| APROSYS | | Cost Benefit Analysis for Introduction of Advanced European Full Width (AE-FW) Test |
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# Cost Benefit Analysis for Introduction of Advanced European Full Width (AE-FW) Test

**Deliverable**

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**AP-SP12-0029**

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**Publishable summary**

APROSYS Sub-project 1, Work-Package 1.2, titled 'Advanced Frontal Impact' aims to develop and evaluate a full width high deceleration crash test suitable for regulatory application in Europe, known as the Advanced European Full Width (AE-FW) test.

This deliverable (123B) reports on task 1.2.3 of WP1.2. This task consisted of two activities. The first activity aimed to perform accident analysis to help specify the test configuration and other parameters for the AE-FW test. The second activity aimed to perform a cost benefit analysis. This report details the work of the second activity.

A cost benefit analysis has been performed based on the assumption that 100% of the vehicles in the fleet met the AE-FW test requirements. Obviously, in the first ten years or so, before full fleet penetration is achieved the number of vehicles in the fleet meeting the requirements will be less and hence the benefit will be less.

Analyses were performed to estimate the potential benefit of introducing a full width (AE-FW) test into European legislation. The performance requirements and associated limits of the AE-FW test have not been finalised yet, so the analyses performed give only an indicative estimate of the potential benefit. The benefit was estimated for the EU15, EU25 and EU27 countries by scaling the results of a study which estimated the benefit for GB. For the EU15 countries a potential benefit of up to about **€2,000Million** was calculated per year assuming that all vehicles complied with the test requirements.

An analysis was performed to estimate the cost of introducing a full width (AE-FW) test into European legislation based on two assumed levels of performance limits. The cost estimated for the EU-15 countries per year to enable new registrations to comply was about **€240Million** to meet performance limits similar to US FMVSS208 and about **€460Million** to meet limits similar to UN ECE Regulation 94. The analysis was based on the modifications required to enable a FIAT Bravo to meet the AE-FW test requirements. Hence it was implicitly assumed that the performance of the FIAT Bravo in the AE-FW test was representative of the performance of all cars in the European fleet.

In summary, this initial cost benefit analysis indicated that the value of the potential benefit of introducing the AE-FW test in Europe is about 4 times higher than the costs to meet performance limits in the test required by UN ECE R94. However, more stringent performance limits and other measures may be needed to deliver all of the estimated potential benefit, which would require additional modifications to the car and hence increase the cost.

Recommendations for further work are given.

**Acknowledgement**

Following participants contributed to this deliverable report.

| Company | Representative | Chapters |
|---|---|---|
| TRL | M Edwards | 1, 2, 4, 5 |
| FIAT | G Tanucci | 3 |

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# 1. Introduction

The European 6th Framework Programme Integrated Project (IP) on Advanced Protection Systems (APROSYS) focuses on the field of passive vehicle safety. The overall aim of sub-project 1 (SP1), titled ‘Car Accidents’, is to reduce the number of car occupant fatalities and serious injuries by developing test procedures that, once implemented in regulation and / or consumer testing, will improve a car’s crashworthiness in frontal and side impacts.

The next step to improve a car’s crashworthiness in frontal impacts is to improve compatibility in vehicle to vehicle impacts. To assess a car’s frontal impact crashworthiness, including its compatibility, an integrated set of test procedures is required, which assesses both the car’s self and partner (compatibility) protection. The set of test procedures should contain both a full overlap test and an offset (partial overlap) test as recommended by the IHRA frontal impact working group [IHRA 2001]. A full width test is required to provide a high deceleration pulse to control the occupant’s deceleration and check that the vehicle’s restraint system provides sufficient protection at high deceleration levels. An offset test is required to load one side of the vehicle to check compartment integrity, i.e. that the vehicle can absorb the impact energy in one side without significant compartment intrusion. The offset test also provides a softer deceleration pulse than the full width test, which checks that the restraint system provides good protection for a range of pulses and is not over-optimised to one pulse. The main factors influencing a vehicle’s compatibility, which need to be assessed, are its structural interaction potential, its frontal force levels and its compartment integrity [Edwards 2001].

The European Enhanced Vehicle-safety Committee (EEVC) Working Group 15 has helped co-ordinate work to develop an integrated set of test procedures to assess a vehicle’s frontal impact performance, including its compatibility. EEVC WG15 reported in May 2007 [EEVC 2007] and made the following two proposals for a set of test procedures:

Set 1

- Full Width Deformable Barrier (FWDB) test to assess a vehicle’s structural interaction potential and provide a high deceleration pulse to test the restraint system.
- ODB test with EEVC barrier to assess a vehicle’s compartment integrity and frontal force levels and also provide a softer deceleration pulse to test the restraint system.

Set 2

- Full Width Rigid Barrier (FWRB) test to provide a high deceleration pulse to test the restraint system.
- ODB test with Progressive Deformable Barrier (PDB) test to assess a vehicle’s structural interaction, frontal force levels and compartment integrity and also provide a softer deceleration pulse to test the restraint system.

In addition, EEVC WG15 also recommended that a combination of the FWDB and PDB tests should be considered as a possible third set of procedures, but no work was done so far to investigate this option.

To help the development of the chosen set of test procedures, APROSYS SP1, Work Package 1.2 (WP1.2), titled ‘Advanced Frontal Impact’ aims to:

- Develop and evaluate a full width high deceleration crash test suitable for inclusion in an integrated set of test procedures for regulatory and /or consumer testing application in Europe. The test will be referred to as the Advanced European Full Width (AE-FW) test in this deliverable.
- Perform an associated cost benefit analysis for the introduction of this test into European regulatory and / or consumer testing.

WP1.2 consists of the following tasks:

1. Specification of the AE-FW test and assessment protocol
2. Evaluation of the AE-FW test and assessment protocol
3. Accident and cost benefit analysis

The objective of the work reported in this deliverable was:

- To perform a cost benefit analysis for the introduction of the AE-FW test in Europe.

The benefit analysis work consisted of a review of previous analyses performed as part of, and in support of, the APROSYS project [Stanzel 2006, Thompson 2007]. The results of these analyses, which were based on accident data for individual countries, were scaled to give an initial estimate of the range of possible benefit for Europe. The following limitations of the analysis should be noted:

- Scaling of benefit estimated for an individual country to give a European benefit estimate should only be used to give an approximation indication of the magnitude of the benefit because the accident pattern varies considerably from country to country and hence this type of direct scaling can introduce large errors.
- The performance requirements and associated limits of the AE-FW test have not been finalised yet. This means that, at this stage, the analyses performed give only indicative estimates of the benefit because assumptions have to be made to determine the effect of introducing the AE-FW test on the risk of injury for casualties.

The cost analysis was performed by an industrial partner, FIAT, because industry has much better access to the information required to conduct this type of analysis. The analysis was based on the cost of modifying (upgrading) an existing typical European car to meet possible future AE-FW test performance requirements. It should be noted that using this approach gives an upper limit to the costs because the costs will be lower if the modifications are built into the car from the original design stage. The car chosen to represent a 'typical' European car was a FIAT Bravo. As stated earlier, the performance requirements and limits of the AE-FW test have not been finalised yet, so the following limits were assumed to calculate a range for possible costs depending on the limits chosen:

- Performance limits equivalent to the US FMVSS 208 full width test limits with a test speed of 35 mile/h, i.e. 56 km/h, [FMVSS 208]
- Performance limits equivalent to the UN ECE Regulation 94 offset test limits, [UN ECE R94]

Please note that, overall, the UNECE R94 limits are more stringent than the FMVSS208 limits, in particular for the thorax.

