**	**Injuries**	
				Fatal Reduced by xx to serious	**Serious Reduced by xx to minor**
Frontal	Rigid UP	Car occupants	55-60 km/h	20%	30%
Frontal	Energy absorbing UP		Up to 75 km/h	30%	30%
Side	Rigid UP	Motor cyclists, pedestrians, bicyclists	Up to 35 km/h	19%	30%
Rear	Rigid UP		Up to 45 km/h	32%	30%
	Energy absorbing UP	Car occupants	Up to 60 km/h	42%	30%

Source: Rechnitzer, 1993, Haworth, 2002, various studies

APPENDIX 6: RESULTS OF BENEFIT-COST ANALYSIS

1. Estimate the number of (rigid and articulated) trucks in the fleet in the next year;
- Note the number of underrun protected (UP) and non UP vehicles in fleet the last year, starting 2008,
- Reduce these by a 3% assumed fleet attrition rate,
- Note the number of vehicles that were registered in the last year,
- Multiply this by 0.8 to remove the influence of European vehicles assumed to be already fitted with; and
- Add this to the last year's reduced UP fleet to get the size of the UP fleet and the total fleet for the next year.

Heavy vehicle type > 4.5tonnes	**No. of vehicles on previous year's register (2008) (units)**	**Annual attrition (units)**	**Estimated no. of registrations annually adjusted for European trucks (units)**	**Estimated no. of vehicles on succeeding year's register (2009) (units)**	**Estimated no. of registrations annually**
Rigid	305,184	9,156	13,648	313,088	17,060
Articulated	79,132	2,374	4,829	82,794	6,036
All trucks	384,316	11,529	18,477	395,883	23,096

Source: ABS Census Yearbook 2008, NRTC Cost Allocation Model

2. Estimate the unit cost of a front UP device.

Front UP device	**Cost (2005$)**	**Model Production Run (units)**	**Unit cost (2005$)**
ECE Program (Euro 300,0000)	$4,000,000	100,000	
Unit Program cost (amortised from above estimates)			$40.00
ECE Program Materials			$275.00
ECE Program Production			$75.00
ECE Program Control			$25.00
Product Liability			$25.00
Total			**$440.00**
Total (adjusted from 2005 to 2009 dollars)			**$514.74**

Source: VBG (component supplier), Sweden and Scania, Sweden

3. Estimate the unit cost of a side UP device;
- Estimate the unit cost of a side UP device per vehicle metre,
- Note the proportion of each type (rigid and articulated) and length of trucks in the fleet this year'
- Multiply this by the length of different types of truck and trailers,
- Calculate a weighted average unit cost (rigid and articulated) by proportioning this out by the relative numbers of different trucks and trailers in the fleet.

Side UP device (34 m total needed for a 19 m vehicle)	**Cost (2005$)**	**Cost/linear metre**
ECE Program		
Unit Program cost		
ECE Program Materials		

ECE Program Production		
ECE Program Control		
Product Liability		
Total (Euro 780 + 20% shipping) for 34 m	**$1,560.00**	**$45.88**
Total (adjusted from 2005 to 2009 dollars) for 1 m		**$53.68**

Source: VBG (component supplier), Sweden and Scania, Sweden

Summary of cost of UP for heavy Trucks (2005$)	**length (m)**	**Cost SUP**		**Proportion summary**	**Average cost SUPS**
3 axle semi-trailer	19	$872		0.05	$44
5 axle semi-trailer	19	$872		0.2	$174
6 axle semi-trailer	19	$872		0.4	$349
7 axle B-Double	25	$1,147		0.05	$57
8 axle B-Double	25	$1,147		0.05	$57
9 axle B-Double	25	$1,147		0.15	$172
Double Road Train	36.5	$1,675		0.05	$84
Triple Road Train	53.5	$2,455		0.05	$123
2 axle rigid truck	12.5	$574		0.4	$229
3 axle rigid truck	12.5	$574		0.3	$172
4 axle Twin-Steer rigid truck	12.5	$574		0.1	$57
2 axle rigid truck with 2 axle dog trailer	19	$872		0.15	$131
3 axle rigid truck with 3 axle dog trailer	19	$872		0.05	$44
				Fleet average (SUPS)	$847
				(2009$)	$1,158

4. Estimate the unit cost of a rear UP device.

Rear UP device	**Cost (2005$)**		**Unit cost**
ECE Program			
Aluminium Beam (Euro 154 + 20%)	$308.00		
Mounting brackets (Euro 231 +20%)	$465.00		
ECE Program Production			
ECE Program Control			
Product Liability			
Total	**$773.00**		**$773.00**
Total (adjusted from 2005 to 2009 dollars)			**$904.30**

Source: VBG (component supplier), Sweden and Scania, Sweden

5. Estimate the effectiveness of the different UP device types;

- Note the reported effectiveness of devices under studies at various speeds to reduce fatal, serious and minor injuries,
- Average the effectiveness at various speeds,
- Both increase and decrease the effectiveness to give a number of alternative scenarios (A,B,C,) for sensitivity analysis,
- Add an extra scenario to represent energy absorbing UP devices (D).

Scenario A - Low effectiveness									
Rigid UP Effectiveness									
Fatal injury	**speed**	**20km/h**	**30km/h**	**40km/h**	**50km/h**	**60km/h**	**70km/h**	**100km/h**	
	g			**15**	**20**	**25**	**35**	**50**	
Front UP (ECE R93) effectiveness				55%	55%	30%	10%	0%	
Proportion of front underruns				15%	15%	25%	35%	20%	
Weighted average front underrun effectiveness									**25%**
Side UP (ECE R73) effectiveness				35%	20%	10%	0%	0%	
Proportion of side underruns				25%	45%	25%	5%	0%	
Weighted average side underrun effectiveness									**20%**
Rear UP (ECE R58) effectiveness				40%	35%	25%	0%	0%	
Proportion of rear underruns				45%	40%	10%	5%	0%	
Weighted average rear underrun effectiveness									**35%**
Serious injury	**speed**	**20km/h**	**30km/h**	**40km/h**	**50km/h**	**60km/h**	**70km/h**	**100km/h**	
	g			**15**	**20**	**25**	**35**	**50**	
Front UP (ECE R93) effectiveness			70%	40%	35%	35%	0%	0%	
Proportion of front underruns			5%	30%	45%	10%	0%	0%	
Weighted average front underrun effectiveness									**35%**
Side UP (ECE R73) effectiveness			40%	35%	15%	10%	0%	0%	
Proportion of side underruns			20%	50%	30%	0%	0%	0%	
Weighted average side underrun effectiveness									**30%**
Rear UP (ECE R58) effectiveness			60%	45%	38%	10%	0%	0%	
Proportion of rear underruns			25%	45%	30%	5%	0%	0%	
Weighted average rear underrun effectiveness									**45%**

Scenario B - Most likely effectiveness									
Rigid UP Effectiveness									
Fatal injury	**speed**	**20km/h**	**30km/h**	**40km/h**	**50km/h**	**60km/h**	**70km/h**	**100km/h**	
	g			**15**	**20**	**25**	**35**	**50**	
Front UP (ECE R93) effectiveness				65%	60%	35%	15%	0%	
Proportion of front underruns				15%	15%	25%	35%	20%	
Weighted average front underrun effectiveness									**30%**
Side UP (ECE R73) effectiveness				40%	25%	15%	0%	0%	
Proportion of side underruns				25%	45%	25%	5%	0%	
Weighted average side underrun effectiveness									**25%**
Rear UP (ECE R58) effectiveness				45%	40%	30%	0%	0%	
Proportion of rear underruns				45%	40%	10%	5%	0%	
Weighted average rear underrun effectiveness									**39%**
Serious injury	**speed**	**20km/h**	**30km/h**	**40km/h**	**50km/h**	**60km/h**	**70km/h**	**100km/h**	
	g			**15**	**20**	**25**	**35**	**50**	
Front UP (ECE R93) effectiveness			75%	45%	40%	40%	0%	0%	
Proportion of front underruns			5%	30%	45%	10%	0%	0%	
Weighted average front underrun effectiveness									**39%**
Side UP (ECE R73) effectiveness			50%	40%	20%	15%	0%	0%	
Proportion of side underruns			20%	50%	30%	0%	0%	0%	
Weighted average side underrun effectiveness									**36%**
Rear UP (ECE R58) effectiveness			65%	50%	45%	15%	0%	0%	
Proportion of rear underruns			25%	45%	30%	5%	0%	0%	
Weighted average rear underrun effectiveness									**50%**

Scenario C - High effectiveness									
Rigid UP Effectiveness									
Fatal injury	**speed**	**20km/h**	**30km/h**	**40km/h**	**50km/h**	**60km/h**	**70km/h**	**100km/h**	
	g			**15**	**20**	**25**	**35**	**50**	
Front UP (ECE R93) effectiveness				70%	65%	45%	20%	0%	
Proportion of front underruns				15%	15%	25%	35%	20%	

Weighted average front underrun effectiveness									**35%**
Side UP (ECE R73) effectiveness				45%	30%	20%	0%	0%	
Proportion of side underruns				25%	45%	25%	5%	0%	
Weighted average side underrun effectiveness									**30%**
Rear UP (ECE R58) effectiveness				50%	45%	35%	0%	0%	
Proportion of rear underruns				45%	40%	10%	5%	0%	
Weighted average rear underrun effectiveness									**44%**
Serious injury	**speed**	**20km/h**	**30km/h**	**40km/h**	**50km/h**	**60km/h**	**70km/h**	**100km/h**	
	g			**15**	**20**	**25**	**35**	**50**	
Front UP (ECE R93) effectiveness			80%	50%	45%	45%	5%	0%	
Proportion of front underruns			5%	30%	45%	10%	0%	0%	
Weighted average front underrun effectiveness									**44%**
Side UP (ECE R73) effectiveness			55%	45%	25%	20%	0%	0%	
Proportion of side underruns			20%	50%	30%	0%	0%	0%	
Weighted average side underrun effectiveness									**41%**
Rear UP (ECE R58) effectiveness			70%	55%	50%	20%	0%	0%	
Proportion of rear underruns			25%	45%	30%	5%	0%	0%	
Weighted average rear underrun effectiveness									**55%**

Scenario D - Energy absorbing									
Energy Absorbing UP Effectiveness									
Fatal injury	**speed**	**20km/h**	**30km/h**	**40km/h**	**50km/h**	**60km/h**	**70km/h**	**100km/h**	
	g			**15**	**20**	**25**	**35**	**50**	
Front UP (ECE R93) effectiveness				75%	70%	50%	25%	0%	
Proportion of front underruns				15%	15%	25%	35%	20%	
Weighted average front underrun effectiveness									39%
Side UP (ECE R73) effectiveness				50%	35%	25%	0%	0%	
Proportion of side underruns				25%	45%	25%	5%	0%	
Weighted average side underrun effectiveness									35%
Rear UP (ECE R58) effectiveness				55%	50%	40%	10%	0%	
Proportion of rear underruns				45%	40%	10%	5%	0%	
Weighted average rear underrun effectiveness									49%

Serious injury	**speed**	**20km/h**	**30km/h**	**40km/h**	**50km/h**	**60km/h**	**70km/h**	**100km/h**	
	g			**15**	**20**	**25**	**35**	**50**	
Front UP (ECE R93) effectiveness			85%	55%	50%	55%	15%	0%	
Proportion of front underruns			5%	30%	45%	10%	0%	0%	
Weighted average front underrun effectiveness									49%
Side UP (ECE R73) effectiveness			60%	50%	30%	25%	0%	0%	
Proportion of side underruns			20%	50%	30%	0%	0%	0%	
Weighted average side underrun effectiveness									46%
Rear UP (ECE R58) effectiveness			75%	60%	55%	25%	0%	0%	
Proportion of rear underruns			25%	45%	30%	5%	0%	0%	
Weighted average rear underrun effectiveness									60%

Summary of effectiveness of UP devices

Scenario A - Low			
Rigid UP	Front	Side	Rear
Fatal injury	25%	20%	35%
Serious injury	35%	30%	45%

Scenario B - Most Likely			
Rigid UP	Front	Side	Rear
Fatal injury	30%	25%	39%
Serious injury	39%	36%	50%

Scenario C - High			
Rigid UP	Front	Side	Rear
Fatal injury	35%	30%	44%
Serious injury	44%	41%	55%

Scenario D - Energy Absorbin UP	Front	Side	Rear
Fatal injury	39%	35%	49%
Serious injury	49%	46%	60%

Source: Haworth (2002), Rechnitzer (1993), VC-COMPAT studies, Elvik.

