Estimation of the benefits for the UK for potential options to modify UNECE Regulation No. 95

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Abstract - The side impact problem in Europe remains substantial. UK data shows that between 22% and 26% of car occupant casualties are involved in a side impact, but this rises to between 29% and 38% for those who are fatally injured. This indicates the more injurious nature of side impacts compared with frontal impacts. The European Enhanced Vehicle safety Committee (EEVC) has performed work to address the side impact issue since 1979. As part of its continuing work, it has recently investigated potential options for regulatory changes to improve side impact protection in cars further. To support this work the UK undertook an analysis to estimate the benefit for potential options to modify UNECE Regulation 95. The analysis used the UK national STATS19 and detailed Co-operative Crash Injury Study (CCIS) accident databases. Of the potential options reviewed, it was found that the addition of a pole test offered the greatest benefit.

INTRODUCTION

The side impact problem in Europe remains substantial. UK data shows that between 22% and 26% of car occupant casualties are involved in a side impact, but this rises to between 29% and 38% for those fatally injured. The higher percentage of fatally injured compared to all involved indicates the more injurious nature of side impacts compared with other impacts (mainly frontal impacts).

Currently in Europe, Directive 96/79/EC and UNECE Regulation No. 95 set the minimum standards for the side impact crashworthiness performance of cars and vans (M_1 and N_1 vehicles where the reference point of the lowest seat is less than or equal to 700 mm from the ground). There are some small differences between the Directive and the Regulation due to the fact that the Regulation has been updated more recently than the Directive, but overall they are essentially the same. They both consist of a test in which a Mobile Deformable Barrier (MDB), comprising a deformable barrier face on a trolley which represents a car, is propelled into the side of the vehicle to be tested at 50 km/h. Occupant injury protection is assessed using an instrumented crash test dummy, the EuroSID.

The European Enhanced Vehicle safety Committee (EEVC) have performed work to address the side impact issue since 1979, including the development of the current regulatory side impact test procedure. As part of its continuing work, it has recently investigated potential options for regulatory changes to improve side impact protection in cars further.

To support this work, on behalf of the UK Department for Transport (DfT), TRL undertook an analysis to estimate the UK benefit for the following potential options to modify the side impact legislation (i.e. UNECE Regulation 95):

- Option A – No change
    - Allow current measures to propagate throughout the vehicle fleet. This entails the replacement of old vehicles in the fleet which are not regulatory compliant with new vehicles. These new vehicles will be regulatory compliant and may also have much higher safety performance levels as encouraged by Euro NCAP.
- Option B – Amend the existing Regulation 95 MDB test.
    - Replace the current Regulation 95 MDB test with the Advanced European Mobile Deformable Barrier (AE-MDB) test [1, 2]. The configuration and performance requirements assumed for the AE-MDB test were: test speed 50 km/h; barrier mass 1500 kg; barrier face version 3.9; perpendicular impact; impact point 250 mm rear of the R-point; dummies ES-2 driver and rear passenger; UNECE Regulation 95 dummy criteria and performance limits.
- Option C – Add a pole test to the existing Regulation 95 MDB test.

  - The configuration and performance requirements assumed for the pole test were: test speed 29 km/h, perpendicular impact, impact point aligned with head centre of gravity, ES-2 driver dummy; UNECE Regulation 95 dummy criteria and performance limits. Note: this test configuration is the same as currently used by Euro NCAP.
- Option D – Add a head impact test procedure to the existing Regulation 95 MDB test.
  - The configuration and performance requirements assumed for the interior headform test were for the Free Motion Headform (FMH) test defined by EEVC WG13 [3]
- Option E – Combination of Options B and C.

An additional analysis was performed to estimate the benefit of an AE-MDB test with a higher test speed (Option B*). It should be noted that before this option could be considered for legislative or consumer testing, further research would be necessary to address outstanding key issues. These include the suitability of the current test tools, in particular the barrier face and dummy, at higher test speeds. Initial research shows that the current barrier face would probably need to be modified to increase its depth to prevent it 'bottoming out' before it would be suitable for use in a regulatory regime. In a 60 km/h AE-MDB test performed by the UK and reported to EEVC WG13 it was seen that the barrier face was very close to 'bottoming out' [4].

The following key assumptions of the analysis should be noted:

- The potential effects of primary safety measures such as Electronic Stability Control (ESC) and Brake Assist Systems (BAS) were not taken into account in the analysis performed.
- The benefits for the pole test were calculated based on the assumption that the Regulation would require the vehicle to be fitted with a countermeasure, such as a curtain airbag, which would offer protection for head strikes against all objects between the A and C pillars, such as the cant rail and B pillar, in a range of impacts and not just car-to-pole accidents. A countermeasure such as a head-thorax airbag which did not offer protection for head strikes over all of this area would not fulfil this requirement. To enforce the fitment of this type of countermeasure the modified Regulation would need to include measures, in addition to the pole test, to assess if adequate protection was provided for areas between the A and C pillars that are not in alignment with the pole.

DATA SOURCES

Two sources of accident data were used for this work, the national STATS19 database and the detailed Co-operative Crash Injury Study (CCIS) database.

STATS19

STATS19 is a database of traffic collisions in Great Britain that result in injury to at least one person and are reported to the police. The database primarily records information on where the collision took place, when the collision occurred, the conditions at the time and location of the collision, details of the vehicles involved, and information about the casualties. When police attend a road traffic accident the officers on the scene fill out a series of standard forms. The severity of the casualties involved in the accident is assessed by the investigating police officer. Each casualty is recorded as being either slightly, seriously, or fatally injured. Fatal injury includes only casualties who died less than 30 days after the accident, not including suicides or death from natural causes. Serious injury includes casualties who were admitted to hospital as an in-patient. Slight injury includes minor cuts, bruises, and whiplash. The full definitions of these injury severities (and all other information recorded in STATS19) are given in the STATS20 document which accompanies the STATS19 form. These definitions are also available online at www.stats19.org.uk.

Data for accidents in 2006 and 2007 were used for this analysis.