Another issue that affects the cost analysis is that many vehicles that are sold in Europe are also sold in other parts of the world, such as the US, where full width test requirements apply. The cost of modifying these vehicles to meet the AE-FW test performance limits is likely to be less than that for a 'typical' European car, so the effect of this on the cost analysis is discussed.

The organisation of this deliverable is as follows. Firstly, the benefit analysis work leading to the derivation of an initial estimate for the range of likely benefit for Europe is described in Section 2. Following this the cost analysis is described in Section 3. Next, a discussion of the cost benefit for the introduction of the AE-FW test at a European level is described in Section 4 and finally conclusions are given in Section 5.

# 2. Benefit Analysis

Previously, as part of and in support of the APROSYS project, two analyses have been performed to estimate the benefit of introducing a Full Width Test (in particular the AE-FW test) in Europe. The first analysis was performed as part of the APROSYS SP8.3 work [Stanzel 2006]. This analysis concluded that the benefit for the introduction for a full width test in Europe would be 'marginal', i.e. reduce the number of MAIS 2+[1] injured car occupants by a factor of about 1.9%. However, a review of this work showed that there were some confounding factors in the analysis which were not taken into account and which would likely cause an under-estimate of the predicted benefit. In response to this finding, a second analysis was performed by TRL in support of the APROSYS project funded by the UK Department for Transport (DfT) [Thompson 2007]. This analysis predicted that the introduction of a full width frontal impact test would be expected to reduce annual fatalities in Great Britain (GB) by approximately 3 percent (47 occupants) and serious casualties by approximately 6 percent (813 occupants). This is a significant benefit that is greater than was estimated in the APROSYS SP8.3 benefit analysis.

The following two sections give a brief description of the assumptions, methodology, results and conclusions from each of the analyses described. The third section describes the derivation of an estimate of the benefit of introducing the AE-FW test in Europe.

## 2.3 Benefit Analysis Performed by APROSYS SP8.3

This analysis was performed as part of APROSYS SP8.3 and used the German GIDAS (German In-Depth Accident Study) database as its main data source [Stanzel 2006]. The analysis used an 'equal risk at test speed' assumption. Specifically, the assumption used was that a 'future' car designed for both the EuroNCAP offset test as well as the new full width test would provide equal protection for its occupants in each of these impact configurations, at the corresponding test speed (i.e. 64km/h in the offset test and 56 km/h in the full width test). In addition, it was assumed that the introduction of the full width test would only have a benefit for vehicles involved in full width overlaps in real-world crashes.

The risk of sustaining MAIS 2+ injury levels in a 'state-of-the-art' car in full width and offset frontal crashes for increasing delta-V was calculated. In cases where delta-V was not known, ETS[2] and EES[3] values were converted to an 'equivalent' delta-V value using linear regression. Full width crashes were defined as those with an overlap of between 70 and 100 percent of the front of the vehicle, whilst offset crashes were defined as those with an overlap of between 30 and 50 percent. Logistic risk curves were applied to the accident data for the full width and offset overlap configurations, which are shown in Figure 1 and Figure 2.

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[1] MAIS 2+: Maximum Abbreviated Injury Scale 2 and greater.
[2] ETS Estimated Test Speed
[3] EES Equivalent Energy Speed

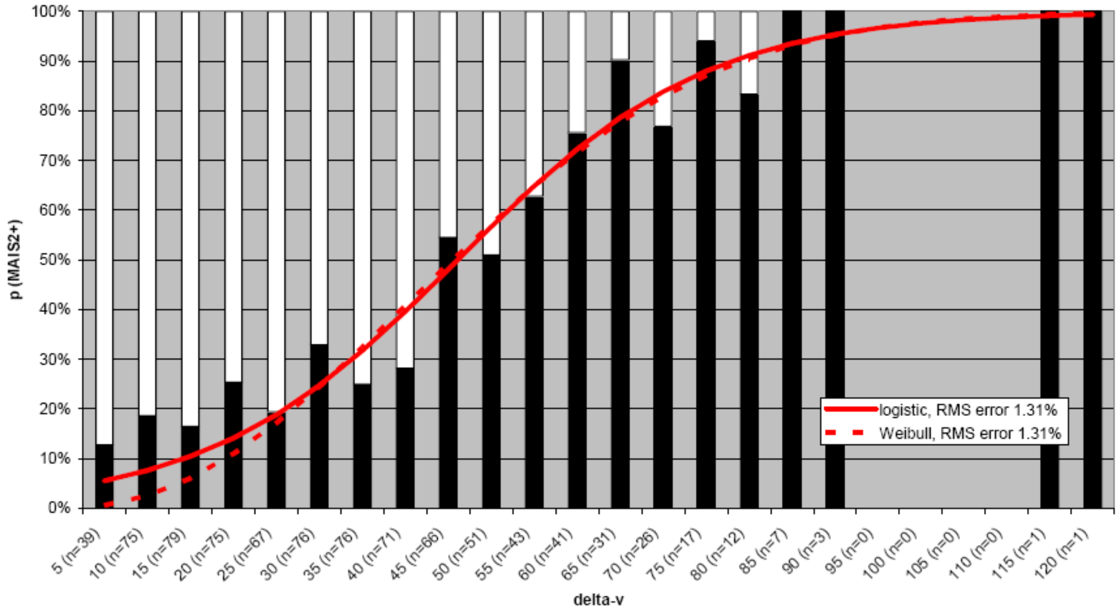


**Figure 1: Risk of MAIS 2+ injury by delta-V in GIDAS data set (full frontal crash, 70-100% overlap).**

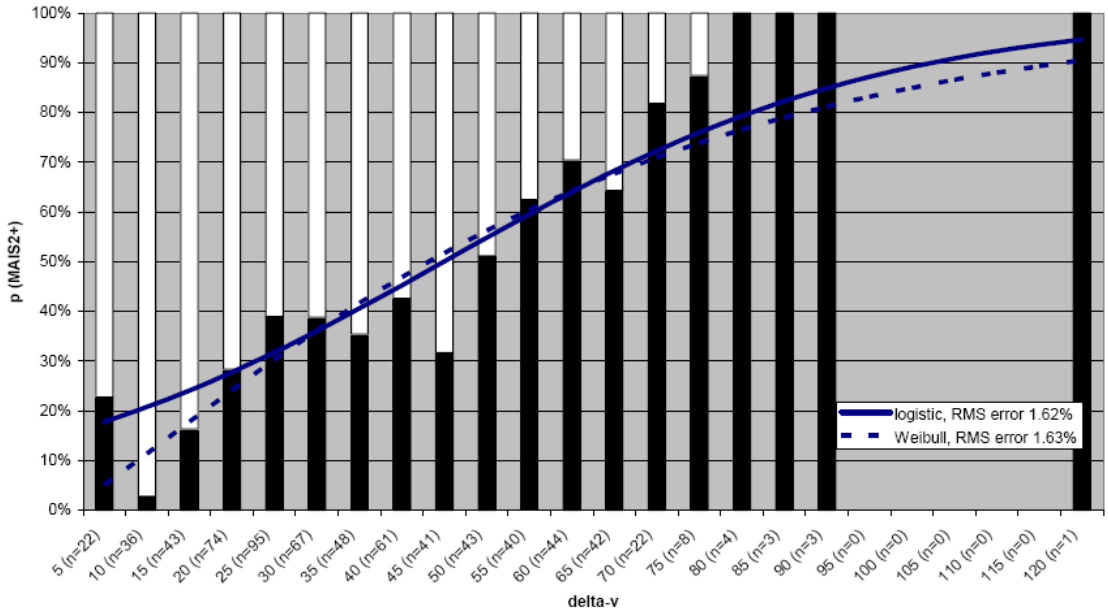


**Figure 2: Risk of MAIS 2+ injury by delta-V in GIDAS data set (offset crash, 30-50% overlap).**

The estimation of benefit, using the 'equal risk at test speed' assumption described previously, aimed to predict a new risk curve for future vehicles in full width crashes by shifting the risk curve horizontally such that it produced an equal risk to the offset crashes at the corresponding test speed, i.e. it was assumed that the shape of the risk curve was determined by the nature of the crash, whilst the horizontal position was determined by the level of protection that the vehicle will offer at a given impact speed.