6. Estimate the overall cost of underrun crashes per year;

- Summarise the 1988-2003 FCD data and other estimates, for underrun crashes with rigid and articulated heavy commercial vehicles over 4.5 tonnes, in to the number of fatal, serious and minor injuries,
- Proportion injuries relating to front, side or rear underrun using State crash databases,
- Note the cost of a single fatality, serious injury and minor injury for passenger vehicles and split this in to trauma cost (injuries) and non-trauma cost (property),
- Multiply the non-trauma cost by 1.5 for the cost of a single heavy vehicle fatality,
- Convert this to 2009 dollars,
- Multiply this by the summarised injury data on numbers to get an overall cost.

UNDERRUN INJURIES - Fatal Crash Database (FCD)

Fatal & serious-injury crashes involving heavy truck under-run

Number of crashes resulting in the death of an occupant of a passenger car/4WD that ran under a heavy truck by heavy truck type and year of crash, Australia 1988-2003

	1988	*1990*	*1992*	*1994*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*Average*
Heavy Rigid Truck	11	16	7	18	9	11	17	14	7	7	8	1	10.5
Articulated Truck	38	37	9	32	13	6	12	20	19	17	11	5	18.3
Heavy Rigid & Artic. Truck	1	0	0	0	0	0	0	1	1	1	1	0	

Number of crashes resulting in the death of a rider on a motorcycle/bicycle that ran under a heavy truck by heavy truck type and year of crash, Australia 1988-2003

	1988	*1990*	*1992*	*1994*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*Average*
Heavy Rigid Truck	5	3	1	3	3	4	3	3	4	4	3	2	3.2
Articulated Truck	5	9	2	0	2	2	4	5	4	3	5	3	3.7
Heavy Rigid & Artic. Truck	0	0	0	0	0	0	0	0	1	0	0	0	

Number of crashes resulting in a death in a passenger car/4WD or on a motorcycle/bicycle that ran under a heavy truck by year of crash, Australia 1988-2003

Heavy truck type	*1988*	*1990*	*1992*	*1994*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*Average*
Heavy Rigid Truck	16	19	8	21	12	15	20	17	11	11	11	3	13.7
Articulated Truck	43	46	11	32	15	8	16	25	23	20	16	8	21.9
Heavy Rigid & Artic. Truck	1	0	0	0	0	0	0	1	2	1	1	0	0.5
Total	58	65	19	53	27	23	36	41	32	30	26	11	35.1

Number of crashes resulting in a death in a passenger car/4WD that ran under a heavy truck by under-run location, heavy truck type & year of crash, Australia 1988-2003

Under-run type	*Heavy truck type*	*1988*	*1990*	*1992*	*1994*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*Average*
side	Heavy Rigid Truck	0	3	1	2	3	3	1	2	0	0	3	0	1.5
	Articulated Truck	0	5	3	3	1	2	0	1	4	7	1	2	2.4
	Heavy Rigid & Artic. Truck	0	0	0	0	0	0	0	0	0	0	1	0	0.1
rear	Heavy Rigid Truck	4	7	0	2	3	2	4	4	2	1	1	0	2.5

	Articulated Truck	4	3	2	2	2	1	2	3	3	3	0	0	2.1
	Heavy Rigid & Artic. Truck	0	0	0	0	0	0	0	1	1	0	0	0	0.2
front	Heavy Rigid Truck	7	6	6	14	3	6	12	8	5	6	4	1	6.5
	Articulated Truck	34	29	4	27	10	3	10	16	12	7	10	3	13.8
	Heavy Rigid & Artic. Truck	1	0	0	0	0	0	0	0	0	1	0	0	0.2
Total	Heavy Rigid Truck	11	16	7	18	9	11	17	14	7	7	8	1	10.5
	Articulated Truck	38	37	9	32	13	6	12	20	19	17	11	5	18.3
	Heavy Rigid & Artic. Truck	1	0	0	0	0	0	0	1	1	1	1	0	0.4

Number of crashes resulting in a death on a motorcycle/bicycle that ran under a heavy truck by under-run location, heavy truck type & year of crash, Australia 1988-2003

Under-run location	*Heavy truck type*	*1988*	*1990*	*1992*	*1994*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*Average*
side	Heavy Rigid Truck	0	1	1	1	0	1	2	3	2	2	2	2	1.4
	Articulated Truck	0	4	1	0	2	1	3	3	4	1	1	0	1.7
	Heavy Rigid & Artic. Truck	0	0	0	0	0	0	0	0	1	0	0	0	0.1
rear	Heavy Rigid Truck	3	0	0	0	0	1	0	0	1	2	0	0	0.6
	Articulated Truck	3	1	0	0	0	0	0	1	0	0	0	0	0.4
front	Heavy Rigid Truck	2	2	0	2	3	2	1	0	1	0	1	0	1.2
	Articulated Truck	2	4	1	0	0	1	1	1	0	2	4	3	1.6
Total	Heavy Rigid Truck	5	3	1	3	3	4	3	3	4	4	3	2	3.2
	Articulated Truck	5	9	2	0	2	2	4	5	4	3	5	3	3.7
	Heavy Rigid & Artic. Truck	0	0	0	0	0	0	0	0	1	0	0	0	0.1

Number of crashes resulting in a death in a passenger car/4WD or on a motorcycle/bicycle that ran under a heavy truck by crash location, heavy truck type & year of crash, Australia 1988-2003

Crash location	*Heavy truck type*	*1988*	*1990*	*1992*	*1994*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*Average*
urban	Articulated Truck	15	18	5	6	3	2	5	8	6	6	6	2	6.8
	Rigid Truck	9	12	3	10	7	10	13	10	4	7	5	3	7.8
	Heavy Rigid & Artic. Truck	0	0	0	0	0	0	0	0	0	1	1	0	0.2
rural	Articulated Truck	28	28	6	26	11	6	11	17	17	14	10	6	15.0
	Heavy Rigid Truck	7	7	5	11	5	5	6	6	7	4	6	0	5.8

	Heavy Rigid & Artic. Truck	1	0	0	0	0	0	0	1	2	0	0	0	0.3
unknown	Articulated Truck	0	0	0	0	1	0	0	0	0	0	0	0	0.1
	Heavy Rigid Truck	0	0	0	0	0	0	1	1	0	0	0	0	0.2

Note: Urban locations refer to areas with a population of at least 1,000 and rural locations refer to areas with a population of 999 or less.

Number of crashes resulting in a death in a passenger car/4WD or on a motorcycle/bicycle that ran under a heavy rigid truck by weight of truck involved by year of crash, Australia 1996-2003

Heavy Rigid Truck weight	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*Average*
4.6 - 12.0t GVM	6	7	3	5	3	1	2	0	3.4
12.1 - 16.5t GVM	4	4	1	6	0	2	0	1	2.3
16.6 - 20.0t GVM	1	1	2	1	2	4	2	0	1.6
> 20.0t GVM	1	3	4	0	1	4	1	0	1.8
Unknown	0	0	10	5	5	0	6	2	3.5
Total	12	15	20	17	11	11	11	3	12.5

Note: All articulated trucks involved in fatal under-run crashes weighed in excess of 20t GVM.

Under-run refers to the situation in which a vehicle runs underneath a heavy rigid or articulated truck. A vehicle can be classified as having run under a truck's cabin, under the side of a truck's tray or under the rear of a truck's tray. In the case of motorcyclists and bicyclists, the rider must still be on the motorcycle or bicycle when it ran under the truck to be classified as having under-run.

Articulated trucks are motor vehicles where the prime mover is separate from the load-carrying trailer. Includes B-doubles, B-Triples and Road Trains.

Heavy rigid trucks are motor vehicles exceeding 4.5 tonnes gross vehicle mass where the cabin is joined to the load-carrying area. Includes rigid trucks towing a separate trailer.

Gross vehicle mass (GVM) refers to the weight of a fully laden vehicle.

Passenger car/4WD includes the following vehicle types: Sedan/Sports/Coupe, Station wagon, Hatchback/Liftback, Convertible, Undefined car, Utility based on car design, Panel van based on car design, Forward control passenger van (3 rows of seats), 4WD not based on car design.

Motorcycle/Bicycle includes the following vehicle types: Motorcycle, Trail Bike, Moped, Quad Bike, Bicycle/Tricycle.

• Figures for motorcycle/bicycle include deaths/injuries to passengers.

• Where multiple trucks are involved in a crash it is not possible to identify which truck was involved in the under run.

These cases are counted in both the heavy rigid and articulated truck categories and are also noted separately.

• Figures do not necessarily represent all such fatal or serious injury crashes that occurred in the period specified.

Sources

Tables 1-2
Australian Transport Safety Bureau (ATSB), 2003. *Fatal Road Crash Database*.

Tables 3-7
Australian Transport Safety Bureau (ATSB), 2007. *Fatal Road Crash Database*.

SUMMARY OF FCD UNDERRUN CRASHES
Resulting in

FATALITIES	1988/ 1990	**1992**	**1994**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**Average**
With cars and 4WDs												
Rigid Truck	10.5/ 16	7	18	9	11	17	13.5	6.5	6.5	7.5	1	10
Artic Truck	37.5/ 37	9	32	13	6	12	19.5	18.5	16.5	10.5	5	18
With motorcycle/bicycle												
Rigid Truck	5/ 3	1	3	3	4	3	3	3.5	4	3	2	3
Artic Truck	5/ 9	2	0	2	2	4	5	3.5	3	5	3	4
Rigid Truck Total	15.5/ 19	8	21	12	15	20	16.5	10	10.5	10.5	3	13
Artic Truck Total	42.5/ 46	11	32	15	8	16	24.5	22	19.5	15.5	8	22
TOTAL FATALITIES	**58/65**	**19**	**53**	**27**	**23**	**36**	**41**	**32**	**30**	**26**	**11**	**35**

SERIOUS INURIES	1988/ 1990	1992	1994	1996	1997	1998	1999	2000	2001	2002	2003	Average
With cars and 4WDs												
Rigid Truck	71/ 108	47	122	61	74	115	91	44	44	51	7	69
Artic Truck	253/ 250	61	216	88	41	81	132	125	111	71	34	122
With motorcycle/bicycle												
Rigid Truck	34/ 20	7	20	20	27	20	20	24	27	20	14	21
Artic Truck	34/ 61	14	0	14	14	27	34	24	20	34	20	24
Rigid Truck Total	105/ 128	54	142	81	101	135	111	68	71	71	20	24
Artic Truck Total	287/ 311	74	216	101	54	108	165	149	132	105	54	146
TOTAL SERIOUS INJURIES	**392/ 439**	**128**	**358**	**182**	**155**	**243**	**277**	**216**	**203**	**176**	**74**	**237**

MINOR INURIES	**1988/ 1990**	**1992**	**1994**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**Average**
With cars and 4WDs												
Rigid Truck	163/ 248	109	279	140	171	264	210	101	101	116	16	160
Artic Truck	582/ 574	140	497	202	93	186	303	287	256	163	78	280

With motorcycle/bicycle												
Rigid Truck	78/ 47	16	47	47	62	47	47	54	62	47	31	49
Artic Truck	78/ 140	31	0	31	31	62	78	54	47	78	47	56
Rigid Truck Total	241/ 295	124	326	186	233	311	256	155	163	163	47	208
Artic Truck Total	660/ 714	171	497	233	124	248	380	342	303	241	124	336
TOTAL MINOR INJURIES	**900/ 1009**	**295**	**823**	**419**	**357**	**559**	**637**	**497**	**466**	**404**	**171**	**545**