Co-operative Crash Injury Study (CCIS)

The CCIS project collected in-depth real world crash data from 1983 to 2010. Vehicle examinations were undertaken at recovery garages several days after the collision. Car occupant injury information was collected and questionnaires were sent to survivors. Accidents were investigated according to a stratified sampling procedure, which favoured cars containing fatal or seriously injured occupants as defined by the British Government definitions of fatal, serious and slight. It also favoured newer vehicles. More information about the study is available at www.ukccis.org.

CCIS data from phases 7 to 8, which encompasses accidents collected from 2001 to 2009, were used for this analysis.

METHODOLOGY

The analysis was performed in two parts; the first part estimated the benefit of Option A (No change) and the second part the benefits of Options B to E.

Part 1: Estimation of the benefit of Option A (No change)

Only the STATS19 national data base was used for this analysis. The benefit of this option arises from the replacement of old vehicles in the fleet which are not regulatory compliant with new vehicles which are regulatory compliant and may also have much higher safety performance levels as encouraged by Euro NCAP.

The legal situation for side impact type approval within the European Union is:

- Since 1st October 1998 legislation for side impact protection (EC Directive 96/27/EC or UNECE Regulation 95) has been mandated for type approval of new vehicle types within the European Union.
- Since 1st October 2003 an approval has been mandated for the first registration of a vehicle.

Hence, all vehicles registered after 1st October 2003 are regulatory compliant and some vehicles registered between 1st October 1998 and 1st October 2003 are regulatory compliant.

The approach used to estimate the benefit was based on the assumption that the total number of casualties (fatal plus serious plus slight) in a 'regulatory compliant' fleet would be the same as in the current fleet, but the proportion of fatal, serious and slight casualties would be different. The analysis consisted of the following steps:

- Derive data samples of car occupant casualties in 'all' cars and 'regulatory compliant' cars involved in side impact accidents and determine casualty distribution by injury severity (fatal, serious, slight).
    - The criterion used to select 'regulatory compliant' cars was those registered in 2004 or later.
- Estimate the benefit based on a comparison of proportion of fatalities and serious casualties in the two data samples.
    - The reduction in the proportions of fatal and seriously injured casualties in the 'regulatory compliant' data sample compared to the 'all' data sample gives a first approximation of the likely benefits associated with the newer regulatory compliant cars. However, the reduction will not all be due to vehicle design influenced by regulation and/or Euro NCAP. For example, newer cars are driven by people with a different demographic with respect to age, gender and other factors compared to older cars. Also, newer cars will have a different exposure and risk to crashes. In the absence of more precise information, for the purposes of this study, it was decided to associate half the proportional reduction

seen to vehicle improvements and half to driver behaviour related and other confounding factors.
- Estimate the number of casualties in a 'regulatory compliant' fleet by application of the casualty distribution calculated in the step above to the 'all' data sample keeping the total number of casualties constant.
- Estimate the benefit from a comparison of the number of casualties in the 'regulatory compliant' fleet with the 'all' data sample.

Part 2: Estimation of the benefit of Options B to E

For this analysis, both the STATS19 national and the CCIS detailed accident databases were used because the detailed information necessary to perform the analysis was not available in the STATS19 database. It should be noted that the STATS19 'regulatory compliant' fleet data sample was used as the baseline for the estimation of the benefit of Options B to E to ensure that the benefits of updating the vehicle fleet (i.e. replacing non-regulatory compliant cars with compliant ones) were not double counted.

The following four-step methodology was used to estimate the benefit for each of the potential regulatory Options B to E:
- Derivation of CCIS data sample equivalent to STATS19 data sample
  - Criteria were used to select seriously injured (MAIS 2+) casualties involved in side impacts in 'regulatory compliant' cars seated on the struck side.
  - The injury distribution of the casualties in terms of MAIS and impact type was determined.
- Identification of the target population in the CCIS data sample.
  - Criteria were used to select casualties in the target population, i.e. those likely to have a reduced risk of injury as a result of the implementation of the potential options for regulatory change.
- Estimation of the injury reduction factors using the CCIS data sample.
  - In-depth case analyses were undertaken for each casualty in the target population and their crash characteristics. For each potential regulatory option, assessments were made of how much the casualty's injuries would have been reduced based on what safety countermeasures would need to be added to the car to enable it to comply. The amount of potential injury reduction was directly related to the car's existing safety features, with less well equipped cars having the greatest potential for injury reduction. Test experience and industry advice were used to define the engineering countermeasures needed for cars with a range of safety performance levels.
- Scaling of the CCIS injury reduction factors using the national STATS19 database.
  - The CCIS injury reduction factors were scaled to estimate the benefit for the UK.

RESULTS

Part 1: Estimation of the benefit of Option A (No change)

Derive data samples of car occupant casualties in 'all' cars and 'regulatory compliant' cars

British national casualty data (STATS19) from 2006 and 2007 were analysed to provide a baseline of current car occupant casualties. In this two year period, there were 330,653 injured car occupants with 3,033 fatalities and 24,052 serious casualties. Table 1 shows the distribution of car occupant casualties in side impacts by impact type. 'Car/LGV' refers to an impact with another car or Light Goods Vehicle (LGV); 'HGV/PSV' refers to an impact with a heavy goods or large passenger vehicle, 'other' refers to impacts with other objects mainly single vehicle accidents and 'multiple' refers to accidents in which there were multiple impacts.

Side impacts were selected using the 'first point of contact' to either the right or left side of the car. This includes all ages of cars and associated side impact performance levels. 'Regulatory compliant' cars were selected using a criterion of those registered in 2004 or later (Table 2).