The methodology used assumed that delta-V in real-world crashes was 10 percent higher than test speed as a result of rebound. Using this assumption, the risk of sustaining a MAIS 2+ injury in an offset impact at 70.4km/h (10 percent greater than the EuroNCAP test speed of 64 km/h) was found to be 72.6%. The risk curve for the full width crashes was shifted horizontally such that an equal risk of 72.6% corresponded to the proposed test speed of 56 km/h, or 61.6 km/h when

10 percent was added. This resulted in a shift of 1.4km/h to the right for the injury risk curve for full width impacts, as shown in Figure 3.

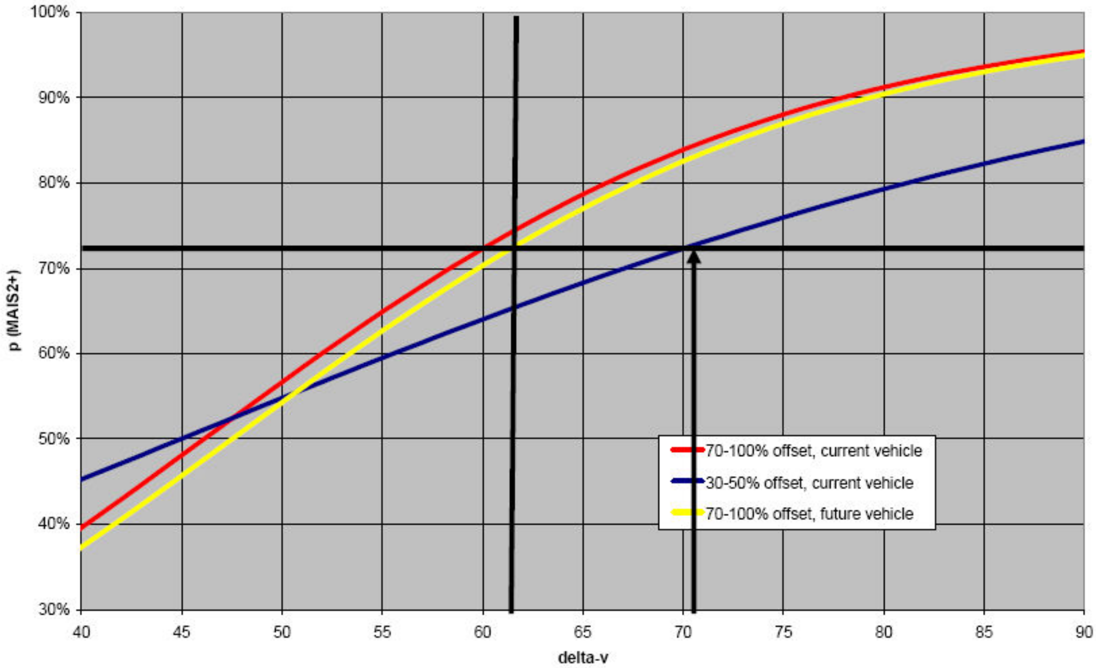


**Figure 3: Prediction of the risk curve for future vehicles in full width crashes.**

The difference between this new injury risk curve for full width impacts and the current one was used to determine the overall benefit of the introduction of a full width test. The calculated benefit, in terms of MAIS 2+ injuries, indicated that the full width test would be expected to reduce the number of occupants sustaining MAIS 2+ injuries by approximately 1.9%, based on the 7079 occupants sustaining MAIS 2+ injuries in the German GIDAS data sample.

A review of this analysis [Thompson 2007] examined the following key factors:

- The sensitivity of the risk curves.
- The effect of using different accident data from a different country, such as the UK's CCIS (Co-operative Crash Injury Study) database.
- The effect of estimating the benefit for higher severity injuries, i.e. MAIS 3+ injuries instead of MAIS 2+ injuries.
- The investigation of potential confounding factors.

The main finding of this review was that the analysis did not take into account a key confounding factor and had this factor been taken into account the benefit predicted would, most likely, have been greater. The effect of this key confounding factor is explained in more detail below.

The analysis assumed implicitly that the distribution of injury for occupants in the 'full width' and 'offset' occupant samples was similar because the analysis only considered the overall MAIS occupant injury level when estimating the benefit of introducing a full width test. However, Thompson, using British Co-operative Crash Injury Study (CCIS) accident data, clearly showed that the distribution of injury for occupants injured in 'full width' and 'offset' crashes is different, especially for occupants with MAIS 3+ injuries. Figure 4 shows that MAIS 3+ injured occupants in 'full width' crashes sustain more thorax injury and less right leg injury than those in 'offset' crashes. The effect of this is that the risk of sustaining a thorax injury in a 'full width' crash is greater than in an 'offset crash' and vice versa for a leg injury, although the overall risk of injury is similar. Hence, an analysis that only considers the overall occupant injury risk, as the SP8.3 analysis did, will predict little benefit because overall injury risk is similar between 'full width' and 'offset' crashes, but if the analysis considered indvidual body regions it would predict greater benefit because the injury risk is substantially different for individual body regions between 'full width' and 'offset' crashes.

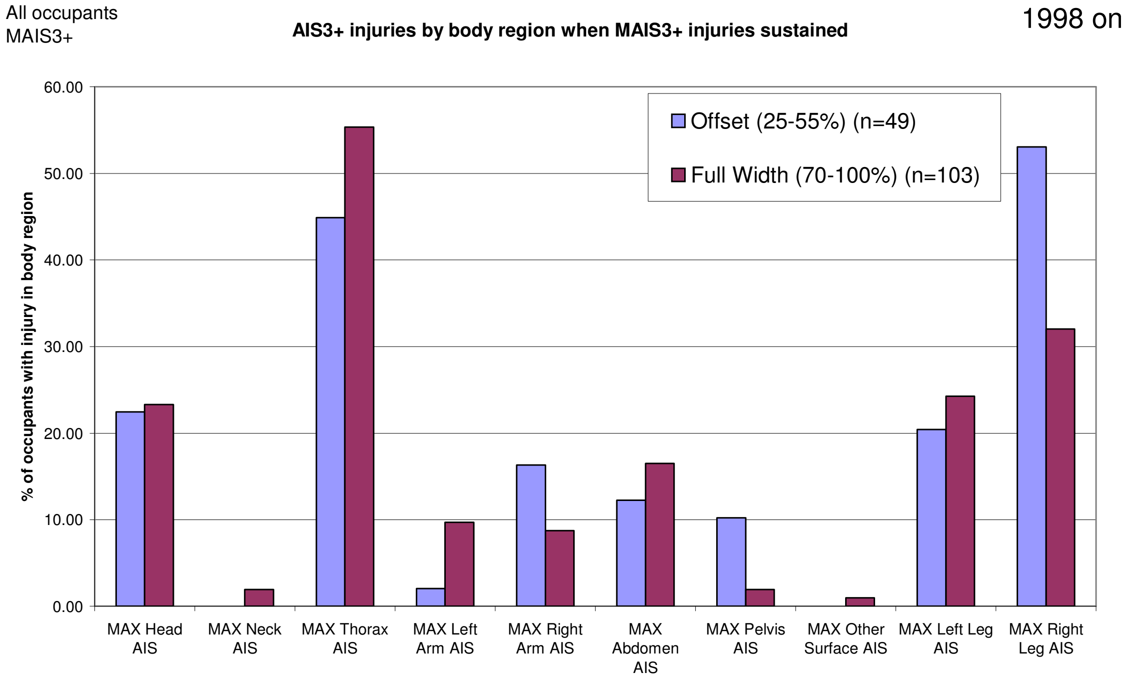


**Figure 4: Comparison of injury distribution by body region for AIS3+ injuries in 'full width' and 'offset' crashes.**

## 2.4 Benefit Analysis Performed by TRL

This analysis was performed by TRL on behalf of the UK Department for Transport (DfT) to support the work of the APROSYS project [Thompson 2007]. This analysis calculated the benefit of introducing a full width test in Europe for GB and used national accident data (STATS19) and detailed accident data (Co-operative Crash Injury Study (CCIS)).