Source: ATSB FCD, 1988 – 2003

BREAK-UP OF UNDERRUN INJURIES

FATAL INJURIES					
Crash type	**Total**	**Front**	**Side**	**Rear**	**Front/side**
Proportions		66%	18%	7%	10%
Rigid Truck	13	9	2	1	1
Proportions		65%	15%	5%	15%
Articulated Truck	22	14	3	1	3

SERIOUS INJURIES					
Crash type	**Total**	**Front**	**Side**	**Rear**	**Front/side**
Proportions		66%	18%	7%	10%
Rigid Truck	91	60	16	6	9
Proportions		65%	15%	5%	15%
Articulated Truck	146	95	22	7	22

MINOR INJURIES					
Crash type	**Total**	**Front**	**Side**	**Rear**	**Front/side**
Proportions		66%	18%	7%	10%
Rigid Truck	208	137	37	15	21
Proportions		65%	15%	5%	15%
Articulated Truck	336	219	50	17	50

Source: ATSB FCD, 1988 - 2003, Serious injuries estimated from Haworth et al (2002) and NSW, VIC and QLD databases. Minor injuries from Haworth et al (2002)

UNIT COST OF HEAVY VEHICLE CRASHES							
	(2005$)			**(2005$)**		**(2009$)**	
Crash	**Passenger vehicle**	**Passenger vehicle (per person injured)**	**Passenger vehicle (other than person)**	**Heavy vehicle (per person injured)**	**Heavy vehicle (other than person)**	**Heavy vehicle (per person injured)**	**Heavy vehicle (other thar person)**
Fatal	$1,652,994	$1,500,000	$152,994	$1,500,000	$229,491	$2,597,515	$397,404
Serious	$407,990	$325,000	$82,990	$325,000	$124,485	$562,795	$215,568
Minor	$13,776	$11,611	$2,165	$11,611	$3,248	$20,106	$5,624

Property damage	$5,808	$0	$5,808	$0	$8,712	$0	$15,086

Source: BTE Report 102 and other reports/studies

Note: Heavy vehicle crashes cost 50% more than passenger car crashes (Neville Inquiry). There are two components in the cost resulting from a heavy vehicle crash, one relates to the injury to persons and other relates to heavy vehicle damages and immobility. The BTRE Report provides a value (fatal, serious and minor injuries) while Sweatman et al, 1995, Carney, 1991 and the Neville Inquiry provide values for the second component. They range from 1.5 to 2 times that for a passenger vehicle crash. This analysis uses a value of 1.5 times that of a passenger vehicle crash. Heavy vehicle (other than person) = 1.5 times (Passenger vehicle (other than person))

ESTIMATED COST OF UNDERRUN CRASHES (2009$)				
PERSONS (Trauma) **Rigid Trucks**				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$26,485,991	$6,272,998	$2,439,499	$35,198,488
Serious	$38,735,762	$9,174,259	$3,567,768	$51,477,789
Minor	$348,513	$65,346	$21,782	$435,641
All injuries	$65,570,266	$15,512,604	$6,029,049	$87,111,918
Articulated Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$45,023,588	$8,441,923	$2,813,974	$56,279,485
Serious	$65,846,997	$12,346,312	$4,115,437	$82,308,746
Minor	$5,410,658	$1,014,498	$338,166	$1,014,498
All injuries	$116,281,242	$21,802,733	$7,267,578	$139,602,729
All Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$71,509,579	$14,714,921	$5,253,473	$91,477,973
Serious	$104,582,759	$21,520,571	$7,683,205	$133,786,535
Minor	$5,759,170	$1,079,844	$359,948	$1,450,139
All injuries	$181,851,509	$37,315,336	$13,296,626	$226,714,647

OTHER THAN PERSONS (Non-Trauma) **Rigid Trucks**				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$4,052,198	$959,731	$373,229	$5,385,158
Serious	$14,836,989	$3,514,024	$1,952,235	$20,303,248
Minor	$97,476	$18,277	$6,092	$121,845
All injuries	$18,986,663	$4,492,031	$2,331,556	$25,810,250
Articulated Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$6,888,339	$1,291,564	$430,521	$8,610,423
Serious	$25,221,426	$4,729,017	$1,576,339	$31,526,782
Minor	$567,493	$94,582	$283,747	$945,822
All injuries	$32,677,258	$6,115,163	$2,290,607	$41,083,028
All Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$10,940,537	$2,251,295	$803,750	$13,995,581

Serious	$40,058,415	$8,243,041	$3,528,574	$51,830,030
Minor	$664,970	$112,859	$289,839	$1,067,668
All injuries	$51,663,921	$10,607,195	$4,622,163	$66,893,279

Note: Estimated cost of underrun crashes = cost of injuries to persons and costs to other than persons (includes truck damage and immobility)

7. Calculate the possible overall yearly benefit from installing UP devices to the whole fleet;
   - Multiply the yearly injury numbers and types (fatal, serious, minor) by the effectiveness of the UP devices for each effectiveness scenario,
   - Cascade any reduction in injury down to the next level ie fatal injuries saved become serious injuries, serious injuries saved become minor injuries (note that minor injuries are not cascaded to injury free),
   - Take the reduced injury numbers away from the original injury numbers to get the net reduction in injuries.

The four effectiveness rates for UP devices A, B, C and D above where estimated for 100 per cent fitment to new vehicles (Option 8 mandatory standards). This was then repeated for a 15 per cent UP fitment rate to new vehicles (refer Table 12) (Option 1 self regulation) as a comparison.

Scenario A

Total Benefits from UP (2009$) (Trauma and Non-Trauma)				
Rigid Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$7,634,547	$1,464,628	$970,391	$10,069,566
Serious	$17,166,992	$3,531,257	$2,296,392	$22,994,641
Minor	$0	$0	$0	$0
All injuries	$24,801,539	$4,995,885	$3,266,783	$33,064,207
Articulated Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$12,977,982	$1,971,031	$1,119,351	$16,068,363
Serious	$29,182,202	$4,752,209	$2,345,534	$36,279,946
Minor	$0	$0	$0	$0
All injuries	$42,160,184	$6,723,240	$3,464,885	$52,348,309
All Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$20,612,529	$3,435,659	$2,089,742	$26,137,929
Serious	$46,349,194	$8,283,467	$4,641,926	$59,274,587
Minor	$0	$0	$0	$0
All injuries	$66,961,723	$11,719,125	$6,731,668	$85,412,516

Scenario B

Total Benefits from UP (2009$) (Trauma and Non-Trauma)				
Rigid Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$9,092,052	$1,808,182	$1,103,996	$12,004,230
Serious	$19,422,927	$4,227,995	$2,578,828	$26,229,750
Minor	$0	$0	$0	$0
All injuries	$28,514,979	$6,036,177	$3,682,824	$38,233,979
Articulated Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$15,455,596	$2,433,372	$1,273,464	$19,162,432
Serious	$33,017,071	$5,689,848	$2,633,687	$41,340,606
Minor	$0	$0	$0	$0
All injuries	$48,472,667	$8,123,219	$3,907,151	$60,503,038
All Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$24,547,648	$4,241,554	$2,377,460	$31,166,662
Serious	$52,439,998	$9,917,842	$5,212,515	$67,570,355
Minor	$0	$0	$0	$0
All injuries	$76,987,646	$14,159,396	$7,589,975	$98,737,017

Scenario C

Total Benefits from UP (2009$) (Trauma and Non-Trauma)				
Rigid Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$10,688,366	$2,151,737	$1,237,600	$14,077,703
Serious	$21,652,777	$4,797,849	$2,829,722	$29,280,348
Minor	$0	$0	$0	$0
All injuries	$32,341,144	$6,949,586	$4,067,322	$43,358,052
Articulated Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$18,169,174	$2,895,712	$1,427,578	$22,492,464
Serious	$36,807,598	$6,456,733	$2,889,315	$46,153,646
Minor	$0	$0	$0	$0
All injuries	$54,976,772	$9,352,445	$4,316,893	$68,646,110
All Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$28,857,540	$5,047,449	$2,665,178	$36,570,168
Serious	$58,460,375	$11,254,582	$5,719,037	$75,433,994
Minor	$0	$0	$0	$0
All injuries	$87,317,916	$16,302,031	$8,384,215	$112,004,162

Scenario D

Total Benefits from UP (2009$) (Trauma and Non-Trauma)				
Rigid Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$11,937,656	$2,495,291	$1,385,269	$15,818,216
Serious	$24,245,466	$5,367,704	$3,077,973	$32,691,142
Minor	$0	$0	$0	$0
All injuries	$36,183,122	$7,862,995	$4,463,241	$48,509,358
Articulated Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$20,292,844	$3,358,053	$1,597,914	$25,248,811
Serious	$41,214,914	$7,223,618	$3,141,895	$51,580,427
Minor	$0	$0	$0	$0
All injuries	$61,507,758	$10,581,670	$4,739,809	$76,829,238
All Trucks				
Injury	**Front**	**Side**	**Rear**	**Total**
Fatal	$32,230,500	$5,853,344	$2,983,182	$41,067,026
Serious	$65,460,380	$12,591,321	$6,219,868	$84,271,569
Minor	$0	$0	$0	$0
All injuries	$97,690,880	$18,444,666	$9,203,050	$125,338,596

8. Calculate the Net Benefits and Benefit-Cost Ratios for installing UP devices progressively to the whole fleet through new registrations for each device effectiveness scenario.

Determine the fleet registration and crash profile

- Establish a general profile of the vehicle fleet made up of, for any given year of vehicle age up to 20 years old, the number of new registrations as a proportion of the cumulative fleet over the entire period, divided in to the number of fatal or injury crashes as a proportion of the cumulative number of fatal or injury crashes over the same period,
- For any given year after year zero (first registration), reduce the proportions by the generic time discount factor of $(1 + d)^n$,
- Add the proportions up for each year that the safety device of interest has been fitted,
- Multiply the final result by the estimated net saving in injuries established at point 7,
- Calculate the cost to fit the safety device of interest to newly registered vehicles,
- Calculate the Net Present Values of the benefits and costs.
- Calculate the Net Benefits and Benefit-Cost Ratios.

Scenario A - Low Effectiveness Barrier

Rigid Trucks			Front				Side				Rear		
Period (yrs)	**Rate**	**Multiplier**	**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**		**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**		**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**
10	4%	0.4190	$3,365,954	$7,025,041	1.479		-$8,016,193	$10,109,297	0.207		-$10,973,050	$12,341,720	0.1109
10	5%	0.4000	$2,894,836	$7,025,041	1.412		-$8,111,092	$10,109,297	0.198		-$11,035,105	$12,341,720	0.1059
10	6%	0.3823	$2,456,989	$7,025,041	1.350		-$8,199,290	$10,109,297	0.189		-$11,092,776	$12,341,720	0.1012
10	7%	0.3659	$2,049,543	$7,025,041	1.292		-$8,281,363	$10,109,297	0.181		-$11,146,444	$12,341,720	0.0968
10	12%	0.2988	$386,063	$7,025,041	1.055		-$8,616,445	$10,109,297	0.148		-$11,365,552	$12,341,720	0.0791
15	4%	0.5769	$7,283,090	$7,025,041	2.037		-$7,227,147	$10,109,297	0.285		-$10,457,097	$12,341,720	0.1527
15	5%	0.5396	$6,358,027	$7,025,041	1.905		-$7,413,486	$10,109,297	0.267		-$10,578,944	$12,341,720	0.1428
15	6%	0.5059	$5,522,966	$7,025,041	1.786		-$7,581,696	$10,109,297	0.250		-$10,688,935	$12,341,720	0.1339
15	7%	0.4755	$4,767,447	$7,025,041	1.679		-$7,733,884	$10,109,297	0.235		-$10,788,450	$12,341,720	0.1259
15	12%	0.3600	$1,902,275	$7,025,041	1.271		-$8,311,028	$10,109,297	0.178		-$11,165,842	$12,341,720	0.0953
20	4%	0.6593	$9,327,544	$7,025,041	2.328		-$6,815,323	$10,109,297	0.326		-$10,187,808	$12,341,720	0.1745
20	5%	0.6093	$8,086,169	$7,025,041	2.151		-$7,065,379	$10,109,297	0.301		-$10,351,318	$12,341,720	0.1613
20	6%	0.5649	$6,986,308	$7,025,041	1.994		-$7,286,929	$10,109,297	0.279		-$10,496,188	$12,341,720	0.1495
20	7%	0.5255	$6,008,703	$7,025,041	1.855		-$7,483,852	$10,109,297	0.260		-$10,624,955	$12,341,720	0.1391
20	12%	0.3825	$2,460,955	$7,025,041	1.350		-$8,198,491	$10,109,297	0.189		-$11,092,254	$12,341,720	0.1012
25	4%	0.6829	$9,912,682	$7,025,041	2.411		-$6,697,456	$10,109,297	0.337		-$10,110,735	$12,341,720	0.1808
25	5%	0.6283	$8,558,276	$7,025,041	2.218		-$6,970,280	$10,109,297	0.311		-$10,289,133	$12,341,720	0.1663
25	6%	0.5803	$7,368,058	$7,025,041	2.049		-$7,210,031	$10,109,297	0.287		-$10,445,905	$12,341,720	0.1536
25	7%	0.5380	$6,318,055	$7,025,041	1.899		-$7,421,538	$10,109,297	0.266		-$10,584,209	$12,341,720	0.1424
25	12%	0.3870	$2,572,448	$7,025,041	1.366		-$8,176,032	$10,109,297	0.191		-$11,077,568	$12,341,720	0.1024