Table 1. Distribution of car occupant side impact casualties in STATS19 (2006 & 2007)

Impact Type	All Car Occupant Injury Severity			Total
	Fatal	Serious	Slight	
Car/LGV-Car	237 (0.64%)	1,763 (4.74%)	35,174 (94.62%)	37,174 (100%)
HGV/PSV-Car	67 (1.61%)	215 (5.18%)	3,870 (93.21%)	4,152 (100%)
Other-Car	442 (2.21%)	2,294 (11.49%)	17,223 (86.29%)	19,959 (100%)
Multiple-Car	415 (2.26%)	1,951 (10.63%)	15,988 (87.11%)	18,354 (100%)
Total	1,161 (1.46%)	6,223 (7.81%)	72,255 (90.73%)	79,639 (100%)

Table 2. Distribution of car occupant side impact casualties in STATS19 (2006 & 2007) in 'regulatory compliant' cars, i.e. those registered in 2004 or later

Impact Type	Car Occupant Injury Severity for cars registered in 2004 or later			Total
	Fatal	Serious	Slight	
Car/LGV-Car	25 (0.37%)	246 (3.69%)	6,396 (95.94%)	6,667 (100%)
HGV/PSV-Car	9 (1.16%)	31 (4.00%)	735 (94.84%)	775 (100%)
Other-Car	64 (2.12%)	309 (10.22%)	2,651 (87.67%)	3,024 (100%)
Multiple-Car	59 (1.49%)	325 (8.20%)	3,577 (90.31%)	3,961 (100%)
Total	157 (1.09%)	911 (6.31%)	13,359 (92.60%)	14,427 (100%)

Estimate benefit

The number of casualties in a 'regulatory compliant' fleet was estimated (Table 3) using the methodology described in the section above.

Table 3. Number and distribution of car occupant side impact casualties (2006 & 2007) in GB if all cars were 'regulatory compliant'

Impact Type	Car Occupant Injury Severity			Total
	Fatal	Serious	Slight	
Car/LGV-Car	188 (0.51%)	1,567 (4.22%)	35,418 (95.28%)	37,174 (100%)
HGV/PSV-Car	58 (1.39%)	190 (4.59%)	3,904 (94.02%)	4,152 (100%)
Other-Car	432 (2.17%)	2,167 (10.86%)	17,360 (86.98%)	19,959 (100%)
Multiple-Car	344 (1.88%)	1,728 (9.42%)	16,281 (88.71%)	18,354 (100%)
Total	1,022 (1.28%)	5,653 (7.10%)	72,964 (91.62%)	79,639 (100%)

From a comparison of Table 1 and Table 3, it was estimated that 139 fatalities and 570 seriously injured casualties would have been prevented in the two year period (2006 to 2007) in Great Britain if all cars performed as vehicles registered post 2004. This is an average of 70 fatalities and 285 serious casualties per year for GB or based on all car occupants, reductions of 4.6% of the fatalities and 2.4% of the serious casualties. For the UK this scales to 72 fatalities and 295 serious casualties.

Part 2: Estimation of the benefit of Options B to E

Derivation of CCIS data samples

The following selection criteria were used to derive a CCIS data sample equivalent to the STATS19 data sample:

- Cars with only one significant impact to either the left or right side
- ‘Regulatory compliant’ cars
- Casualties with known injury data, with MAIS greater than or equal to 2
- Casualties seated on the struck-side of the vehicle.

Regulatory compliant cars were selected in the following manner:

- Select cars registered post 2000.
- Review cars in sample registered before 1st October 2003 to remove cars which did not have a safety performance level sufficient to be regulatory compliant. Euro NCAP test results and industry advisors were used to help perform this review.

Initially to select cars that were regulatory compliant a criterion of ‘those registered post 1 October 2003’ was considered. However, it was found that with this approach the data sample size was not large enough to perform a meaningful analysis. Hence, the approach was modified to the one described above.

This resulted in a data sample of 214 MAIS 2+ casualties, of which 55 were killed. The casualties were further categorised with respect to the nature of their crash. Table 4 highlights their MAIS distribution by crash type. These categories were chosen to be compatible with national UK casualty statistics (STATS19). ‘Car/LGV’ refers to car occupants seated on the struck side who were involved in an impact with another car or Light Goods Vehicle (LGV); ‘HGV/PSV’ refers to these car occupants involved in an impact with a heavy goods or large passenger vehicle. The ‘Other’ category involves single vehicle accidents with narrow and wide objects. The multiple impact (Multi) category comprises occupants whose cars had more than one impact, but the primary impact met the criteria and all other impacts were known to have been minor (typically less than 10cm of crush). Genuine multiple impacts (i.e. those with more than one significant impact) were excluded.

Table 4. Distribution of Injury (MAIS and police severity) by crash type

MAIS	Car/LGV	HGV/PSV	Other	Multi	Total
1	0	0	0	0	0
2	49	5	13	7	74
3	28	3	23	13	67
4	9	6	16	6	37
5	2	5	13	5	25
6	4	2	5	0	11
Total	92	21	70	31	214
Police Severity					
Fatal	12	10	27	6	55
Serious	80	11	43	25	159

Identification of the target population

It was assumed that casualties in side swipe type accidents, those in accidents in which the passenger compartment was not struck or those which received injuries to body regions not assessed by the ES-2 dummy (i.e. arms and legs) would not benefit from the potential regulatory options and hence should not be included in the target population. The following additional criteria were applied to select casualties to be included in the target population:

- Casualties in accidents with loading to the passenger compartment (i.e. between A and C pillars) and from an impact direction of ±45º to the perpendicular
- Casualties with serious injury (AIS 2+) to the body regions assessed by EuroSID (i.e. head, thorax, abdomen, or pelvis)

This resulted in a total of 112 casualties in the target population who sustained AIS 2+ injuries to one or combinations of the head (H), thorax (T), abdomen (A) or pelvic (P) body regions (Table 5).

Table 5. Relationship of target population (in bold) to CCIS data sample

MAIS 2+ injured casualties	Car loading meets criteria (n=133)		Car loading does not meet criteria (n= 81)		Total	
	Fatal	Serious	Fatal	Serious	Fatal	Serious
With H, T, A or P AIS 2+	**41**	**71**	14	42	55	113
Without H, T, A or P AIS 2+	0	21	0	25	0	46
Total	41	92	14	67	55	159

Estimation of the injury reduction factors

In-depth case-by-case analysis was undertaken for each casualty in the target population. Assessments were made of how much the injuries to the head, thorax, abdomen and pelvis of each casualty would have been reduced if the vehicle had been designed to meet each of the potential regulatory Options (B, C, D or E) or Option B* (an AE-MDB test with a test speed of about 65 km/h).