A full width test produces a higher deceleration in a car than the offset deformable barrier test, and so it is a more severe test for the restraint systems in the car. Following this argument, the analysis was based on the assumption that the introduction of a full width test in Europe would encourage improved restraint systems, which would in turn reduce restraint-induced injury.
In this analysis, it was assumed that the main body regions where a reduction in restraint-induced injury would be observed would be the thorax and abdomen, areas normally loaded by the webbing of a three-point seat belt. The analysis assumed that thorax and abdomen injuries would be reduced in a 'future' car meeting the requirements of a new full width frontal impact test. Restraint-induced thorax and abdomen injuries were assumed to be those which occurred in frontal impacts where there was little or no intrusion.

The methodology to calculate the benefit was as follows. Firstly, a target population that could benefit from the introduction of a full width frontal impact test was derived using the detailed CCIS database. In this target population, individual casualties were assessed in terms of both the overall MAIS level and the AIS injury levels sustained by the thorax and abdomen. From this, 'new' MAIS levels were calculated for each case by reducing thorax and abdomen AIS levels, and the distribution of these 'new' MAIS levels was compared with the original MAIS distribution to give an estimated benefit in terms of reduction in MAIS. As the GB national accident data only records injury levels in terms of the police casualty severity measures (fatal, serious, slight and uninjured), the benefit in these terms was calculated. This was done by calculating the percentage distribution of fatal, serious and slight injuries for each MAIS level in the original target population, and using these figures to transform MAIS benefit into police severity benefit.

The last step involved the scaling of the CCIS benefit up to a national level for GB by using the national STATS19 accident statistics, which required the calculation of an equivalent target population in STATS19 to that used in CCIS. From this, a national benefit for GB for the introduction of a full width frontal impact test was derived.

In summary, the methodology used in this benefit analysis consisted of three parts:

- Estimate the benefit in terms of reduction in injury (MAIS) for each individual casualty within the target population, using the detailed CCIS data set.
- Transform benefit calculated in terms of MAIS reduction to the police casualty severity measures (fatal, serious, slight and uninjured) in order to give benefit in these terms.
- Scale to national level in GB using the national STATS19 statistics, using benefit proportions calculated from the CCIS data set.

A number of calculations were performed using different target populations. The most realistic target population was considered to be casualties who were belted and aged less than 65 years involved in frontal impacts with an impact severity (ETS) less than the test severity (56 km/h) with little occupant compartment intrusion, less than 5 cm.

The MAIS for these casualties was recalculated assuming that thorax and abdomen injuries would be reduced by a maximum of 2 AIS levels, with no injuries being reduced to a level lower than AIS 1 (Table 1 ). This assumption was based on previous work [Cuerden et al. 2001] in which expert judgement was used to derive subjective estimates of potential reductions in the severity of an AIS injury to given body regions for the fitment of improved restraint systems. Examples of how this calculation works are given below:

If an casualty had an AIS 5 thorax or abdomen injury, it was reduced to AIS 3. However, if a casualty had an AIS 2 thorax or abdomen injury it was reduced to AIS 1 and there was no reduction for AIS 1 injuries. If the casualty had an AIS 5 thorax injury and also an AIS 5 head injury even though the AIS 5 thorax injury was reduced an AIS 3, there was no reduction for the head injury and thus the casualty's MAIS remained at 5.

**Table 1: Change in MAIS levels for CCIS data set with thorax and abdomen injuries reduced.**

| MAIS | Original data set (No. of occupants) | Data set with applied benefit (No. of occupants) | Change (No.) |
|---|---|---|---|
| 0 | 296 | 296 | 0 |
| 1 | 1084 | 1174 | +90 |
| 2 | 280 | 219 | -61 |
| 3 | 135 | 115 | -20 |
| 4 | 37 | 29 | -8 |
| 5 | 35 | 34 | -1 |
| 6 | 2 | 2 | 0 |
| Total | 1869 | 1869 | - |

Transformation of the benefit calculated above in terms of MAIS into the police severity scale and scaling from the CCIS sample to the national level predicted that the benefit for GB for the introduction of a full width frontal impact test would to reduce **annual car occupant** fatalities in GB by approximately 3 percent (47 occupants) and serious casualties by approximately 6 percent (812 occupants) (Table 2). This is a significant benefit that is greater than was estimated in the SP8.3 benefit analysis.

**Table 2: Annual reduction in car occupant casualties for GB.**

| | GB National Benefit | | |
|---|---|---|---|
| | Original number | Reduction | % Reduction |
| Fatalities | 1695 | 47 | 2.77 |
| Serious Casualties | 14,512 | 812 | 5.60 |

An additional interesting finding was that if the calculation was repeated using a target population that included elderly casualties, i.e. those over 65 years old, the benefit predicted increased substantially to a 5 percent reduction in fatalities and a 7 percent reduction in seriously injured casualties. This indicates a large potential benefit for restraint systems that could provide better protection to elderly occupants.

## 2.5 Estimation of Benefit for Europe

The analyses above indicate that the benefit of introducing a full width test could be to reduce **annual car occupant** fatalities by up to approximately 3 percent and serious casualties by up to approximately 6 percent depending on the assumptions used for the analysis.

In this section, to give an indication of the benefit of introducing a full width test for Europe the benefit calculated for GB was scaled. However as mentioned in the Introduction section, it should be noted that scaling of benefit estimated for an individual country to give a European benefit estimate will only give a very approximate indication of the magnitude of the benefit because the accident pattern varies considerably from country to country and hence this type of direct scaling can introduce large errors.

The scaling was performed for the EU-15, EU25 and EU-27 countries as follows:

*How many fatal and serious road accident casualties are there per year in EU-15, EU-25 and EU27 countries?*
European road accident statistical data details that there were 29,516 road accident fatalities in EU-15 countries, 39,434 fatalities in EU-25 countries and 42,955 fatalities in EU-27 countries in 2006 [Eurostat 2008]. An estimation of the number of seriously injured casualties was derived by using the ratio that there are about 7 seriously injured casualties for every fatality derived by Mackay [Mackay 2005].

*How many of these were car occupant casualties?*
The European Union Road Federation reports that 52% of the road fatalities in the EU-15 in 2006 were car passengers or drivers [ERF 2008]. For this analysis, it was assumed that the percentage of seriously injured occupants in cars is the same, and also that this percentage is the same for the EU-25 and EU-27 countries.

*How many of these car occupant casualties will be prevented as a result of the introduction of a full width test?*
To determine this the percentage benefit estimated for GB was used, i.e. a reduction in **annual car occupant** fatalities of 2.8 percent and serious casualties of 5.6 percent.