Articulated Trucks			Front				Side				Rear		
Period (yrs)	**Rate**	**Multiplier**	**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**		**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**		**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**
10	4%	0.4190	$15,177,927	$2,485,745	7.106		-$3,170,915	$5,987,722	0.470		-$2,915,335	$4,367,003	0.3324
10	5%	0.4000	$14,377,072	$2,485,745	6.784		-$3,298,626	$5,987,722	0.449		-$2,981,152	$4,367,003	0.3173
10	6%	0.3823	$13,632,776	$2,485,745	6.484		-$3,417,318	$5,987,722	0.429		-$3,042,321	$4,367,003	0.3033
10	7%	0.3659	$12,940,158	$2,485,745	6.206		-$3,527,769	$5,987,722	0.411		-$3,099,243	$4,367,003	0.2903
10	12%	0.2988	$10,112,406	$2,485,745	5.068		-$3,978,708	$5,987,722	0.336		-$3,331,639	$4,367,003	0.237
15	4%	0.5769	$21,836,675	$2,485,745	9.785		-$2,109,051	$5,987,722	0.648		-$2,368,093	$4,367,003	0.4577
15	5%	0.5396	$20,264,158	$2,485,745	9.152		-$2,359,819	$5,987,722	0.606		-$2,497,329	$4,367,003	0.4281
15	6%	0.5059	$18,844,636	$2,485,745	8.581		-$2,586,188	$5,987,722	0.568		-$2,613,990	$4,367,003	0.4014
15	7%	0.4755	$17,560,328	$2,485,745	8.064		-$2,790,996	$5,987,722	0.534		-$2,719,540	$4,367,003	0.3773
15	12%	0.3600	$12,689,816	$2,485,745	6.105		-$3,567,691	$5,987,722	0.404		-$3,119,817	$4,367,003	0.2856
20	4%	0.6593	$25,312,045	$2,485,745	11.183		-$1,554,838	$5,987,722	0.740		-$2,082,474	$4,367,003	0.5231
20	5%	0.6093	$23,201,830	$2,485,745	10.334		-$1,891,351	$5,987,722	0.684		-$2,255,900	$4,367,003	0.4834
20	6%	0.5649	$21,332,175	$2,485,745	9.582		-$2,189,503	$5,987,722	0.634		-$2,409,555	$4,367,003	0.4482
20	7%	0.5255	$19,670,342	$2,485,745	8.913		-$2,454,514	$5,987,722	0.590		-$2,546,131	$4,367,003	0.4170
20	12%	0.3825	$13,639,518	$2,485,745	6.487		-$3,416,243	$5,987,722	0.429		-$3,041,767	$4,367,003	0.3035
25	4%	0.6829	$26,306,723	$2,485,745	11.583		-$1,396,217	$5,987,722	0.767		-$2,000,728	$4,367,003	0.5419
25	5%	0.6283	$24,004,366	$2,485,745	10.657		-$1,763,372	$5,987,722	0.706		-$2,189,944	$4,367,003	0.4985
25	6%	0.5803	$21,981,111	$2,485,745	9.843		-$2,086,018	$5,987,722	0.652		-$2,356,223	$4,367,003	0.4604
25	7%	0.5380	$20,196,210	$2,485,745	9.125		-$2,370,654	$5,987,722	0.604		-$2,502,913	$4,367,003	0.4269
25	12%	0.3870	$13,829,045	$2,485,745	6.563		-$3,386,020	$5,987,722	0.435		-$3,026,191	$4,367,003	0.3070

Scenario B - Most Likely Effectiveness Barrier

Rigid Trucks			**Front**			**Side**			**Rear**		
Period (yrs)	**Rate**	**Multiplier**	**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**	**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**	**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**
10	4%	0.4190	$4,921,758	$7,025,041	1.701	-$7,580,346	$10,109,297	0.250	-$10,798,743	$12,341,720	0.125
10	5%	0.4000	$4,380,101	$7,025,041	1.623	-$7,695,006	$10,109,297	0.239	-$10,868,700	$12,341,720	0.1194
10	6%	0.3823	$3,876,697	$7,025,041	1.552	-$7,801,569	$10,109,297	0.228	-$10,933,717	$12,341,720	0.1141
10	7%	0.3659	$3,408,246	$7,025,041	1.485	-$7,900,733	$10,109,297	0.218	-$10,994,219	$12,341,720	0.1092
10	12%	0.2988	$1,495,700	$7,025,041	1.213	-$8,305,589	$10,109,297	0.178	-$11,241,232	$12,341,720	0.089
15	4%	0.5769	$9,425,392	$7,025,041	2.342	-$6,626,997	$10,109,297	0.344	-$10,217,081	$12,341,720	0.1722
15	5%	0.5396	$8,361,822	$7,025,041	2.190	-$6,852,138	$10,109,297	0.322	-$10,354,445	$12,341,720	0.1610
15	6%	0.5059	$7,401,731	$7,025,041	2.054	-$7,055,374	$10,109,297	0.302	-$10,478,445	$12,341,720	0.1510
15	**7%**	**0.4755**	**$6,533,091**	**$7,025,041**	**1.930**	**-$7,239,252**	**$10,109,297**	**0.284**	**-$10,590,633**	**$12,341,720**	**0.1419**
15	12%	0.3600	$3,238,928	$7,025,041	1.461	-$7,936,575	$10,109,297	0.215	-$11,016,088	$12,341,720	0.1074
20	4%	0.6593	$11,775,954	$7,025,041	2.676	-$6,129,420	$10,109,297	0.394	-$9,913,496	$12,341,720	0.1967
20	5%	0.6093	$10,348,713	$7,025,041	2.473	-$6,431,544	$10,109,297	0.364	-$10,097,830	$12,341,720	0.1818
20	6%	0.5649	$9,084,174	$7,025,041	2.293	-$6,699,227	$10,109,297	0.337	-$10,261,151	$12,341,720	0.1686
20	7%	0.5255	$7,960,196	$7,025,041	2.133	-$6,937,156	$10,109,297	0.314	-$10,406,317	$12,341,720	0.1568
20	12%	0.3825	$3,881,257	$7,025,041	1.552	-$7,800,604	$10,109,297	0.228	-$10,933,128	$12,341,720	0.1141
25	4%	0.6829	$12,448,703	$7,025,041	2.772	-$5,987,009	$10,109,297	0.408	-$9,826,608	$12,341,720	0.2038
25	5%	0.6283	$10,891,507	$7,025,041	2.550	-$6,316,643	$10,109,297	0.375	-$10,027,726	$12,341,720	0.1875
25	6%	0.5803	$9,523,081	$7,025,041	2.356	-$6,606,318	$10,109,297	0.347	-$10,204,464	$12,341,720	0.1732
25	7%	0.5380	$8,315,866	$7,025,041	2.184	-$6,861,866	$10,109,297	0.321	-$10,360,381	$12,341,720	0.1605
25	12%	0.3870	$4,009,443	$7,025,041	1.571	-$7,773,469	$10,109,297	0.231	-$10,916,572	$12,341,720	0.1155

Articulated Trucks			**Front**				**Side**				**Rear**		
Period (yrs)	**Rate**	**Multiplier**	**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**		**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**		**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**
10	4%	0.4190	$17,822,641	$2,485,745	8.170		-$2,584,372	$5,987,722	0.568		-$2,730,040	$4,367,003	0.3748
10	5%	0.4000	$16,901,878	$2,485,745	7.800		-$2,738,676	$5,987,722	0.543		-$2,804,259	$4,367,003	0.3579
10	6%	0.3823	$16,046,140	$2,485,745	7.455		-$2,882,084	$5,987,722	0.519		-$2,873,236	$4,367,003	0.3421
10	7%	0.3659	$15,249,819	$2,485,745	7.135		-$3,015,534	$5,987,722	0.496		-$2,937,423	$4,367,003	0.3274
10	12%	0.2988	$11,998,679	$2,485,745	5.827		-$3,560,372	$5,987,722	0.405		-$3,199,482	$4,367,003	0.267
15	4%	0.5769	$25,478,378	$2,485,745	11.250		-$1,301,396	$5,987,722	0.783		-$2,112,948	$4,367,003	0.5162
15	5%	0.5396	$23,670,414	$2,485,745	10.522		-$1,604,381	$5,987,722	0.732		-$2,258,679	$4,367,003	0.4828
15	6%	0.5059	$22,038,353	$2,485,745	9.866		-$1,877,888	$5,987,722	0.686		-$2,390,232	$4,367,003	0.4527
15	**7%**	**0.4755**	**$20,561,750**	**$2,485,745**	**9.272**		**-$2,125,342**	**$5,987,722**	**0.645**		**-$2,509,254**	**$4,367,003**	**0.4254**
15	12%	0.3600	$14,961,995	$2,485,745	7.019		-$3,063,769	$5,987,722	0.488		-$2,960,623	$4,367,003	0.3220
20	4%	0.6593	$29,474,102	$2,485,745	12.857		-$631,779	$5,987,722	0.894		-$1,790,871	$4,367,003	0.5899
20	5%	0.6093	$27,047,933	$2,485,745	11.881		-$1,038,365	$5,987,722	0.827		-$1,986,433	$4,367,003	0.5451
20	6%	0.5649	$24,898,341	$2,485,745	11.016		-$1,398,601	$5,987,722	0.766		-$2,159,702	$4,367,003	0.5054
20	7%	0.5255	$22,987,688	$2,485,745	10.248		-$1,718,795	$5,987,722	0.713		-$2,313,710	$4,367,003	0.4702
20	12%	0.3825	$16,053,892	$2,485,745	7.458		-$2,880,785	$5,987,722	0.519		-$2,872,611	$4,367,003	0.3422
25	4%	0.6829	$30,617,710	$2,485,745	13.317		-$440,129	$5,987,722	0.926		-$1,698,691	$4,367,003	0.6110
25	5%	0.6283	$27,970,629	$2,485,745	12.252		-$883,736	$5,987,722	0.852		-$1,912,059	$4,367,003	0.5622
25	6%	0.5803	$25,644,440	$2,485,745	11.317		-$1,273,567	$5,987,722	0.787		-$2,099,562	$4,367,003	0.5192
25	7%	0.5380	$23,592,292	$2,485,745	10.491		-$1,617,473	$5,987,722	0.730		-$2,264,976	$4,367,003	0.4813
25	12%	0.3870	$16,271,796	$2,485,745	7.546		-$2,844,268	$5,987,722	0.525		-$2,855,046	$4,367,003	0.3462