A set of protocols were developed to help assist the researchers in their expert judgements, regarding whether or not a vehicle meeting a particular option would then have the potential to mitigate a body region injury and if so to what extent. Flow charts detailing this process are included in Appendix A. Whether or not an injury could be mitigated was based on what safety countermeasures would need to be added to the car to enable it to comply with the potential regulatory option considered, which in turn depended on the current safety performance level of the car. Car safety performance levels were defined as:

- Just meets current regulatory requirements, has no side thorax bag
- Mid Euro NCAP score (side impact score of 13 using 2008 protocol), has side thorax bag but no head curtain bag
- High Euro NCAP score (side impact score of 18 using 2008 protocol), has side thorax and head curtain airbag.

The amount of potential injury reduction was directly related to the vehicles' existing safety features, with less well equipped cars having the greatest potential for injury reduction. Other factors considered on a case-by-case level included the influence of the seat belt (used or not), any other confounding factors such as subsequent rollovers, the severity of the crash (Delta-v) and the characteristics of the casualty (age, gender).

After reviewing every case, the occupants' MAIS was recalculated assuming that their vehicle met each option. The predicted MAIS distributions for the CCIS sample are shown in Table 6, Table **7**, Table 8, Table 9 and Table 10 for each of the options. It should be noted that it was assumed that no injury would be reduced to less than an AIS 1 because it was thought that it would not be realistic to assume that the improved countermeasure could mitigate the injury completely. Examples of case analyses are shown in Appendix B.

Table 6. Predicted MAIS distribution for the CCIS sample if all cars complied with Option B (AE-MDB test)

MAIS	Car/LGV	HGV/PSV	Other	Multi	Total
1	12	0	2	1	15
2	49	5	14	7	75
3	17	4	24	15	60
4	8	5	15	5	33
5	2	5	10	3	20
6	4	2	5	0	11
Total	92	21	70	31	214

Table 7. Predicted MAIS distribution for the CCIS sample if all cars complied with Option C (Pole test)

MAIS	Car/LGV	HGV/PSV	Other	Multi	Total
1	33	1	5	2	41
2	33	6	24	9	72
3	13	3	19	13	48
4	7	4	9	6	26
5	2	5	9	1	17
6	4	2	4	0	10
Total	92	21	70	31	214

Table 8. Predicted MAIS distribution for the CCIS sample if all cars complied with Option D (Free Motion Headform test)

MAIS	Car/LGV	HGV/PSV	Other	Multi	Total
1	6	0	1	0	7
2	45	5	13	7	70
3	26	3	22	13	64
4	9	6	16	7	38
5	2	5	13	4	24
6	4	2	5	0	11
Total	92	21	70	31	214

Table 9. Predicted MAIS distribution for the CCIS sample if all cars complied with Option E (AE-MDB and Pole test)

MAIS	Car/LGV	HGV/PSV	Other	Multi	Total
1	33	1	5	2	41
2	33	6	24	10	73
3	13	3	19	14	49
4	7	4	9	5	25
5	2	5	9	0	16
6	4	2	4	0	10
Total	92	21	70	31	214

Table 10. Predicted MAIS distribution for the CCIS sample if all cars complied with Option B* (AE-MDB test with test speed of about 65 km/h)

MAIS	Car/LGV	HGV/PSV	Other	Multi	Total
1	16	0	2	2	20
2	45	5	17	8	75
3	17	4	21	14	56
4	8	5	15	4	32
5	2	5	10	3	20
6	4	2	5	0	11
Total	92	21	70	31	214

Using Table 4 and cross referencing by injury severity, a relationship between a casualty's injury expressed in terms of MAIS and a casualty's injury expressed in terms of the police severity scale (i.e. fatal, serious and slight) was developed as shown in Table 11.

Table 11. Fatal, Serious and Slight Injury risk functions by MAIS

MAIS	Fatal (Proportion)	Serious (Proportion)	Slight (Proportion)
1	0	0	1
2	0	1	0
3	0.015	0.985	0
4	0.649	0.351	0
5	0.760	0.240	0
6	1	0	0

This relationship was used to transform the predicted injury in terms of MAIS to the police severity scale (i.e. fatal, serious and slight). Comparison of the predicted injury distribution (in terms of the police severity scale) with the known injury distribution (also in terms of the police severity scale[b]) yielded predicted injury reduction factors for each option by crash type (Table 12).

Table 12. Predicted injury reduction factors for each option by crash type

Option	Car/LGV		HGV/PSV		Other		Multi	
	Fatal	Serious	Fatal	Serious	Fatal	Serious	Fatal[a]	Serious[a]
(B)AE-MDB	0.931	0.850	0.935	1.000	0.886	0.953	0.909	0.960
(C) Pole	0.871	0.588	0.867	0.909	0.663	0.884	0.767	0.920
(D) FMH	0.997	0.925	1.000	1.000	0.999	0.976	0.998	1.000
(E)AE-MDB & Pole	0.871	0.588	0.867	0.909	0.663	0.884	0.767	0.920
(B*)AE-MDB (higher test speed)	0.931	0.811	0.935	1.000	0.762	0.891	0.815	0.960

[b] *In the CCIS database a casualty's injuries are recorded in both the police severity and AIS injury scales*

[a] *Due to the relatively small CCIS sample size for multiple impacts and the nature of these events, a proportional injury reduction factor was assigned based on all impact types.*

Scaling of CCIS injury reduction factors to estimate benefit for GB and UK

An equivalent STATS19 data sample to the CCIS one was formed to enable the predicted injury factors in Table 12 to be applied. Firstly, the number and distribution of casualties in struck-side impacts were estimated (Table 13), using the estimate of the number and distribution of car occupant casualties (2006 & 2007) in all side impacts if all cars were 'regulatory compliant' as a basis (Table 3).