**Table 3: Calculation of Benefit for Europe for introduction of full width test.**

| | | EU-15 | EU-25 | EU-27 |
|---|---|---|---|---|
| No. of Road Accident Casualties (A) | Fatal | 29,516 | 39,434 | 42,955 |
| | Serious | 206,612 | 276,038 | 300,685 |
| No. of Car Occupant Casualties (B) [B = A * 0.52] | Fatal | 15,348 | 20,506 | 22,337 |
| | Serious | 107,438 | 143,540 | 156,356 |
| No. of Car Occupants Casualties Prevented - Benefit [Fatal = B * 0.028, Serious = B * 0.056] | Fatal | 430 | 574 | 625 |
| | Serious | 6,017 | 8,038 | 8,756 |

*What is the financial benefit of these reductions in fatalities and serious injuries?*
To determine this, the monetary value of each life saved and serious injury avoided from the Road Casualties Great Britain 2006 [RCGB 2006] report was used. The values used were £1,489,450 for each life saved and £167,360 for each serious injury prevented. These values include the following elements of cost:

- Loss of output due to injury. This is calculated as the present value of the expected loss of earnings plus any non-wage payments (National Insurance contributions, etc.) paid by the employer.
- Ambulance costs and the costs of hospital treatment.
- Human costs, based on Willingness To Pay (WTP) values, which represent pain, grief and suffering to the casualty, relatives and friends, and, for fatal casualties, the intrinsic loss of enjoyment of life over and above the consumption of goods and services.

It should be noted that the GB values are, in general, higher than those used for other European countries as they include a 'Willingness to Pay' element. However, they were still used for this analysis because other published values were not easily obtainable.

**Table 4: Financial benefit, i.e. monetary value of casualties prevented.**

| | Casualties Prevented | | Financial Benefit per casualty | | Financial Benefit (£Million) | | |
|---|---|---|---|---|---|---|---|
| | Fatal | Serious | Fatal | Serious | Fatal | Serious | TOTAL |
| EU-15 | 430 | 6,017 | £1,489,450 | £167,360 | £640M | £1,007M | £1,647M |
| EU-25 | 574 | 8,038 | £1,489,450 | £167,360 | £855M | £1,345M | £2,200M |
| EU-27 | 625 | 8,756 | £1,489,450 | £167,360 | £932M | £1,465M | £2,397M |

If an exchange rate of 1.2 Euro per GBP is assumed the financial benefit of introducing the Advanced European Full Width (AE-FW) test into Europe could be:
- Up to €1,976Million for the EU-15 countries
- Up to €2,640Million for the EU-25 countries
- Up to €2,876Million for the EU-27 countries

per year assuming that all vehicles on the road complied with the test requirements.

# 3. Cost Analysis

The cost analysis was performed by FIAT. It was based on an estimate of the cost of the work required to upgrade the FIAT BRAVO to achieve the UN ECE Regulation 94 limits (first scenario) and the US FMVSS208 limits (second scenario) in an Advanced European Full Width (AE-FW) test and not decrease Euro NCAP performance. The Fiat BRAVO was chosen to represent a typical European car that is not designed to meet the US FMVSS208 full width test requirements. Therefore the analysis should give an upper estimate for the cost to introduce the AE-FW test because the FIAT BRAVO is likely to require more modifications to meet future AE-FW test requirements than a car that already meets the US FMVSS208 full width test requirements. Because the performance limits for the AE-FW test have not been determined yet, it was decided to perform the cost analysis using two assumptions. The first of these was that the performance limits of a future AE-FW test would be similar to those currently required in the UN ECE Regulation 94 frontal impact Offset Deformable Barrier (ODB) test, on the basis that a car should offer at least a similar level of protection in full width impacts to that currently enforced for offset impacts. The second assumption was that the performance limits would be similar to the US FMVSS208 limits on the basis of harmonisation.

A summary of the UN-ECE R94 and US FMVSS208 performance limits are shown in the following table for reference.

**Table 5: Summary of UN ECE R94 and US FMVSS208 performance limits.**

| **Criteria** | **R94 Limit** | **FMVSS208 Limit** |
|---|---|---|
| $HIC_{36}$ | 1000 | 1000 |
| $HIC_{15}$ | | 700 |
| Head Resultant Acceleration (3 ms excedence) | 80g | |
| Neck Extension Moment | 57 Nm | |
| Neck tension +Z | | 4.17 KN |
| Neck compression –Z | | 4.00 KN |
| $N_{ij}$ | | 1.0 |
| Chest Deflection | 50 mm | 63mm |
| Viscous Criterion | 1.00 | |
| Chest acceleration (3 ms excedence) | | 60g |
| Femur Compression | 9.7 kN | 10.0 KN |
| Knee Displacement | 15 mm | |
| Tibia Compression | 8 kN | |
| Tibia Index | 1.3 | |

Within APROSYS SP1.2, FIAT performed three AE-FW tests with the FIAT BRAVO as part of the task to evaluate the AE-FW test [APROSYS 2008]. Two of these tests were performed with a rigid barrier and one with a deformable face. The data from these tests was used in the following cost analysis to determine the modifications necessary to the FIAT BRAVO to meet assumed future AE-FW test requirements.

**Driver performance vs UN ECE R94 limits:**

The biomechanical performances were repeatable in all three AE-FW tests, Two tests on the rigid wall and 1 test on the deformable barrier were undertaken in the Fiat laboratory and so there were no significant differences between the rigid wall tests and the deformable face test:

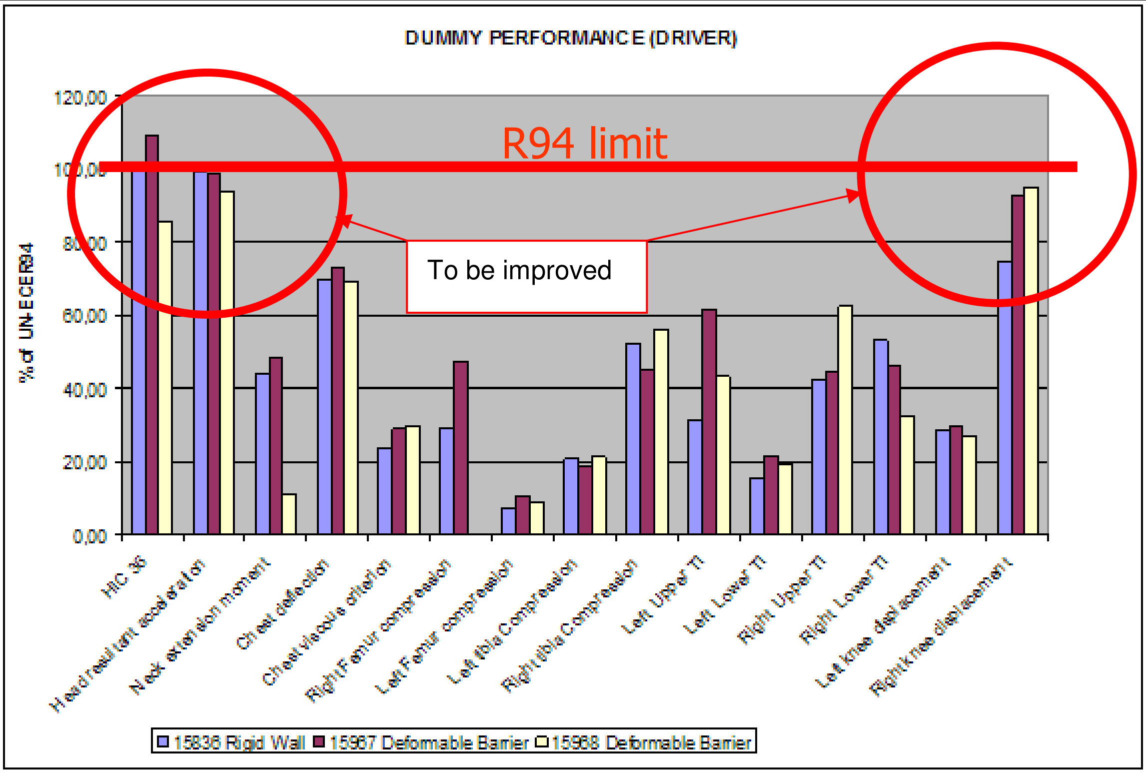


**Figure 5: Driver (front left) maximum dummy injury criteria values shown as a percentage of UN ECE R94 limits for Fiat Bravo tests**