Scenario C - High Effectiveness Barrier

Rigid Trucks			**Front**				**Side**				**Rear**		
Period (yrs)	**Rate**	**Multiplier**	**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**		**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**		**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**
10	4%	0.4190	$6,524,790	$7,025,041	1.929		-$7,197,659	$10,109,297	0.288		-$10,637,652	$12,341,720	0.1381
10	5%	0.4000	$5,910,453	$7,025,041	1.841		-$7,329,670	$10,109,297	0.275		-$10,714,913	$12,341,720	0.1318
10	6%	0.3823	$5,339,502	$7,025,041	1.760		-$7,452,358	$10,109,297	0.263		-$10,786,717	$12,341,720	0.1260
10	7%	0.3659	$4,808,193	$7,025,041	1.684		-$7,566,528	$10,109,297	0.252		-$10,853,536	$12,341,720	0.1206
10	12%	0.2988	$2,639,020	$7,025,041	1.376		-$8,032,648	$10,109,297	0.205		-$11,126,338	$12,341,720	0.0985
15	4%	0.5769	$11,632,725	$7,025,041	2.656		-$6,100,047	$10,109,297	0.397		-$9,995,262	$12,341,720	0.1901
15	5%	0.5396	$10,426,445	$7,025,041	2.484		-$6,359,257	$10,109,297	0.371		-$10,146,967	$12,341,720	0.1778
15	6%	0.5059	$9,337,528	$7,025,041	2.329		-$6,593,247	$10,109,297	0.348		-$10,283,913	$12,341,720	0.1667
15	7%	0.4755	$8,352,333	$7,025,041	2.189		-$6,804,950	$10,109,297	0.327		-$10,407,814	$12,341,720	0.1567
15	12%	0.3600	$4,616,156	$7,025,041	1.657		-$7,607,793	$10,109,297	0.247		-$10,877,687	$12,341,720	0.1186
20	4%	0.6593	$14,298,688	$7,025,041	3.035		-$5,527,175	$10,109,297	0.453		-$9,659,982	$12,341,720	0.2173
20	5%	0.6093	$12,679,938	$7,025,041	2.805		-$5,875,018	$10,109,297	0.419		-$9,863,561	$12,341,720	0.2008
20	6%	0.5649	$11,245,723	$7,025,041	2.601		-$6,183,207	$10,109,297	0.388		-$10,043,933	$12,341,720	0.1862
20	7%	0.5255	$9,970,928	$7,025,041	2.419		-$6,457,140	$10,109,297	0.361		-$10,204,255	$12,341,720	0.1732
20	12%	0.3825	$5,344,674	$7,025,041	1.761		-$7,451,247	$10,109,297	0.263		-$10,786,067	$12,341,720	0.1260
25	4%	0.6829	$15,061,707	$7,025,041	3.144		-$5,363,214	$10,109,297	0.469		-$9,564,023	$12,341,720	0.2251
25	5%	0.6283	$13,295,565	$7,025,041	2.893		-$5,742,730	$10,109,297	0.432		-$9,786,138	$12,341,720	0.2071
25	6%	0.5803	$11,743,523	$7,025,041	2.672		-$6,076,238	$10,109,297	0.399		-$9,981,328	$12,341,720	0.1913
25	7%	0.5380	$10,374,322	$7,025,041	2.477		-$6,370,457	$10,109,297	0.370		-$10,153,523	$12,341,720	0.1773
25	12%	0.3870	$5,490,060	$7,025,041	1.781		-$7,420,006	$10,109,297	0.266		-$10,767,783	$12,341,720	0.1275

Articulated Trucks			Front				Side				Rear		
Period (yrs)	Rate	Multiplier	NPV Benefits (2009$)	Cost (2009$)	BCR		NPV Benefits (2009$)	Cost (2009$)	BCR		NPV Benefits (2009$)	Cost (2009$)	BCR
10	4%	0.4190	$20,547,638	$2,485,745	9.266		-$2,069,368	$5,987,722	0.654		-$2,558,372	$4,367,003	0.4142
10	5%	0.4000	$19,503,326	$2,485,745	8.846		-$2,247,023	$5,987,722	0.625		-$2,640,374	$4,367,003	0.3954
10	6%	0.3823	$18,532,765	$2,485,745	8.456		-$2,412,131	$5,987,722	0.597		-$2,716,585	$4,367,003	0.3779
10	7%	0.3659	$17,629,593	$2,485,745	8.092		-$2,565,775	$5,987,722	0.571		-$2,787,504	$4,367,003	0.3617
10	12%	0.2988	$13,942,212	$2,485,745	6.609		-$3,193,059	$5,987,722	0.467		-$3,077,045	$4,367,003	0.2954
15	4%	0.5769	$29,230,628	$2,485,745	12.759		-$592,250	$5,987,722	0.901		-$1,876,566	$4,367,003	0.5703
15	5%	0.5396	$27,180,070	$2,485,745	11.934		-$941,083	$5,987,722	0.843		-$2,037,580	$4,367,003	0.5334
15	6%	0.5059	$25,329,018	$2,485,745	11.190		-$1,255,978	$5,987,722	0.790		-$2,182,928	$4,367,003	0.5001
15	7%	0.4755	$23,654,283	$2,485,745	10.516		-$1,540,877	$5,987,722	0.743		-$2,314,432	$4,367,003	0.4700
15	12%	0.3600	$17,303,148	$2,485,745	7.961		-$2,621,309	$5,987,722	0.562		-$2,813,137	$4,367,003	0.3558
20	4%	0.6593	$33,762,503	$2,485,745	14.582		$178,696	$5,987,722	1.030		-$1,520,713	$4,367,003	0.6518
20	5%	0.6093	$31,010,787	$2,485,745	13.475		-$289,416	$5,987,722	0.952		-$1,736,784	$4,367,003	0.6023
20	6%	0.5649	$28,572,762	$2,485,745	12.495		-$704,164	$5,987,722	0.882		-$1,928,223	$4,367,003	0.5585
20	7%	0.5255	$26,405,736	$2,485,745	11.623		-$1,072,810	$5,987,722	0.821		-$2,098,382	$4,367,003	0.5195
20	12%	0.3825	$18,541,557	$2,485,745	8.459		-$2,410,635	$5,987,722	0.597		-$2,715,894	$4,367,003	0.3781
25	4%	0.6829	$35,059,560	$2,485,745	15.104		$399,346	$5,987,722	1.067		-$1,418,865	$4,367,003	0.6751
25	5%	0.6283	$32,057,292	$2,485,745	13.896		-$111,388	$5,987,722	0.981		-$1,654,610	$4,367,003	0.6211
25	6%	0.5803	$29,418,973	$2,485,745	12.835		-$560,209	$5,987,722	0.906		-$1,861,776	$4,367,003	0.5737
25	7%	0.5380	$27,091,466	$2,485,745	11.899		-$956,156	$5,987,722	0.840		-$2,044,537	$4,367,003	0.5318
25	12%	0.3870	$18,788,700	$2,485,745	8.559		-$2,368,592	$5,987,722	0.604		-$2,696,488	$4,367,003	0.3825

Scenario D - Energy Absorbing Barrier

Rigid Trucks			Front				Side				Rear		
Period (yrs)	Rate	Multiplier	NPV Benefits (2009$)	Cost (2009$)	BCR		NPV Benefits (2009$)	Cost (2009$)	BCR		NPV Benefits (2009$)	Cost (2009$)	BCR
10	4%	0.4190	-$145,998,852	$161,158,340	0.094		-$157,864,015	$161,158,340	0.020		-$281,255,957	$283,125,902	0.0066
10	5%	0.4000	-$146,686,169	$161,158,340	0.090		-$158,013,376	$161,158,340	0.020		-$281,340,739	$283,125,902	0.0063
10	6%	0.3246	-$149,413,480	$161,158,340	0.073		-$158,606,051	$161,158,340	0.016		-$281,677,157	$283,125,902	0.0051
10	7%	0.3131	-$149,829,572	$161,158,340	0.070		-$158,696,473	$161,158,340	0.015		-$281,728,482	$283,125,902	0.0049
10	12%	0.2260	-$152,981,515	$161,158,340	0.051		-$159,381,425	$161,158,340	0.011		-$282,117,279	$283,125,902	0.0036
15	4%	0.5769	-$140,284,117	$161,158,340	0.130		-$156,622,139	$161,158,340	0.028		-$280,551,036	$283,125,902	0.0091
15	5%	0.5152	-$142,516,930	$161,158,340	0.116		-$157,107,354	$161,158,340	0.025		-$280,826,457	$283,125,902	0.0081
15	6%	0.4627	-$144,416,274	$161,158,340	0.104		-$157,520,103	$161,158,340	0.023		-$281,060,744	$283,125,902	0.0073
15	7%	0.4157	-$146,116,932	$161,158,340	0.093		-$157,889,675	$161,158,340	0.020		-$281,270,522	$283,125,902	0.0066
15	12%	0.3143	-$149,786,851	$161,158,340	0.071		-$158,687,189	$161,158,340	0.015		-$281,723,212	$283,125,902	0.0050
20	4%	0.6593	-$137,301,451	$161,158,340	0.148		-$155,973,973	$161,158,340	0.032		-$280,183,120	$283,125,902	0.0104
20	5%	0.6015	-$139,395,052	$161,158,340	0.135		-$156,428,935	$161,158,340	0.029		-$280,441,369	$283,125,902	0.0095
20	6%	0.5491	-$141,290,252	$161,158,340	0.123		-$156,840,784	$161,158,340	0.027		-$280,675,144	$283,125,902	0.0087
20	7%	0.5024	-$142,978,448	$161,158,340	0.113		-$157,207,647	$161,158,340	0.025		-$280,883,386	$283,125,902	0.0079
20	12%	0.3674	-$147,863,168	$161,158,340	0.082		-$158,269,151	$161,158,340	0.018		-$281,485,923	$283,125,902	0.0058
25	4%	0.6829	-$136,447,789	$161,158,340	0.153		-$155,788,462	$161,158,340	0.033		-$280,077,819	$283,125,902	0.0108
25	5%	0.6263	-$138,498,083	$161,158,340	0.141		-$156,234,014	$161,158,340	0.031		-$280,330,726	$283,125,902	0.0099
25	6%	0.5767	-$140,292,344	$161,158,340	0.129		-$156,623,927	$161,158,340	0.028		-$280,552,051	$283,125,902	0.0091
25	7%	0.5330	-$141,874,499	$161,158,340	0.120		-$156,967,747	$161,158,340	0.026		-$280,747,212	$283,125,902	0.0084
25	12%	0.3842	-$147,258,033	$161,158,340	0.086		-$158,137,649	$161,158,340	0.019		-$281,411,279	$283,125,902	0.0061

