IMPACT ASSESSMENT INSTITUTE analytics

acustica

"Cost benefit analysis for Euro 5 L-category noise emission"

Final results for presentation at UNECE/GRPB/TF-VS

April 4th, 2022 | IAI / Acustica

The project

- Expert review and reassessment of cost benefit analysis for Euro 5 L-category noise emission
- Consortium comprising expertise in scrutiny, noise and traffic modelling
- Objective analysis of the 2017 CBA
- Reassessment using new data (Noise Source Ranking tests by TU Graz)
- To draw on ACEM (and other) expertise and inputs

General comments on CBA

- Thorough analysis with methodical approach
- Strongly guided by results of public consultation
- Some rhetorical statements inconsistent with evidence
- Apparent absence of many references and sources
- The authors were not able to share detail on the calculation of the numerical results

Overall CBA result (Annex)

Table V.1: Annual benefits and costs, B/C ratio and net present value for scenario with 2 dB lower limits for L-category vehicles, traffic noise levels as in 2040, 0% illegal exhausts and baseline market growth (BAU).

		N-EU	S-EU	EU28
Total Benefits	MEuro	97	1113	1210
Total Costs	MEuro			631
Benefit/Cost Ratio	-			1,92
ΔL_{DEN}	dB	0,3	0,7	

	Northern Europe	Benefits including discounting MEuro				Southern Europe	Benefits including discounting MEuro				EU28 Stakeholder costs Costs including discounting (Meuro)					
Year	dB reduction	Exposed people	Amenity	Health	Total Benefits	Acc. Benefits	dB reduction	Exposed people	Amenity	Health	Total Benefits	Acc. Benefits	R&D	Production	Enforcement	Total Costs	Acc. Costs	NPV
2020	0,000	41295782	0,0	0,0	0,0	0,0	0,000	28178335	0,0	0,0	0,0	0,0	4,2	44,0	51,0	99,2	99,2	-99
2021	0,021	41708740	0,4	0,2	0,7	0,7	0,056	28460118	4,8	2,8	7,7	7,7	4,0	42,3	49,0	95,4	194,5	-186
2022	0,042	42125827	0,8	0,5	1,3	2,0	0,112	28744719	9,5	5,6	15,1	22,7	3,7	39,1	45,3	88,2	282,7	-258
2023	0,062	42547086	1,2	0,7	1,9	3,9	0,168	29032166	14,0	8,2	22,2	44,9	3,3	34,8	40,3	78,4	361,0	-312
2024	0,083	42972557	1,6	0,9	2,5	6,4	0,225	29322488	18,2	10,7	29,0	73,9	2,8	29,7	34,5	67,0	428,0	-348
2025	0,104	43402282	1,9	1,1	3,1	9,5	0,281	29615713	22,4	13,2	35,5	109,5	2,3	24,4	28,3	55,1	483,1	-364
2026	0,125	43836305	2,3	1,3	3,6	13,1	0,337	29911870	26,3	15,5	41,8	151,3	1,8	19,3	22,4	43,5	526,6	-362
2027	0,145	44274668	2,6	1,5	4,2	17,3	0,393	30210989	30,1	17,7	47,9	199,2	1,4	14,7	17,0	33,1	559,7	-343
2028	0,166	44717415	2,9	1,7	4,7	21,9	0,449	30513099	33,8	19,9	53,7	252,9	1,0	10,7	12,4	24,2	583,9	-309
2029	0,187	45164589	3,2	1,9	5,1	27,1	0,505	30818230	37,3	21,9	59,2	312,1	0,7	7,5	8,7	17,0	600,8	-262
2030	0,208	45616235	3,5	2,1	5,6	32,7	0,562	31126412	40,6	23,9	64,5	376,6	0,5	5,1	5,9	11,5	612,3	-203
2031	0,228	46072397	3,8	2,2	6,0	38,7	0,618	31437676	43,8	25,8	69,6	446,3	0,3	3,3	3,8	7,5	619,7	-135
2032	0,249	46533121	4,1	2,4	6,5	45,2	0,674	31752053	46,9	27,6	74,5	520,8	0,2	2,1	2,4	4,7	624,4	-58
2033	0,270	46998452	4,3	2,5	6,9	52,0	0,730	32069573	49,8	29,3	79,2	600,0	0,1	1,2	1,4	2,8	627,2	25
2034	0,270	47468437	4,2	2,5	6,7	58,8	0,730	32390269	48,9	28,8	77,7	677,7	0,1	0,7	0,8	1,6	628,8	108
2035	0,270	47943121	4,2	2,4	6,6	65,4	0,730	32714172	48,0	28,2	76,2	753,8	0,0	0,4	0,5	0,9	629,7	190
2036	0,270	48422552	4,1	2,4	6,5	71,9	0,730	33041313	47,0	27,7	74,7	828,6	0,0	0,2	0,2	0,5	630,2	270
2037	0,270	48906778	4,0	2,4	6,4	78,2	0,730	33371727	46,1	27,2	73,3	901,9	0,0	0,1	0,1	0,2	630,4	350
2038	0,270	49395846	3,9	2,3	6,2	84,5	0,730	33705444	45,3	26,6	71,9	973,8	0,0	0,1	0,1	0,1	630,5	428
2039	0,270	49889804	3,8	2,3	6,1	90,6	0,730	34042498	44,4	26,1	70,5	1044,3	0,0	0,0	0,0	0,1	630,6	504
2040	0,270	50388702	3,8	2,2	6,0	96,6	0,730	34382923	43,5	25,6	69,2	1113,5	0,0	0,0	0,0	0,0	630,6	579