The performance of the driver needs to be improved in the **head** and in the **legs/knee:**

- the head acceleration performance is close to the limits because the interaction with the airbag is very hard. So it is necessary to have a retuning of the belt load limiter and the driver airbag vent-hole → **introduction of a degressive load limiter**
- the knee-displacement is close to the limits because the contact between knee and dashboard is very hard so it is necessary to have a lower forward movement of the pelvis → **introduction of a double pretensioner**

In addition:

- the performance of the chest deflection is at 70 %, so it is possible that the tuning of the belt load limiter and the driver airbag could decrease this performance. So in order to guarantee to stay under the R94 limits and not to decrease the performance in Euro NCAP test, it is necessary to introduce a **collapsible steering column.**

**Passenger performance vs UN ECE R94 limits**

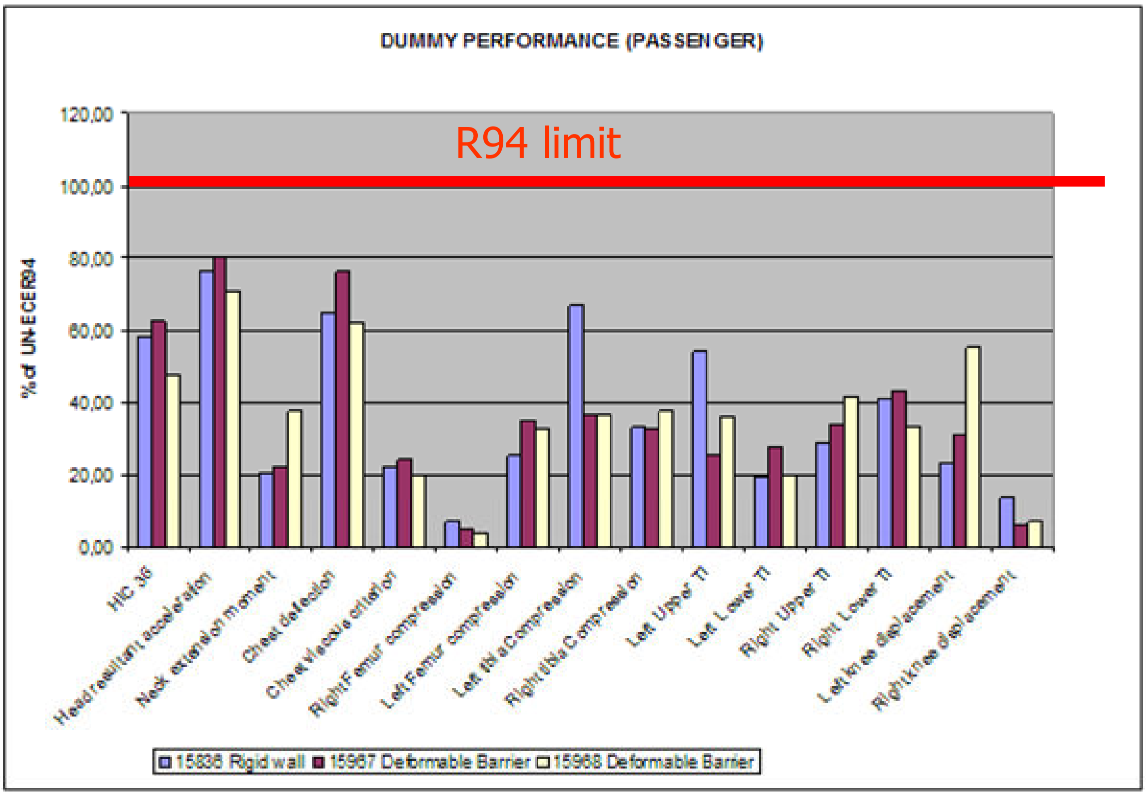


**Figure 7: Passenger (front right) maximum dummy injury criteria values shown as a percentage of UN-ECE R94 limits for Fiat Bravo tests**

On the passenger side the performance is well within the UN ECE R94 limits.

**Driver performance vs FMVSS208 limits:**

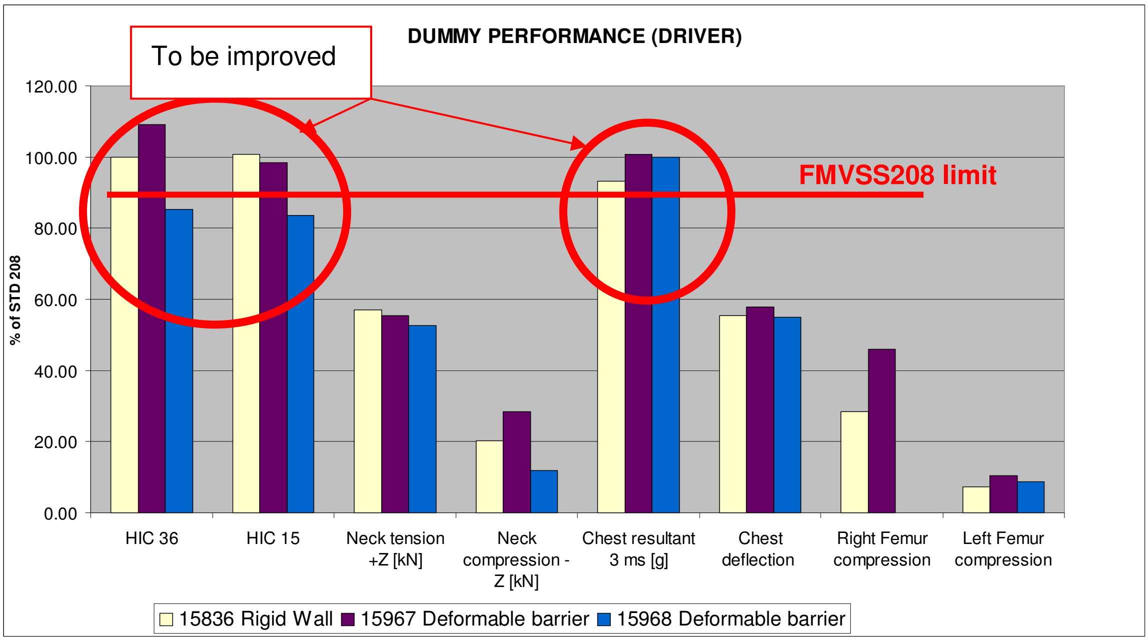


**Figure 8: Driver (front left) maximum dummy injury criteria values shown as a percentage of FMVSS 208 limits for Fiat Bravo tests**

The performance of the driver has to be improved in the HIC and in chest resultant 3ms excedence**:**

- Introduction of the degressive load limiter and of the collapsible steering column and retuning of the driver airbag