Articulated Trucks			Front				Side				Rear		
Period (yrs)	**Rate**	**Multiplier**	**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**		**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**		**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**
10	4%	0.4190	-$16,847,801	$42,617,444	0.605		-$98,224,544	$102,657,901	0.043		-$72,885,283	$74,871,100	0.0265
10	5%	0.4000	-$18,016,173	$42,617,444	0.577		-$98,425,548	$102,657,901	0.041		-$72,975,318	$74,871,100	0.0253
10	6%	0.3823	-$19,102,032	$42,617,444	0.552		-$98,612,357	$102,657,901	0.039		-$73,058,994	$74,871,100	0.0242
10	7%	0.3659	-$20,112,497	$42,617,444	0.528		-$98,786,196	$102,657,901	0.038		-$73,136,861	$74,871,100	0.0232
10	12%	0.2988	-$24,237,921	$42,617,444	0.431		-$99,495,926	$102,657,901	0.031		-$73,454,768	$74,871,100	0.0189
15	4%	0.5769	-$7,133,312	$42,617,444	0.833		-$96,553,283	$102,657,901	0.059		-$72,136,681	$74,871,100	0.0365
15	5%	0.5396	-$9,427,466	$42,617,444	0.779		-$96,947,965	$102,657,901	0.056		-$72,313,469	$74,871,100	0.0342
15	6%	0.5059	-$11,498,415	$42,617,444	0.730		-$97,304,247	$102,657,901	0.052		-$72,473,057	$74,871,100	0.0320
15	7%	0.4755	-$13,372,101	$42,617,444	0.686		-$97,626,592	$102,657,901	0.049		-$72,617,444	$74,871,100	0.0301
15	12%	0.3600	-$20,477,721	$42,617,444	0.519		-$98,849,028	$102,657,901	0.037		-$73,165,006	$74,871,100	0.0228
20	4%	0.6593	-$2,063,072	$42,617,444	0.952		-$95,681,009	$102,657,901	0.068		-$71,745,966	$74,871,100	0.0417
20	5%	0.6093	-$5,141,678	$42,617,444	0.879		-$96,210,646	$102,657,901	0.063		-$71,983,205	$74,871,100	0.0386
20	6%	0.5649	-$7,869,330	$42,617,444	0.815		-$96,679,906	$102,657,901	0.058		-$72,193,399	$74,871,100	0.0358
20	7%	0.5255	-$10,293,789	$42,617,444	0.758		-$97,097,005	$102,657,901	0.054		-$72,380,228	$74,871,100	0.0333
20	12%	0.3825	-$19,092,195	$42,617,444	0.552		-$98,610,665	$102,657,901	0.039		-$73,058,236	$74,871,100	0.0242
25	4%	0.6829	-$611,929	$42,617,444	0.986		-$95,431,358	$102,657,901	0.070		-$71,634,141	$74,871,100	0.0432
25	5%	0.6283	-$3,970,854	$42,617,444	0.907		-$96,009,220	$102,657,901	0.065		-$71,892,981	$74,871,100	0.0398
25	6%	0.5803	-$6,922,592	$42,617,444	0.838		-$96,517,031	$102,657,901	0.060		-$72,120,443	$74,871,100	0.0367
25	7%	0.5380	-$9,526,596	$42,617,444	0.776		-$96,965,019	$102,657,901	0.055		-$72,321,108	$74,871,100	0.0341
25	12%	0.3870	-$18,815,693	$42,617,444	0.558		-$98,563,096	$102,657,901	0.040		-$73,036,929	$74,871,100	0.0245

Summary of Benefit-Costs and Net Benefits

Scenario A - Low Effectiveness Barrier

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
BCR - Rigid	2.4	1.7	1.1	0.3	0.2	0.1	0.2	0.1	0.1
Net benefits ($m per year)	9.9	4.8	0.4	-6.7	-7.7	-8.6	-10.1	-10.8	-11.4
BCR - Articulated	11.6	8.1	5.1	0.8	0.5	0.3	0.5	0.4	0.2
Net benefits ($m per year)	26.3	17.6	10.1	-1.4	-2.8	-4.0	-2.0	-2.7	-3.3

Scenario B - Most Likely Effectiveness Barrier

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
BCR - Rigid	2.8	1.9	1.2	0.4	0.3	0.2	0.2	0.1	0.1
Net benefits ($m per year)	12.4	6.5	1.5	-6.0	-7.2	-8.3	-9.8	-10.6	-11.2
BCR - Articulated	13.3	9.3	5.8	0.9	0.6	0.4	0.6	0.4	0.3
Net benefits ($m per year)	30.6	20.6	12.0	-0.4	-2.1	-3.6	-1.7	-2.5	-3.2

Scenario C - High Effectiveness Barrier

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
BCR - Rigid	3.1	2.2	1.4	0.5	0.3	0.2	0.2	0.2	0.1
Net benefits ($m per year)	15.1	8.4	2.6	-5.4	-6.8	-8.0	-9.6	-10.4	-11.1
BCR - Articulated	15.1	10.5	6.6	1.1	0.7	0.5	0.7	0.5	0.3
Net benefits ($m per year)	35.1	23.7	13.9	0.4	-1.5	-3.2	-1.4	-2.3	-3.1

Scenario D - Energy Absorbing Barrier

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
BCR - Rigid	0.15	0.09	0.05	0.03	0.02	0.01	0.01	0.01	0.00
Net benefits ($m per year)	-136.4	-146.1	-153.0	-155.8	-157.9	-159.4	-280.1	-281.3	-282.1
BCR - Articulated	0.99	0.69	0.43	0.07	0.05	0.03	0.04	0.03	0.02
Net benefits ($m per year)	-0.6	-13.4	-24.2	-95.4	-97.6	-99.5	-71.6	-72.6	-73.5

Best Case - 25 year period @4%, costed for fatalities, injuries and other costs

Likely Case - 15 year period @7%, costed for fatalities, injuries and other costs
Worst Case - 10 year pay-off @12%, costed for fatalities, injuries and other costs

Summary of Benefit-Cost Ratios (BCR) and Net Benefits (2009$) from the provision of UP on new heavy commercial vehicles
Scenarios A, B and C combined

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
BCR - Rigid	3.1	1.9	1.1	0.5	0.3	0.1	0.2	0.1	0.1
Net benefits ($m per year)	15.1	6.5	0.4	-5.4	-7.2	-8.6	-9.6	-10.6	-11.4
BCR - Articulated	15.1	9.3	5.1	1.1	0.6	0.3	0.7	0.4	0.2
Net benefits ($m per year)	35.1	20.6	10.1	0.4	-2.1	-4.0	-1.4	-2.5	-3.3

Sensitivities to cost estimates

Summary of Benefit-Cost Ratios (BCR) from the provision of UP on new heavy commercial vehicles - Scenarios A, B and C combined, plus additional 10% device costs

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
Rigid	2.9	1.8	1.0	0.4	0.3	0.1	0.2	0.1	0.1
Net benefits ($m per year)	14.4	5.8	-0.3	-6.4	-8.3	-9.6	-10.8	-11.8	-12.6
Articulated	13.7	8.4	4.6	1.0	0.6	0.2	0.6	0.4	0.2
Net benefits ($m per year)	34.8	20.3	9.9	-0.2	-2.7	-4.6	-1.9	-2.9	-3.8

Summary of Benefit-Cost Ratios (BCR) from the provision of UP on new heavy commercial vehicles - Scenarios A, B and C combined, plus additional 20% device costs

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
Rigid	2.6	1.6	0.9	0.4	0.2	0.1	0.2	0.1	0.1
Net benefits ($m per year)	13.7	5.1	-1.0	-7.4	-9.3	-10.6	-12.0	-13.1	-13.8
Articulated	12.6	7.7	4.2	0.9	0.5	0.2	0.6	0.4	0.1
Net benefits ($m per year)	34.6	20.1	9.6	-0.8	-3.3	-5.2	-2.3	-3.4	-4.2

Sensitivity of extra load on the axle(s)

Summary of Benefit-Cost Ratios (BCR) and Net Benefits from the provision of UP on new heavy commercial vehicles - Scenarios A, B and C combined, plus productivity loss for articulated trucks*

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
BCR - Rigid									
Net benefits ($m per year)									
BCR - Articulated	10.1	6.2	3.4						
Net benefits ($m per year)	33.8	19.3	8.9						

* Productivity loss due to additional mass of UP on front axle if axle limits are not raised

Summary of Benefit-Cost Ratios (BCR) and Net Benefits from the provision of UP on new heavy commercial vehicles - Scenarios A, B and C combined, plus road wear for articulated trucks**

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
BCR - Rigid									
Net benefits ($m per year)									
BCR - Articulated	10.0	6.1	3.3						
Net benefits ($m per year)	33.8	19.3	8.8						

** Road wear cost due to additional mass of UP on front axle if axle limits are raised

Note. The results were calculated as follows:

Productivity Loss

Articulated trucks, $21.1 m (2009$) productivity loss for the fleet for 100 kg UP device (refer page 41). This is multiplied by the percentage new fleet each year to the total fleet (approx 5 per cent) to give an additional $1.23 m in UP device costs per year). Although this is then calculated through the Benefit-Cost model, it can also be seen by inspection that the Net Benefits are reduced by about this amount.

Road Wear

Articulated trucks, annual cost = 4,829 trucks x 57 542 km (annual distance travelled by articulated trucks) x $0.0046 = $1.28m in UP device costs per year. Although this is then calculated through the Benefit-Cost model, it can also be seen by inspection that the Net Benefits are reduced by about this amount.

Source: ABS (2005) for vehicle numbers, ABS (2002) Year Book Australia for distance travelled, and NTC (2006) for road damage cost.

Option 1 - Self Regulation

Summary of Benefit-Cost Ratios (BCR) and Net Benefits (2009$) from the provision of UP on new heavy commercial vehicles - Scenarios A, B and C combined, but only 15 per cent fitment rate of the UP device

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
Rigid	3.1	1.9	1.1	0.5	0.3	0.1	0.2	0.1	0.1
Net benefits ($m per year)	2.3	1.0	0.1	-0.8	-1.1	-1.3	-1.4	-1.6	0.1
Articulated	15.1	9.3	5.1	1.1	0.6	0.3	0.7	0.4	0.2
Net benefits ($m per year)	5.3	**3.1**	1.5	0.1	-0.3	-0.6	-0.2	-0.4	-0.5

Best Case - 25 year period @4%, costed for fatalities, injuries and other costs

Likely Case - 15 year period @7%, costed for fatalities, injuries and other costs
Worst Case - 10 year pay-off @12%, costed for fatalities, injuries and other costs

Scenario B - Most Likely Effectiveness Barrier - 15 per cent fitment rate of the UP device

Rigid Trucks			**Front**				**Side**				**Rear**		
Period (yrs)	**Rate**	**Multiplier**	**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**		**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**		**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**
10	4%	0.4190	$738,264	$1,053,756	1.701		-$1,137,052	$1,516,395	0.250		-$1,619,811	$1,851,258	0.125
10	5%	0.4000	$657,015	$1,053,756	1.623		-$1,154,251	$1,516,395	0.239		-$1,630,305	$1,851,258	0.1194
10	6%	0.3823	$581,505	$1,053,756	1.552		-$1,170,235	$1,516,395	0.228		-$1,640,058	$1,851,258	0.1141
10	7%	0.3659	$511,237	$1,053,756	1.485		-$1,185,110	$1,516,395	0.218		-$1,649,133	$1,851,258	0.1092
10	12%	0.2988	$224,355	$1,053,756	1.213		-$1,245,838	$1,516,395	0.178		-$1,686,185	$1,851,258	0.089
15	4%	0.5769	$1,413,809	$1,053,756	2.342		-$994,050	$1,516,395	0.344		-$1,532,562	$1,851,258	0.1722
15	5%	0.5396	$1,254,273	$1,053,756	2.190		-$1,027,821	$1,516,395	0.322		-$1,553,167	$1,851,258	0.1610
15	6%	0.5059	$1,110,260	$1,053,756	2.054		-$1,058,306	$1,516,395	0.302		-$1,571,767	$1,851,258	0.1510
15	**7%**	**0.4755**	**$979,964**	**$1,053,756**	**1.930**		-$1,085,888	$1,516,395	0.284		-$1,588,595	$1,851,258	0.1419
15	12%	0.3600	$485,839	$1,053,756	1.461		-$1,190,486	$1,516,395	0.215		-$1,652,413	$1,851,258	0.1074
20	4%	0.6593	$1,766,393	$1,053,756	2.676		-$919,413	$1,516,395	0.394		-$1,487,024	$1,851,258	0.1967
20	5%	0.6093	$1,552,307	$1,053,756	2.473		-$964,732	$1,516,395	0.364		-$1,514,675	$1,851,258	0.1818