Table 13. Number and distribution of car occupant struck-side impact casualties (2006 & 2007) in GB if all cars were 'regulatory compliant'

Impact Type	Car Occupant Injury Severity			Total
	Fatal	Serious	Slight	
Car/LGV-Car	113	925	19,834	20,872
HGV/PSV-Car	35	112	2,186	2,333
Other-Car	251	1,148	8,159	9,558
Multiple-Car	213	968	9,118	10,299
Total	612	3,153	39,297	43,062

Next, using CCIS data, the nature of multiple impact crashes was investigated to determine the proportion of fatal, serious and slight crashes where there was only one principal or significant impact versus those with genuine multiple impact damage. Approximately 80% of the cars in the data set with more than one impact, had a side impact which was the most serious and the other damage was relatively minor (typically less than 10cm of crush). An additional factor was included in the scaling to ensure that benefit was only assumed for this type of multiple impact.

The injury reduction factors estimated (Table 12) were then applied to the car occupant struck-side casualties in regulatory compliant cars (Table 13) to estimate the benefits of Options B to E for GB and scaled to estimate the benefits for the UK[c] (Table 14).

Table 14. Predicted benefit for UK per year for Options B to E and B* () denotes percentage of all car occupant fatalities / serious injuries. Note: benefits for Options B to E and B* are in addition to Option A; e.g. the total number of lives saved for Option C is 72 + 75 = 147

Options	Car Occupant Injury Severity		
	Fatal	Serious	Slight
(B) AE-MDB	+28 (+2%)	+88 (+0.7%)	-116
(C) Pole	+75 (+5%)	+230 (+2%)	-305
(D) FMH	+1(+0.07%)	+49 (+0.4%)	-50
(E) AE-MDB + Pole	+75 (+5%)	+230 (+2%)	-305
(B*) AE-MDB higher test speed	+51 (+4%)	+115 (+1%)	-166

In summary, the results show that from the proposed Options B to E, Option C (pole test) or Option E (combination of AE-MDB and pole tests) offers the greatest potential additional benefit. An increase

[c] *United Kingdom (UK) comprises Great Britain (GB) and Northern Ireland*

in the AE-MDB test speed from 50 km/h to about 65 km/h almost doubles the potential benefit of the AE-MDB test but it is still less than the benefit for the pole test.

DISCUSSION

The benefits predicted are likely to be conservative (i.e. a low estimate) because of the assumptions made to perform the analysis. The assumptions are outlined below and the effect of them on the accuracy of the results discussed:

- Only casualties in specific impact configurations (occupant compartment struck directly with an impact direction of +/- 45 degrees from the perpendicular) were included in the target population. This reduced the target population by 38% (from 214 to 133 MAIS 2+ injured occupants). It is reasonable to assume that some of the excluded casualties would have benefited from the measures considered, for example a curtain airbag could benefit those that sustained head injuries in accidents in which the occupant compartment was not struck directly.
- Only casualties with an AIS 2 or greater injury to their head, thorax, abdomen or pelvis were considered with respect to injury reduction because these are the body regions that are assessed by the dummy. This reduced the target population by a further 10% (from 133 to 112) even though it is likely that improvements to the side structures and airbag restraints would, for example, have prevented leg fractures too, but this possible benefit was not counted.
- Casualties in genuine multiple impacts were not included in the target population, and so there are a proportion of casualties who could benefit to some degree from the measures considered who were not counted.
- Assessing the injury severity by MAIS alone does not reflect the multi-trauma experienced in the real-world. For example, casualties predicted to experience some benefit, (especially with respect to AE-MDB and Pole tests) such as a reduction in a thorax injury from AIS 3 to AIS 1, but who also had injuries to other body regions, may have been scored as no change to their MAIS, even though their overall trauma was significantly reduced.
- Following-on from the point above, the injury reduction factors were calculated based on the correlation of MAIS and morbidity. This is likely to be a less reliable measure than overall trauma assessment, as it is accepted that significant injury to multi-body regions is more life threatening than single injuries of the same severity. Therefore, the injury reduction factors are conservative estimates.

It is interesting to note that Option C (Pole test) offers as much benefit as Option E (AE-MDB and Pole tests combined). The reason for this was that for the protection of the front seat occupant (in the majority of cases the driver) it was assumed that the pole test would introduce at least all the countermeasures that an AE-MDB test would. For the rear seated occupant it was assumed that the AE-MDB test would introduce additional countermeasures compared to the pole test for head and thorax protection. However, because the number of rear seated occupants in the data sample was small, the effect of this was not seen in the predicted benefit.

CONCLUSIONS

The benefit was estimated for the UK for each of the proposed regulatory Options A to E and for Option B* (a higher speed AE-MDB test), in terms of lives and serious injuries saved.

For Option A (no change) it was estimated that 72 lives would be saved per year (5% of car occupant fatalities) and 295 serious injuries (2% of car occupant serious injuries). This indicates that there is still much benefit to be gained from allowing current safety measures, i.e. Regulation 95 and Euro NCAP, to propagate throughout the vehicle fleet. However, it should be noted that this estimate was derived using the simple assumption that half of the decrease of the injury proportions seen between cars that were regulatory compliant (registered in 2004 or later) and those that may not be regulatory compliant (registered before 2004) was due to the increased safety performance levels of the vehicles. It was assumed that other factors such as the difference in the demographic of the occupants driving the older and newer cars accounted for the other half. Hence, to gain greater confidence in this estimate it is recommended that a more detailed study is performed using logistic regression type analysis to understand better the effect of factors such as the occupant demographic.

For Options B to E and Option B* the following benefits over and above those for Option A were estimated:

Options	Car Occupant Injury Severity	
	Fatal	Serious
(B) AE-MDB	+28 (+2%)	+88 (+0.7%)
(C) Pole	+75 (+5%)	+230 (+2%)
(D) FMH	+1(+0.07%)	+49 (+0.4%)
(E) AE-MDB + Pole	+75 (+5%)	+230 (+2%)
(B*) AE-MDB higher test speed	+51 (+4%)	+115 (+1%)

() expressed as a percentage of all car occupant fatalities / serious injuries.