**Passenger performance vs FMVSS208 limits:**

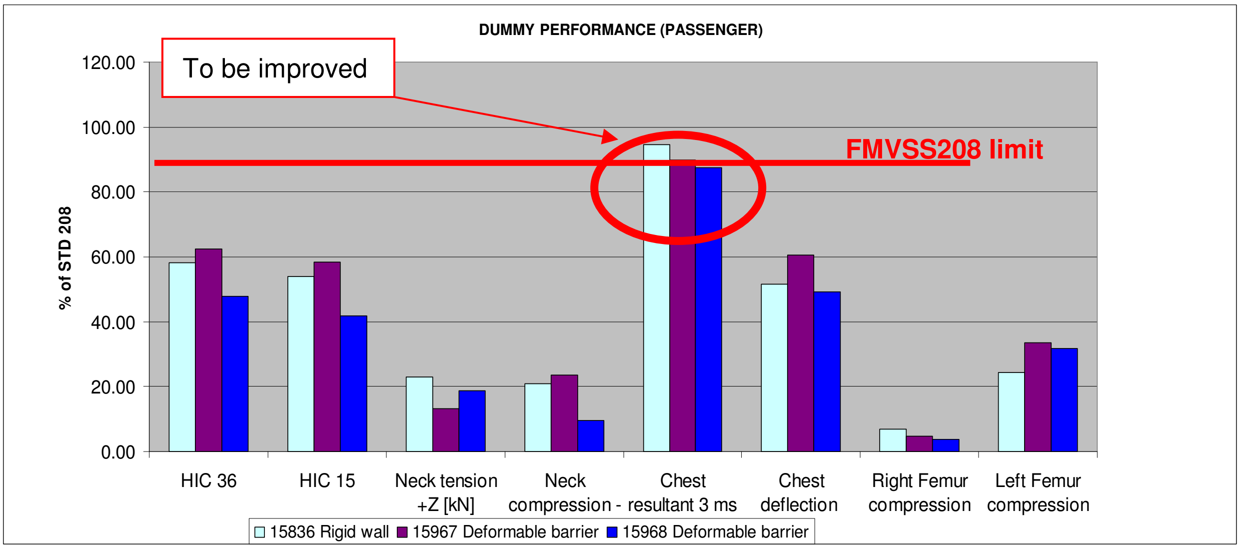


**Figure 9: Passenger (front right) maximum dummy injury criteria values shown as a percentage of FMVSS 208 limits for Fiat Bravo tests**

The performance of the passenger has to be improved and in chest resultant 3ms excedence**:**

- Introduction of the degressive load limiter and retuning of the passenger airbag

From the analysis of the Fiat APROSYS tests results it was decided that only changes to the restraint system would be necessary to meet the requirements and no structural modifications would need to be made. In this section no costs have been included for the inclusion of rear occupants in the test.

**Table 6: Summary of necessary restraint component changes to meet future AE-FW test requirements.**

| COMPONET | CURRENT SITUATION | TO ADD FOR R94 LIMITS (scenario 1) | TO ADD FOR FMSS208 LIMITS (scenario 2) |
|---|---|---|---|
| Dual stage driver bag | X | X | X |
| Dual stage passenger bag | X | X | X |
| Collapsable steering column | | X | X |
| Single pretensioner | X | | X |
| Double pretensioner | | X | |
| Simple Load limiter | X | | |
| Degressive load limiter | | X | X |

Components to add in Fiat Bravo for the two scenarios.

| SCENARIO 1 (R94 LIMITS) | SCENARIO 2 (FMVSS208 LIMITS) |
|---|---|
| Collapsible steering column | Collapsible steering column |
| Double pretensioner | |
| Degressive load limiter | Degressive load limiter |

## Evaluation of costs

The basis of the cost analysis is an economic analysis to evaluate the **surcharge costs** on an existing product (FIAT BRAVO). These costs are divided in three groups:

1. Tooling costs
2. Variable costs
3. Development costs

### 1. Tooling costs

Tooling costs are due to the fixed costs to upgrade the existing tools and to purchase new tools.

| | Δ cost K€ | |
|---|---|---|
| **COMPONENT** | **SCENARIO 1 (R94 LIMITS)** | **SCENARIO 2 (FMVSS208 LIMITS)** |
| **Collapsible steering column** | 1500 | 1500 |
| **Double pretensioner** | 200 | |
| **Degressive load limiter** | 50 | 50 |
| **TOTAL** | 1750 | 1550 |

### 2. Variable costs

Variable costs are due to the parts for each car and all the other costs which depend on the number of cars manufactured

| | Δ cost €/car | |
|---|---|---|
| **COMPONENT** | **SCENARIO 1 (R94 LIMITS)** | **SCENARIO 2 (FMVSS208 LIMITS)** |
| **Collapsible steering column** | 10 | 10 |
| **Double pretensioner** | 8 x 2 | |
| **Degressive load limiter** | 1.5 x 2 | 1.5 x 2 |
| **TOTAL** | 29 | 13 |

## 3. Development costs

Development costs include design costs of new components, virtual analysis costs and development testing costs.

| | Δ cost K€ | |
|---|---|---|
| **COMPONENT** | **SCENARIO 1 (R94 LIMITS)** | **SCENARIO 2 (FMVSS208 LIMITS)** |
| **Collapsable steering column** | 1900 | 1900 |
| **Double pretensioner** | 50 | |
| **Degressive load limiter** | 30 | 30 |
| **TOTAL** | 1980 | 1930 |

## Evaluation total customer surcharge cost per car (€) (Scenario1,Scenario2)

The total customer surcharge cost per car (€) was evaluated by the following formula:

The total customer surcharge cost per car = $\left(\frac{\mathbf{FC}}{\mathbf{n\_cars}} + \mathbf{VC}\right)$

where:
**FC**: Total Fixed cost for customer (€)

**VC**: Variable costs/car

**n_cars** : number of cars manufactured

### SCENARIO 1 (R94 LIMITS):

| | Total Fixed cost for customer (FC) (€) | | Variable costs/car (€) (VC) |
|---|---|---|---|
| | Tooling cost (€) | Development and design costs | |
| | 1750000 | 1980000 | 29 |
| **INDUSTRY** | 3730000 | | 29 |
| **CUSTOMER** | $\left(\frac{FC}{n\_cars} + VC\right)$ | | |

## SCENARIO 2 (FMVSS208 LIMITS):

| | Total Fixed cost for customer (FC) (€) | | Variable costs/car (€) (VC) |
|---|---|---|---|
| | Tooling cost (€) | Development and design costs | |
| | 1550000 | 1930000 | 13 |
| **INDUSTRY** | 3480000 | | 13 |
| **CUSTOMER** | $\left(\frac{FC}{n\_cars} + VC\right)$ | | |

The following table shows total customer surcharge cost per car (€) depending on number of car manufactured.

| Manufactured cars(n_cars) | SCENARIO 1 (€) (R94 LIMITS) | SCENARIO 2 (€) (FMVSS208 LIMITS) |
|---|---|---|
| 100000 | 66 | 48 |
| 500000 | 36 | 20 |
| 1000000 | 32 | 17 |

**SCENARIO 1 (R94 LIMITS):**
**the customer surcharge cost per car is 32 € (it could be even worst if cars manufactured are less than 1,000,000)**

**SCENARIO 2 (FMVSS208 LIMITS):**
**the customer surcharge cost per car is 17 € (it could be even worst if cars manufactured are less than 1,000,000)**

## Costs for Introduction of AE-FW test each year:

To evaluate the total costs per year to introduce the AE-FW test in Europe it is necessary to consider the total number of new registered cars per year.