20	7%	0.5255	$1,194,029	$1,053,756	2.133		-$1,040,573	$1,516,395	0.314		-$1,560,948	$1,851,258	0.1568
20	12%	0.3825	$582,189	$1,053,756	1.552		-$1,170,091	$1,516,395	0.228		-$1,639,969	$1,851,258	0.1141
25	4%	0.6829	$1,867,305	$1,053,756	2.772		-$898,051	$1,516,395	0.408		-$1,473,991	$1,851,258	0.2038
25	5%	0.6283	$1,633,726	$1,053,756	2.550		-$947,496	$1,516,395	0.375		-$1,504,159	$1,851,258	0.1875
25	6%	0.5803	$1,428,462	$1,053,756	2.356		-$990,948	$1,516,395	0.347		-$1,530,670	$1,851,258	0.1732
25	7%	0.5380	$1,247,380	$1,053,756	2.184		-$1,029,280	$1,516,395	0.321		-$1,554,057	$1,851,258	0.1605
25	12%	0.3870	$601,416	$1,053,756	1.571		-$1,166,020	$1,516,395	0.231		-$1,637,486	$1,851,258	0.1155

Articulated Trucks			Front				Side				Rear		
Period (yrs)	**Rate**	**Multiplier**	**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**		**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**		**NPV Benefits (2009$)**	**Cost (2009$)**	**BCR**
10	4%	0.4190	$2,673,396	$372,862	8.170		-$387,656	$898,158	0.568		-$409,506	$655,050	0.3748
10	5%	0.4000	$2,535,282	$372,862	7.800		-$410,801	$898,158	0.543		-$420,639	$655,050	0.3579
10	6%	0.3823	$2,406,921	$372,862	7.455		-$432,313	$898,158	0.519		-$430,985	$655,050	0.3421
10	7%	0.3659	$2,287,473	$372,862	7.135		-$452,330	$898,158	0.496		-$440,613	$655,050	0.3274
10	12%	0.2988	$1,799,802	$372,862	5.827		-$534,056	$898,158	0.405		-$479,922	$655,050	0.267
15	4%	0.5769	$3,821,757	$372,862	11.250		-$195,209	$898,158	0.783		-$316,942	$655,050	0.5162
15	5%	0.5396	$3,550,562	$372,862	10.522		-$240,657	$898,158	0.732		-$338,802	$655,050	0.4828
15	6%	0.5059	$3,305,753	$372,862	9.866		-$281,683	$898,158	0.686		-$358,535	$655,050	0.4527
15	**7%**	**0.4755**	**$3,084,263**	**$372,862**	**9.272**		-$318,801	$898,158	0.645		-$376,388	$655,050	0.4254
15	12%	0.3600	$2,244,299	$372,862	7.019		-$459,565	$898,158	0.488		-$444,093	$655,050	0.3220
20	4%	0.6593	$4,421,115	$372,862	12.857		-$94,767	$898,158	0.894		-$268,631	$655,050	0.5899
20	5%	0.6093	$4,057,190	$372,862	11.881		-$155,755	$898,158	0.827		-$297,965	$655,050	0.5451
20	6%	0.5649	$3,734,751	$372,862	11.016		-$209,790	$898,158	0.766		-$323,955	$655,050	0.5054
20	7%	0.5255	$3,448,153	$372,862	10.248		-$257,819	$898,158	0.713		-$347,057	$655,050	0.4702
20	12%	0.3825	$2,408,084	$372,862	7.458		-$432,118	$898,158	0.519		-$430,892	$655,050	0.3422
25	4%	0.6829	$4,592,656	$372,862	13.317		-$66,019	$898,158	0.926		-$254,804	$655,050	0.6110
25	5%	0.6283	$4,195,594	$372,862	12.252		-$132,560	$898,158	0.852		-$286,809	$655,050	0.5622
25	6%	0.5803	$3,846,666	$372,862	11.317		-$191,035	$898,158	0.787		-$314,934	$655,050	0.5192
25	7%	0.5380	$3,538,844	$372,862	10.491		-$242,621	$898,158	0.730		-$339,746	$655,050	0.4813
25	12%	0.3870	$2,440,769	$372,862	7.546		-$426,640	$898,158	0.525		-$428,257	$655,050	0.3462

APPENDIX 7: LIST OF AFFECTED PARTIES

Affected Party	Represented by
Vehicle manufacturers	Commercial Vehicle Industry Council Federal Chamber of Automotive Industries Truck Industry Council
Vehicle importers	Federal Chamber of Automotive Industries
Automotive component manufacturers	Federation of Automotive Product Manufacturers (member of the FCAI) Australian Road Transport Suppliers Association
After-market automotive component manufacturers	Australian Automotive After-market Association
Automotive design and testing services	Commercial Vehicle Industry Association of Australi
Vehicle certification and compliance services	Commercial Vehicle Industry Association of Australi
Vehicle dealers	Motor Traders Association of Australia
State and territory governments	ACT: Department of Urban Services NSW: Roads and Traffic Authority NT: Department of Transport and Works Queensland: Queensland Transport South Australia: Department of Transport Tasmania: Department of Transport Victoria: VicRoads, Department of Infrastructure Western Australia: Department of Transport
Consumers (comprising of vehicle owners individual heavy vehicle operators, commercial institutions and pedestrian representatives)	Australian Automobile Association representing motoring clubs located in: ACT: NRMA NSW: NRMA NT: Queensland: RACQ South Australia: RACSA Tasmania: RACT Victoria: RACV Western Australia: RACWA Australian Commercial Vehicle Association Australian Motorcycle Council Australian Trucking Association Bicycle Federation of Australia Pedestrian Council of Australia
Services to consumers Insurance Medical treatment	Australian Medical Association Australian Transport Insurers Association Insurance Council of Australia

APPENDIX 8: TECHNICAL LIAISON GROUP

Australian Government	
Department of Transport and Regional Services	
Consumer (Motoring Clubs)	
Australian Automobile Association	
State and Territory Governments	
Department of Urban Services, Australian Capital Territory	
Roads and Traffic Authority, New South Wales	
Department of Transport and Works, Northern Territory	
Queensland Transport, Queensland	
Transport South Australia, South Australia	
Department of Energy, Infrastructure and Resources, Tasmania	
VicRoads, Victoria	
Department of Planning and Infrastructure, Western Australia	
New Zealand Government	
Land Transport Safety Authority	
Industry	
Australian Road Transport Suppliers Association	
Australian Commercial vehicle Association	
Commercial Vehicle Industry Association of Australia	
Federal Chamber of Automotive Industries	
Commercial vehicle Industry Council	

APPENDIX 9: PUBLIC COMMENT

The following is a list of the parties that responded to the invitation for public comment. Comments were recorded below only where they required further discussion within the Regulatory Impact Statement. Only representative bodies have had their names published. No comment was received on the question on page 34 of added length to the vehicle from fitting front underrun.

Organisation	Comments	Discussed further on page:	Summary of departmental response
Australian Motorcycle Council (AMC)	Unable to support any of the options as none advocate side underrun protection to provide increased protection for motorcyclists. Some options may provide a benefit to the community as a whole but at the expense of motorcyclists. The trucking industry benefited by the "Do not overtake turning vehicle" rule. This increased the risk for motorcyclists and others who incorrectly interpret this as a heavy vehicle changing lanes and continue to overtake in the left hand lane. The trucking industry must put some of the profit gained from this rule into improving the safety of motorcyclists by providing side underrun protection.		It is appreciated that motorcyclists would be disappointed by the recommended option as it does not include the provision of side underrun protection. Although the benefit cost analysis does not indicate whether some road user groups would benefit more than others, the recommended option would not be "at the expense of motorcyclists". There could only be an increase in benefits for motorcyclists by having a front underrun protection system fitted. There is no "disbenefit". If the "Do not overtake turning vehicle" rule (which allows longer vehicles to use multiple lanes when negotiating corners) was a significant risk to motorcyclists, then the statistics would show a higher incidence of collisions of motorcycles with articulated vehicles than rigid vehicles and in urban areas (the most likely scenario for this kind of crash) rather than rural areas. However, this is not the case. Table 2 and Appendix 6 shows a fairly even distribution for crashes of motorcycles within rural and urban areas and between rigid and articulated vehicles. Misinterpretation of the intention of a heavy vehicle under the rule is something that may better be addressed through public education.
European	Supports including an Australian Trucking Association		The proposed clarifications have now been included in a draft

design truck manufacturer	sponsored paper containing clarifications of requirements as an appendix or supplement to UNECE R93 in an Australian front underrun rule.		Australian Design Rule for front underrun protection and/or draft Administrator's Circular as appropriate. The final form of the clarifications will be further discussed with the peak bodies within the Technical Liaison Group.
Japanese design truck manufacturer	Request rule comes into force at least 2 years after the final decision, from 1 July 2012 for all new model vehicles and 1 July 2013 for all model vehicles		The standard ADR transition period is 18/24 months, which suggests 2010 at the latest. The technology is existing and relatively unsophisticated and so this request likely relates more to the introduction of other overseas standards than the capacity of industry to respond. The lead time will be further discussed with the peak bodies within the Technical Liaison Group.
Transport company	Protest the removal of the semi-trailer rear bumper requirement in ADR 42/... It should apply to all vehicles where there is a propensity for a rear impacting vehicle to take the collision at occupant head height. The current ADR should be expanded to include the dogs, pigs and rigids. It costs a total of $100 to $200 to fit. We fit it to ALL trailers as a moral obligation to safety, and regard poorly, the lack of attention that DOTARS has placed on rear end protection on other vehicles. When done well, it also provides an excellent facility for rear signage, rego lamps and plate and rear lamps. The existing requirement adequately gives guidance as to the "spirit" of the intention, and that the outcome will be adequate. No amount of testing will provide the perfect bumper for all situations, but at least it will reduce the shear impact. It won't save 100% of occupants, but 90% would be a good outcome. Therefore, either leave the requirement as it is, whereby any reasonable engineer can provide a reasonable barrier, or go one step further to nominate the material range and unsupported lengths. eg. Underrun bar to be no less than 100	25, 44, 45, 55, 57	The RIS concluded that there was no case for rear underrun protection, based on the international standard UNECE R 58 which is the only international standard available. The only device currently providing any sort of rear underrun protection – the semi-trailer bumper requirement of ADR 42/04, has features that would compromise any ability to provide protection in a rear collision. This was discussed on page 25 However, the comments received on this issue did not support the removal of the requirement from ADR 42/04. A counter argument is that the presence of this basic underrun device provides at least some benefits. This is achieved at a very low cost and using an arrangement that industry is familiar and comfortable with. The rear bumper also serves a dual role in providing for fitting of signage, lamps and registration plates. For now, this RIS will not recommend rear underrun protection, but will stop short of recommending the removal of the rear bumper requirement from ADR 42/04. Removal of the requirement is an issue to be raised separately under the review of ADR 42/04. This should include the related issues of the use of UNECE R 58 as an alternative standard and the absorption of state and territory requirements for underrun protection for tilt-tray tow trucks in to ADR 42/04 or 44/02.

	mm dia x 8 mm or 100 x 100 RHS, of 5mm or more thickness, with vertical supports attached to the rear of the trailer frame, or bolted to the truck chassis using 10 mm fish plates, of a size no less than 100 x 100 RHS of 5 mm or more thickness. The vertical member to have an unsupported length to the underrun bar of no more than 250 mm, the brace or diagonal support being no less than 75 x 75 RHS, of 5mm or more thickness, at an angle to the ground level not exceeding 45 degrees. This would keep the concept within an affordable range by avoiding the massive cost of testing, and perhaps save a life or more. We will continue to fit rear impact protection regardless of your legislation, we only fear the discreditable impact of accountants in other manufacturers. Side underrun protection are another issue. The side overhang is usually about 750 mm to the trailer web, a far cry from the rear overhangs. Further, the likelihood is dramatically less for a side impact, and the cost and design restrictions are far more. Also, many trailers with a side overhang use the space to store spare wheels, tool boxes, and water barrels, all energy absorbing to some extent.		
National Roads and Motorist's Association Limited (NRMA)	1. Would support adoption of European requirements for front side and rear underrun protection, in line with Australia's policy of harmonisation with European regulations.		Australia's harmonisation policy is to align domestic standards with international standards, particularly those adopted by the United Nations (UN). It is acknowledged that the European requirements are also converging towards these same standards. However, there is no obligation to adopt a standard where the need for regulatory intervention con not be demonstrated. *Not* adopting a UN based standard would *not* prohibit product that meets it from being supplied to the Australian market.
	2. Should review the RIS as the benefits of front side and rear underrun protection which are substantially underestimated. Other studies have shown these as higher. In particular the RIS shows that rear underrun has a benefit/cost ratio greater than 1.	25, 45	Following an earlier limited exposure draft of this RIS in 2005, the NRMA raised a number of questions (which were all worked through) including the one of underrun protection benefits being underestimated (by up to 300%) when compared to other studies. The other studies being referred to are the