It should be noted that:

- The potential effects of primary safety measures such as Electronic Stability Control (ESC) and Brake Assist Systems (BAS) were not taken into account in the analysis performed.
- The benefits estimated are likely to be conservative because of the nature of the assumptions made to derive them.
- The benefits for the pole test were calculated based on the assumption that the regulation would require the vehicle to be fitted with a countermeasure, such as a curtain airbag, which gives protection for head strike against objects anywhere between the A and C pillars, such as the cant rail and B pillar, in a range of impacts and not just car-to-pole accidents. A countermeasure such as a thorax head airbag which did not offer protection for head strike over all of this area would not fulfil this requirement. To enforce the fitment of this type of countermeasure the regulation would need to include measures, in addition to the pole test, to assess if adequate protection is provided for areas between the A and C pillars that are not in alignment with the pole.

In summary, the results show that from the options considered, Option C (pole test) and Option E (AE-MDB and pole tests) offer the greatest additional benefit. An increase in the AE-MDB test speed from 50 km/h to about 65 km/h almost doubles the potential benefit of the AE-MDB test but it is still less than the benefit for the pole test.

Further work is recommended to investigate the sensitivity of the analysis performed and hence estimate the range of the potential benefits for each of the options considered.

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

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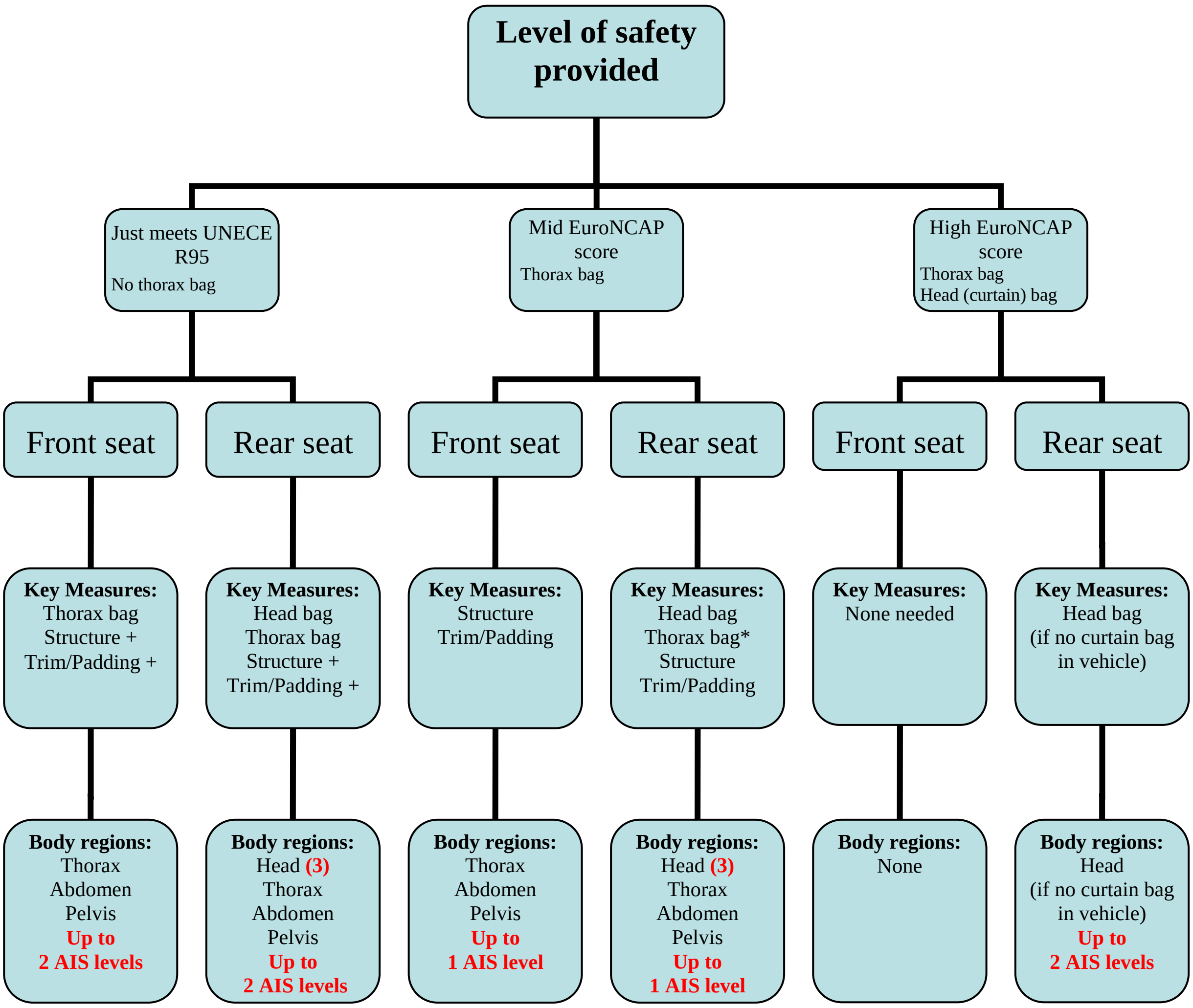
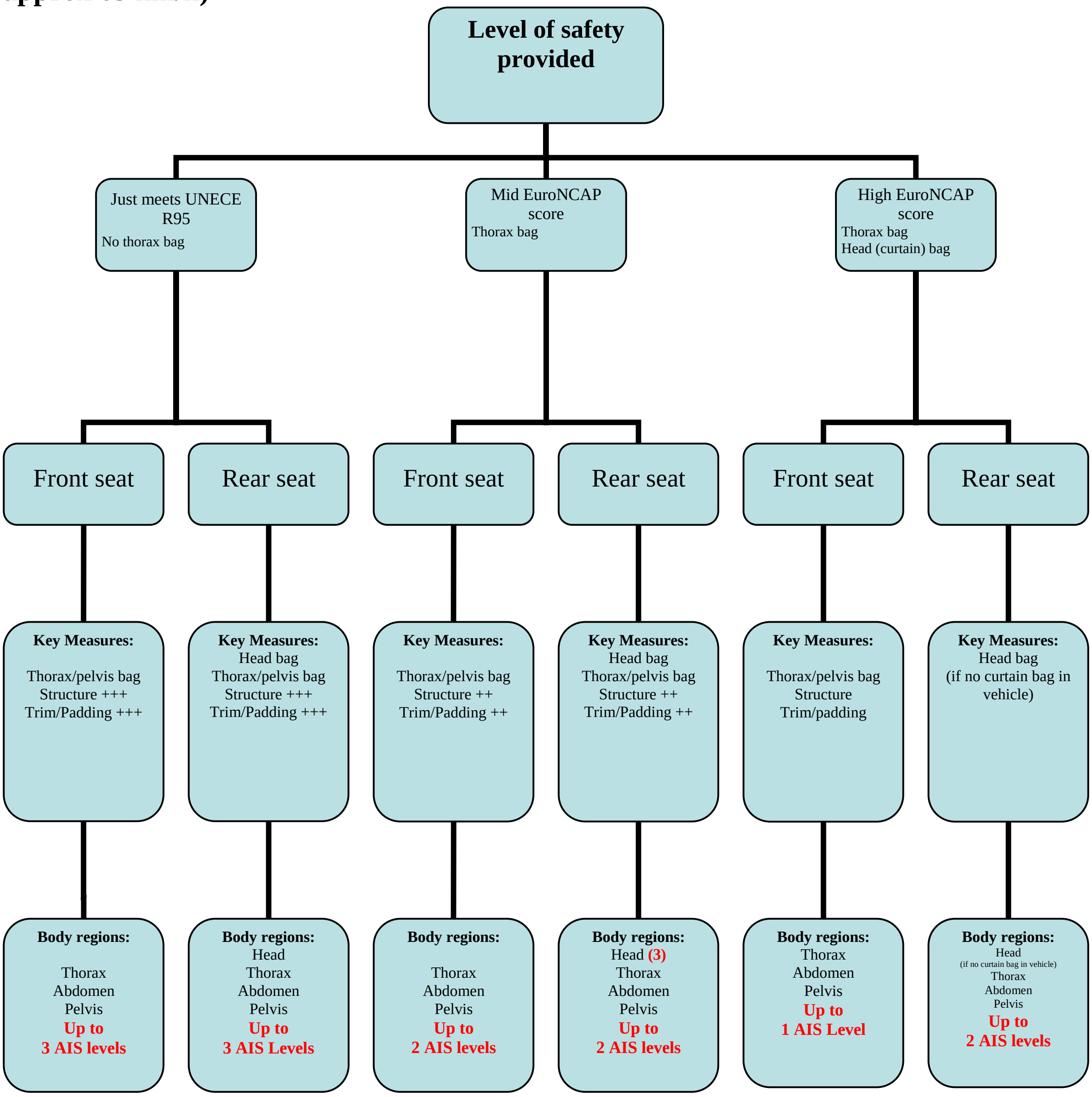
APPENDIX A. Flow charts for UK benefit analysis injury reduction model