The next table shows the number of European passenger-car new registrations:

| New Registrations in EU15 -PC Passenger Cars- | | | | | | |
|---|---|---|---|---|---|---|
| Country | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
| Austria | 314.182 | 309.427 | 293.528 | 279.493 | 300.121 | 311.292 |
| Belgium | 489.621 | 515.204 | 488.683 | 467.569 | 458.796 | 484.757 |
| Denmark | 143.727 | 112.690 | 96.173 | 111.585 | 96.078 | 121.490 |
| Finland | 136.324 | 134.646 | 109.487 | 116.877 | 147.222 | 142.439 |
| France | 2.148.423 | 2.133.884 | 2.254.732 | 2.145.071 | 2.009.246 | 2.013.709 |
| Germany | 3.802.176 | 3.378.343 | 3.341.718 | 3.252.898 | 3.236.938 | 3.266.825 |
| Greece | 261.711 | 290.222 | 280.214 | 268.489 | 257.293 | 289.691 |
| Ireland | 174.242 | 230.795 | 164.730 | 156.125 | 145.223 | 154.136 |
| Italy | 2.338.464 | 2.423.084 | 2.413.455 | 2.279.612 | 2.247.019 | 2.264.688 |
| Luxembourg | (40476) | (41896) | (42833) | (43403) | (43620) | (48234) |
| Netherlands | 611.487 | 597.625 | 530.231 | 510.702 | 488.841 | 483.745 |
| Portugal | 272.883 | 257.836 | 255.210 | 226.092 | 189.792 | 197.645 |
| Spain | 1.406.246 | 1.381.256 | 1.425.573 | 1.331.877 | 1.382.109 | 1.517.286 |
| Sweden | 295.249 | 290.529 | 246.581 | 254.589 | 261.206 | 264.246 |
| United Kingdom | 2.197.615 | 2.221.670 | 2.458.769 | 2.563.631 | 2.579.050 | 2.567.269 |
| EU (15) | 14.592.350 | 14.277.211 | 14.359.084 | 13.964.610 | 13.798.934 | 14.079.218 |

According to these data from ACEA, there are 14,221,978 new registered cars each year on average so the expenditure for the EU15 per year is:

1. **<u>SCENARIO 1</u> (R94 LIMITS):**
   **14,221,978* ( 32€ ) = <u>455,103,296 €</u>**

2. **<u>SCENARIO 2</u> (FMVSS208 LIMITS):**
   **14,221,978* ( 17€ ) = <u>241,773,626 €</u>**

It should be noted that:

- in order to reach the full benefit predicted it is likely that performance limits at least equivalent to R94 would be needed and possibly even more stringent performance limits.
- many cars sold in Europe are also sold in countries such as the US where a full width test is already required and so are likely to perform better in the full width test than the FIAT BRAVO and hence cost less to modify.

## 4. European Cost Benefit Estimate

For the cost benefit comparison below, it was assumed that 100% of the vehicles in the fleet met the AE-FW test requirements. Obviously, in the first ten years or so, before full fleet penetration is achieved the number of vehicles in the fleet meeting the requirements will be less and hence the benefit will be less.

The benefit analyses above estimated that the potential financial benefit of introducing the Advanced European Full Width (AE-FW) test into European legislation could be **up to abut €2,000Million** for the EU-15 countries per year assuming that all vehicles complied to the test requirements. This estimate was made based on the assumption that the introduction of a full width test in Europe would encourage improved restraint systems, which in turn would reduce restraint-induced injury in frontal collisions with little or no compartment intrusion. The level of injury reduction was assumed to be a maximum of 2 AIS levels, with no injuries being reduced to a level lower than AIS 1. This assumption was based on previous work [Cuerden et al. 2001] in which expert judgement was used to derive subjective estimates of potential reductions in the severity of an AIS injury to given body regions for the fitment of improved restraint systems.

The cost analysis above estimated that the cost of introducing the Advanced European Full Width (AE-FW) test into European legislation for the EU-15 countries per year to enable new registrations to comply would be about €240Million to meet performance limits similar to US FMVSS208 and about **€460Million** to meet limits similar to UN ECE Regulation 94. However, it should be noted that many cars sold in Europe are also sold in countries such as the US where a full width test is already required. Therefore they are likely to perform better in the AE-FW test than the FIAT Bravo case car on which the analysis was based and hence cost less to modify, so the cost estimates made are likely to be high.

In summary, for the EU-15 countries, there is a potential benefit of up **to €2,000Million** for the introduction of the AE-FW test. To modify cars to meet performance limits similar to UN ECE R94 in the AE-FW test was estimated to cost up to about **€460Million**.

However, it should be noted that this is an initial analysis and that more stringent performance requirements above UN ECE R94 equivalent ones may be needed to deliver the all of the potential benefit. This would require additional modifications to the car, possibly even adaptive restraint systems, which would obviously increase the cost. In addition, it should be noted that the criterion used to control thoracic injury in regulatory testing with the HYBRIDIII dummy is the sternal deflection. It has been found that this criterion does not correctly assess the effectiveness of improved restraint systems observed in accidentology [Petitjean, 2002]. This indicates that it may also be necessary to upgrade the dummy test tool and / or the thoracic injury criterion to enable a better assessment of the restraint system and ultimately deliver all of the potential benefit.

# 5. Conclusions and Recommendations

A cost benefit analysis has been performed based on the assumption that 100% of the vehicles in the fleet met the AE-FW test requirements. Obviously, in the first ten years or so, before full fleet penetration is achieved the number of vehicles in the fleet meeting the requirements will be less and hence the benefit will be less.

Analyses have been performed to estimate the potential benefit for introducing a full width (AE-FW) test into European legislation. Because the performance requirements and associated limits of the AE-FW test have not been finalised yet, the analyses performed give only an indicative estimate of the potential benefit as assumptions have to be made to determine the effect of the introduction of the AE-FW test on the risk of injury for casualties. The assumption made was that the introduction of a full width test in Europe would encourage improved restraint systems, which in turn would reduce restraint-induced injury in frontal collisions with little or no compartment intrusion. Using this assumption and GB accident data it was estimated that the potential benefit was a reduction in **annual car occupant** fatalities in GB by up to approximately 3 percent (47 occupants) and serious casualties by up to approximately 6 percent (812 occupants). Scaling this to Europe gave a potential financial benefit of up to about **€2,000Million** for the EU-15 countries per year assuming that all vehicles on the road complied with the test requirements.

An analysis has been performed to estimate the cost of introducing a full width (AE-FW) test into European legislation. The cost estimated for the EU-15 countries per year to enable new registrations to comply was about **€240Million** to meet performance limits similar to US FMVSS208 and about **€460Million** to meet limits similar to UN ECE Regulation 94. However, it should be noted that many cars sold in Europe are also sold in countries such as the US where a full width test is already required. Therefore they are likely to perform better in the AE-FW test than the case car on which the analysis was based and hence cost less to modify, so the cost estimates made are likely to be high.

It should be noted that more stringent performance requirements than the UN ECE R94 equivalent ones and other measures may be needed to deliver the all of the estimated potential benefit. This would require additional modifications to the car, possibly even adaptive restraint systems, which would obviously increase the cost. In addition, it should be noted that the criterion used to control thoracic injury in regulatory testing with the HYBRIDIII dummy is the sternal deflection. It has been found that this criterion does not correctly assess the effectiveness of improved restraint systems observed in accidentology [Petitjean, 2002]. This indicates that it may also be necessary to upgrade the dummy test tool and / or the thoracic injury criterion to enable a better assessment of the restraint system and ultimately deliver all of the potential benefit.

In summary, this initial cost benefit analysis indicates that the value of the potential benefit for the introduction of the AE-FW test in Europe is about 4 times higher than the costs to meet performance limits in the test similar to the current UN ECE R94 ones. However, more stringent performance limits and other measures may be needed to deliver the all of the estimated potential benefit, which would require additional modifications to the car and increase the cost.

It is recommended that further work is performed to determine the AE-FW test performance limits required to deliver most or the entire estimated potential benefit and the cost of additional car modifications to meet these limits, if any are necessary. A suggested approach for this work is to relate the expected reduction in dummy injury criteria, as a result of the introduction of the AE-FW test, to occupant injury risk reduction using ‘injury risk’ curves to help determine the performance limits needed.

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# 7. Acknowledgments

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Further information on CCIS can be found at http://www.ukccis.org