			Stage 1 and Stage 2 studies by the Monash University Accident Research Centre (MUARC), commissioned by VicRoads. These have been extremely valuable reports as a basis for further analysis. In these reports, estimation of underrun crashes were made by analysing the description of all fatal crashes in Victoria involving heavy vehicles. However, it is now possible to identify clearly on a National database (the Australian Transport Safety Bureau's Fatal Fatals File database) whether a fatal crash involved underrun. This reveals that these types of crashes are around two and a half times fewer than previously thought, (and the latest data now shows that the number has significantly reduced in recent years). Secondly, and following earlier criticism, this RIS now associates a lower cost to underrun crashes involving heavy vehicles when applying the generally accepted principle that the cost of a heavy vehicle crash is about one and a half times that of a passenger vehicle crash. This multiplier is now applied only to the cost of property damage, not to the cost associated with the fatality itself. This is because the cost of any fatality is the same regardless of the vehicles involved. Refer Appendix 6, part 6. Thirdly, as mentioned elsewhere in this RIS, the MUARC reports used extremely low costs for underrun devices. These appeared to represent manufacturing costs only. Finally it is worth noting that the MUARC reports found no case for rear underrun protection on any type of truck and relied on it being part of a "package" of improvements.
National Transport Commission (NTC)	Option 8 preferred, with modifications as below: 1. Would not support removal of ADR 42/04 rear bumper.		See above. Will no longer be recommended in this RIS.
	2. Interested in comments from state and territory authorities on increasing axle limit to 6.1 t.		No comments on axle limits have been received.
	3. Should consider a package of front/side/rear for artic over		The RIS was unable to justify side or rear underrun protection

	7.5 t and front only for rigid over 7.5 t; or front/side/rear for all over 7.5 t		and therefore could not justify a package. A package solution would be suitable to a case where each area of protection could not be independently applied. In this case, international standards are available for each distinct area.
	4. Would support an exemption for construction vehicles as per UNECE R93.		The current exemptions as per UNECE R93 have been included in a draft Australian Design Rule for front underrun protection. The final form of the exemptions will be further discussed with the peak bodies within the Technical Liaison Group. The NTC have identified this as an area to be worked through.
	5. Should review the road wear cost assumption and refine the calculations.	41	The road wear cost assumption has been reviewed and corrected from \$0.0041 per km to \$0.0038 per km. Referring to the NTC report (NTC 2006), a better estimate than \$0.0041would be approaching \$0.0039, which is the value directly calculable from Table 4 for a 100 kg increase of a rigid axle truck. However, linear interpolation (over a much smaller range of masses than previously) used for the typical B-double vehicle was \$0.0038 per km (Table 2) and for the articulated vehicle \$0.0038 per km (Table 3). It was agreed that the wear relationship varies as the fourth power of load change, and so the cost of road wear had previously been overestimated by about \$1m per annum. The NTC also acknowledged that the value was not directly critical to the overall finding for front underrun and so this has only a minor effect on the outcome.
	6. Should correct two identified errors.	18	The first of these relates to the comment that an offset frontal crash may cause vehicle rotation and so reduce the injury potential. This comment has been deleted. The second of these relates to some costs that should have been reported in 1996 dollars and have instead been reported in 1995 dollars. Correcting this would change a large amount of calculated values, but only slightly, and not the outcome. Therefore it was decided not to make the correction but instead acknowledge that the comment is valid.
Truck Industry Council (TIC)	1. Would support the introduction of an ADR for front underrun protection from 1 July 2012.		The standard ADR transition period is 18/24 months, which suggests 2010 at the latest. The technology is existing and relatively unsophisticated and so this request likely relates

			more to the introduction of other overseas standards than the capacity of industry to respond. The lead time will be further discussed with the peak bodies within the Technical Liaison Group.
	2. Would not support the removal of rear underrun protection.		See above. Will no longer be recommended in this RIS.
	3. Would support allowing an alternative Japanese underrun standard when it is developed for late 2011.		Japan currently does not have a standard for front UP. Any standard that is developed can be looked at as a candidate for adoption. However, Australia has a policy of harmonisation with international standards. Given that Japan is now a signatory to the international UNECE standards system, there would appear to be little merit in adopting any Japanese domestic standard that was not also developed to be compatible with the UN standard.
	4. Would support an exemption for construction vehicles as per UNECE R95.		Yes. See above.
	5. Would not support steer axle masses being determined through an underrun ADR. These have been separately negotiated with the state and territory authorities. If determined through the ADR, the limit would have to be 7.1 tonnes, not 6.1 tonnes as per the RIS.	41	Axle limits are not determined through the ADR system. The RIS demonstrates that the proposed option has a positive net benefit whether or not steer axle limits are raised by 100kg. The proposed axle load limit of 6.1 tonnes was stated simply because this represents 100 kg over the current limit, and because raising the limit was the lower cost option compared to a loss of productivity if the limit was kept the same. The NTC found that raising the limit was the best option for voluntary fitment of safety features including underrun, so it is likely to be the case for mandatory fitment. However, it remains up to the state and territories to determine whether raising the limit is acceptable and if so, what that new limit should be.
	6. Should update the data as it is eight years old and is likely to be showing a reduction in fatalities.		The data has now been updated to the latest available (2003) and is showing a large reduction in fatalities. The effect of the updated data has been analysed and the conclusions to the RIS redrawn such that only front underrun for articulated vehicles is now proposed in its own right.
	7. Should identify parameters for survivability in the studies ie speed and mass of vehicles, as this may affect rural survivability.		The analysis used average effectiveness from studies at speeds between 30 and 100 km/h, weighted in accordance with the distribution of real crash speeds. See Appendix 6, Part 5.
	8. Should correct the European steer axle limits which	34	This has been corrected to 7.1 tonnes (note this does not affect

	should be 7.1 tonnes.		the conclusions).
	9. Should review the costs for North American trucks. As the US does not have the requirement, amortisation costs would be over a few hundred units only. UNECE R93 is tailored to cab-over engine designs and would cost around $2500-3000 per vehicle with a 150kg weight penalty for cab-behind engine designs. ECE R93 FUP is designed for square fronted vehicles.	41	The updated analysis shows that a front underrun protection proposal could tolerate a cost increase of a minimum of 10-20% for all vehicles (European, Japanese and US cab-over and cab-behind) while still remaining viable. In fact, for articulated vehicles, it would still be viable at around 300% of its estimated value ie over $3,500. This tolerance would be even more the case if it were a small segment of the total population of vehicles that need this type of construction. Proposed clarifications from the Australian Trucking Association have now been included in a draft Australian Design Rule for front underrun protection and/or draft Administrator's Circular as appropriate. This includes allowances for displacement measurements on cab-behind engine designs. The final form of the clarifications will be further discussed with the peak bodies within the Technical Liaison Group.
US design truck manufacturer	1. Supports FUP as per Option 8		
	2. Supports including an Australian Trucking Association sponsored paper containing clarifications of requirements as an appendix or supplement to UNECE R93 in an Australian front underrun rule.		Yes. See above.
	3. Estimates the full cost of developing a front underrun protection device as around $650 000 with a unit cost of $1300.		See above.
VicRoads	1. Supports front underrun protection as per Option 8.		
	2. Supports fitting front underrun protection to all heavy vehicles (not just those over 7.5 tonnes).		The data has now been updated (see above) and covers vehicles above 4.5 tonnes. However, the data is also showing a large reduction in fatalities. The effect of this is to redraw the conclusions to the RIS such that only front underrun for articulated vehicles can now be justified. Although vehicles above 4.5 tonnes are included, in practice typical articulated vehicles are well above this mass.

	3. Does not support the withdrawal of ADR 42 for rear bumpers as it does provide some protection and is accepted by industry.		See above. Will no longer be recommended in this RIS.
	4. Suggest that side and rear underrun protection be encouraged on a voluntary basis.		Noted.
	5. Supplied some additional crash data.		Data was supplied for Victoria 1998 to 2006. VicRoads has cautioned that the data is likely to be incomplete and therefore misleading. This appears to be correct as the national figures show a much higher incident of underrun fatalities. What the data does offer is that after 2003 (which is the limit of the ATSB data, but not the Victorian data), the trend remains fairly constant. It also continues to support the ratio between fatality, serious and minor injury originally estimated in the RIS.

APPENDIX 10: INITIAL CONSULTATION - BENEFIT-COST ANALYSIS

The following is part of the economic analysis as originally determined in the consultation Regulation Impact Statement. Since this time, the analysis has been recalculated taking into account the latest crash and registration data.

Original Dataset 1989-1999 - Summary of Benefit-Cost Ratios (BCR) from the provision of UP on new heavy commercial vehicles – Scenarios A, B and C combined

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
Rigid	6.5	4.0	1.7	1.0	0.6	0.2	0.5	0.3	0.1
Articulated	39.2	24.0	10.1	2.8	1.7	0.7	1.7	1.1	0.5

Best case - discount rate 4% over 25 years, high effectiveness device.
Likely case - discount rate 7% over 15 years, Most Likely effectiveness device.
Worst case - discount rate 12% over 10 years, low effectiveness device.

Summary of Benefit-Costs

Scenario A - Low Effectiveness UP

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
Rigid	5.0	3.4	1.7	0.7	0.5	0.2	0.4	0.3	0.1
Articulated	30.0	20.9	10.1	2.0	1.4	0.7	1.4	1.0	0.5

Scenario B - Most Likely Effectiveness UP

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
Rigid	5.7	4.0	1.9	0.8	0.6	0.3	0.4	0.3	0.1
Articulated	34.5	24.0	11.7	2.4	1.7	0.8	1.6	1.1	0.5

Scenario C - High Effectiveness UP

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
Rigid	6.5	4.5	1.9	1.0	0.7	0.3	0.5	0.3	0.1
Articulated	39.2	27.3	13.3	2.8	1.9	0.9	1.7	1.2	0.6

Scenario D - Energy Absorbing UP

	Front			Side			Rear		
	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case	Best Case	Likely Case	Worst Case
Rigid	0.36	0.22	0.09	0.08	0.05	0.02	0.03	0.02	0.01
Articulated	1.66	1.15	0.56	0.12	0.08	0.04	0.07	0.05	0.02

Best Case - 25 year pay-off period @4%, costed for fatalities, injuries and other costs

Likely Case - 15 year pay-off period @7%, costed for fatalities, injuries and other costs

Worst Case - 10 year pay-off period @12%, costed for fatalities and injuries cost only

NOTES

[i] Annually 250 pedestrians are killed. 20 per cent of fatal collisions involve heavy trucks and 20 per cent of truck involved collisions end up as under-run collisions.

[ii] these costs are difficult to estimate and are not included in under-run trauma.

[iii] Information for the period beyond 2003 was not available from the ATSB. See Appendix 3.

[iv] FMVSS, Federal Motor Vehicle Safety Standards

[v] Regulation of the Global Forum for Automotive Technical Regulations, Geneva

[vi] Directive of the European Parliament and the Council, Brussels

[vii] Regulation of the Global Forum for Automotive Technical Regulations, Geneva

[viii] Directive of the European Parliament and the Council, Brussels

[ix] Regulation of the Global Forum for Harmonization of Automotive Technical Regulations, Geneva

[x] Directive of the European Parliament and the Council, Brussels

[xi] Federal Motor Vehicle Safety Standard of the United States

[xii] Regulation of the National Council of Traffic – CONTRAN, Brazil

[xiii] Economic Commission for Europe is an institution formed from the post World War II Bretton Woods Agreement in 1949. The institution was set up to facilitate the economic reconstruction of war ravaged Europe.