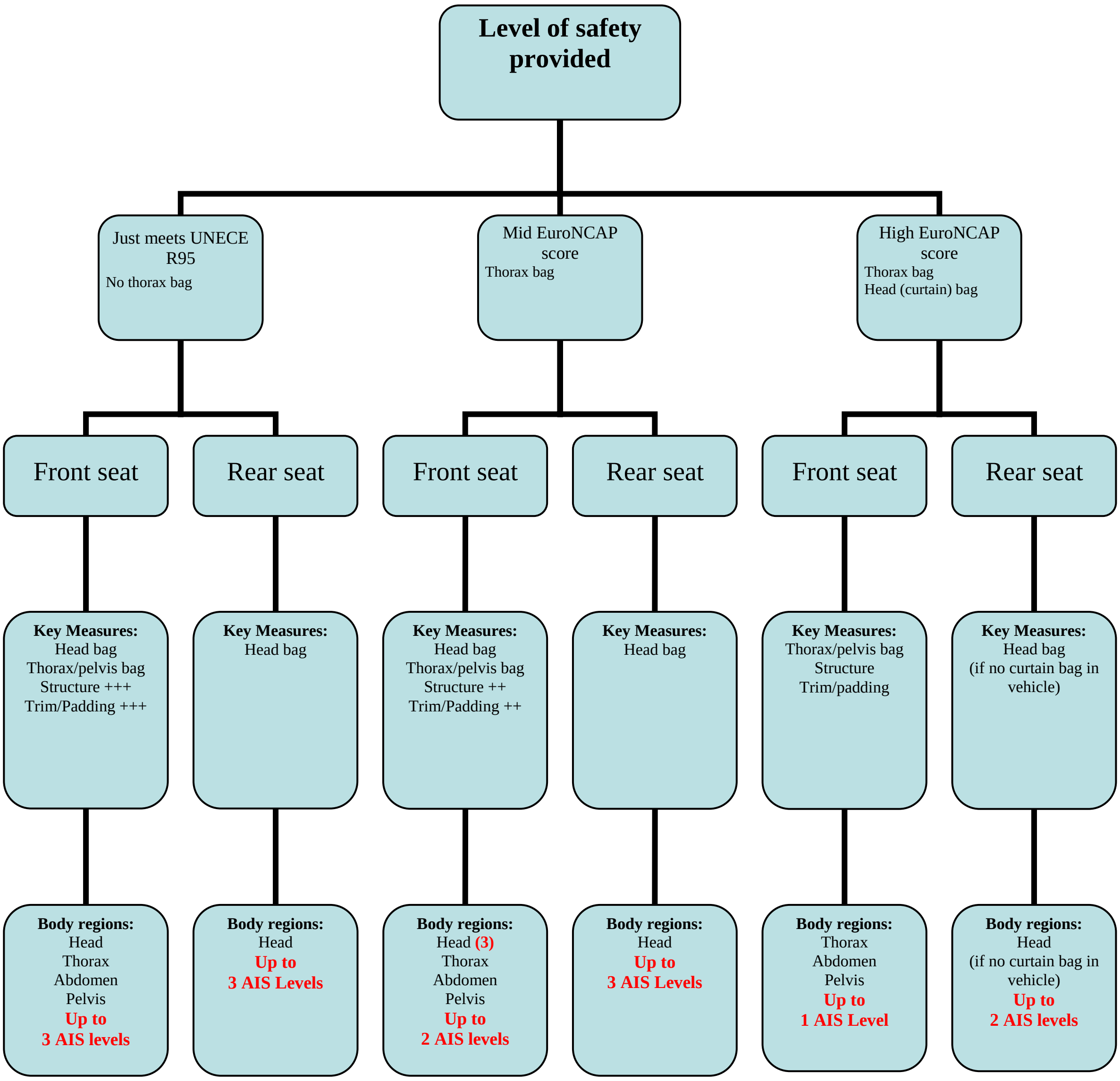
Option B (Advanced European Deformable Barrier AE-MDB test)



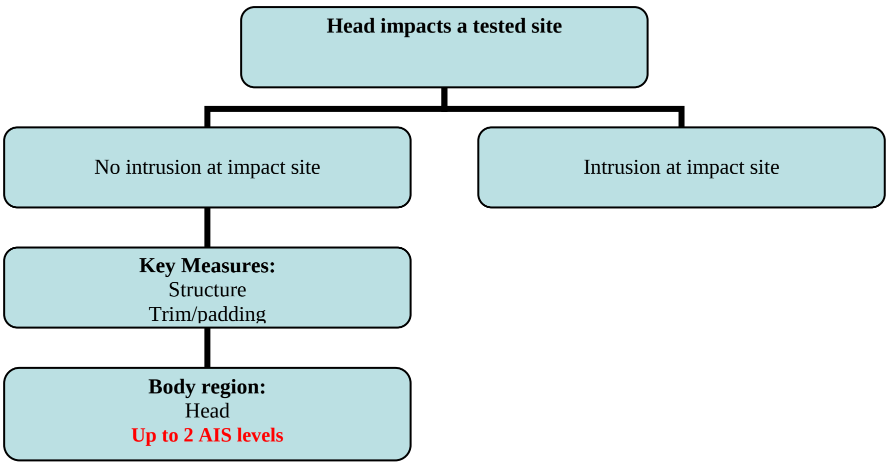
Option B* (Advanced European Deformable Barrier AE-MDB test at higher speed, approx 65 km/h)



Option C (Pole test)



Option D (Free Motion Headform FMH test)



APPENDIX B. Case examples

Case Example 1 (Just meets UNECE R95): Vauxhall Astra and Rover 414

The Vauxhall Astra was registered in 2000 and categorised by the TRL team as 'just meets UNECE R95'. The vehicle was not fitted with side impact airbags (thorax or head). The car collided with the front of a Rover 414 and experienced a lateral impact (direction of force was described as 3 o'clock, where 12 o'clock traditionally describes a head-on impact); with an estimated change of velocity (delta-v) of 33 km/h. There was a maximum crush (deformation) of 47cm.

The car was driven by a 75 year old male who was wearing his seat belt at the time of the accident (MAIS = 3). He sustained AIS 3 thoracic injuries, specifically:

- Bruising:
- Fracture right 6th rib with haemo-pneumothorax (AIS 3); and
- Injury to myocardium and pericardium (AIS 3).

Potential to reduce injuries

If this vehicle was designed to meet a proposed AE-MDB test at 50 km/h, the pole test or the higher speed AE-MDB test (around 65 km/h) then a side thorax airbag would have been fitted to the car. For these options, the team judged that the thorax injuries would have been mitigated from AIS 3 to AIS 1, resulting in a change from serious to slight injury severity outcome.

The FMH test would not be applicable or have had any effect on the outcome of this collision.

Consideration was given to the driver's age, but as he only had one rib fracture it was decided that the introduction of a side thorax airbag would have had significant potential to reduce the severity or have prevented his thoracic injuries.

Case Example 2 (high EuroNCAP score): Alfa Romeo 156 and Vauxhall Combo Van

The Alfa Romeo was registered in 2005 and categorised by the TRL team as ‘a High EuroNCAP scoring car’. The vehicle was fitted with side impact thorax and head (curtain) airbags. The vehicle collided with a Vauxhall Combo van and experienced a lateral impact (direction of force was described as 3 o’clock, where 12 o’clock traditionally describes a head-on impact); with an estimated change of velocity (delta-v) of 29 km/h. There was a maximum crush (deformation) of 52cm.

The car was driven by a 41 year old woman and although it was not known whether she was wearing her seat belt at the time of the accident, this was not considered an important factor given the nature of the impact damage. She suffered serious head (AIS 2) and pelvis (AIS 2) injuries as a result of the collision (MAIS = 2). Her principal injuries were:

- Loss of consciousness (AIS 2); and
- Fracture of left sacrum (AIS 2).

Potential to reduce injuries

If this vehicle was designed to meet a proposed AE-MDB test at 50 km/h, the team judged that the head and pelvic injuries would not have been mitigated. Therefore the driver’s MAIS was unchanged.

If this vehicle was designed to meet the pole test, the team judged that the head injury would not have been mitigated (AIS 2), but the pelvic injury would have reduced from AIS 2 to AIS 1. She would therefore have remained a serious casualty (MAIS = 2) and no benefit was counted within this exercise. However in reality she may well have had a significantly quicker recovery.

The FMH test would not be applicable or have had any effect on the outcome of this collision.

If this vehicle was designed to meet a proposed AE-MDB test at a higher speed (around 65 km/h), the team judged that the head injury would not have been mitigated (AIS 2), but as with the pole test, the pelvic injury would have reduced from AIS 2 to AIS 1. She would therefore have remained a serious casualty (MAIS = 2) and no benefit was counted within this exercise. However in reality she may well have had a significantly quicker recovery.