Derivation of final cost benefit ratio to tabulated data is not presented

TNO provided additional explanation

In parallel we recreated the calculations

Calculation framework based on CBA methodology

Benefits flowchart

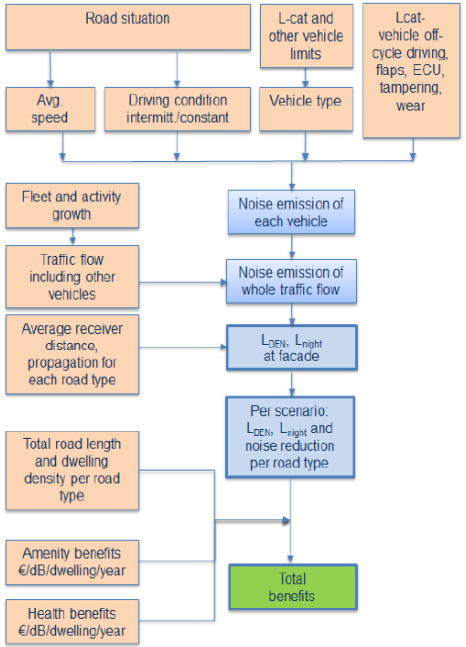


Figure 23: Schematic diagram for monetised benefits of noise reduction of L-cat vehicles

Costs flowchart

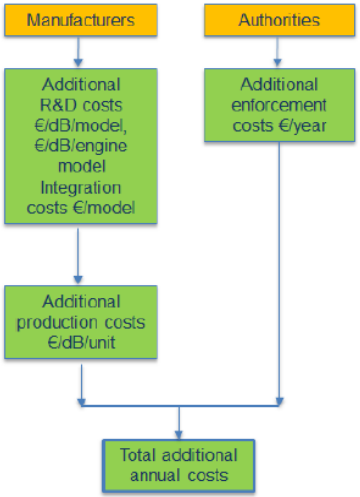
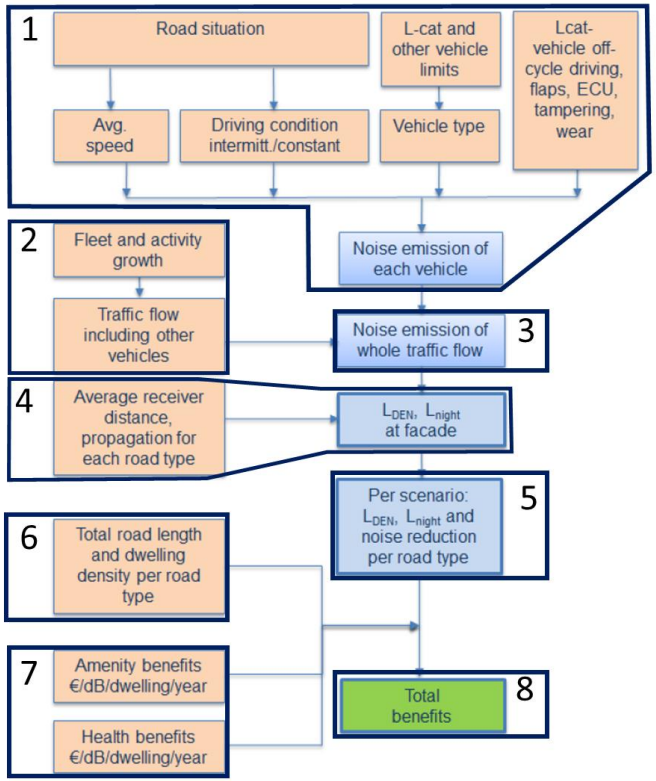
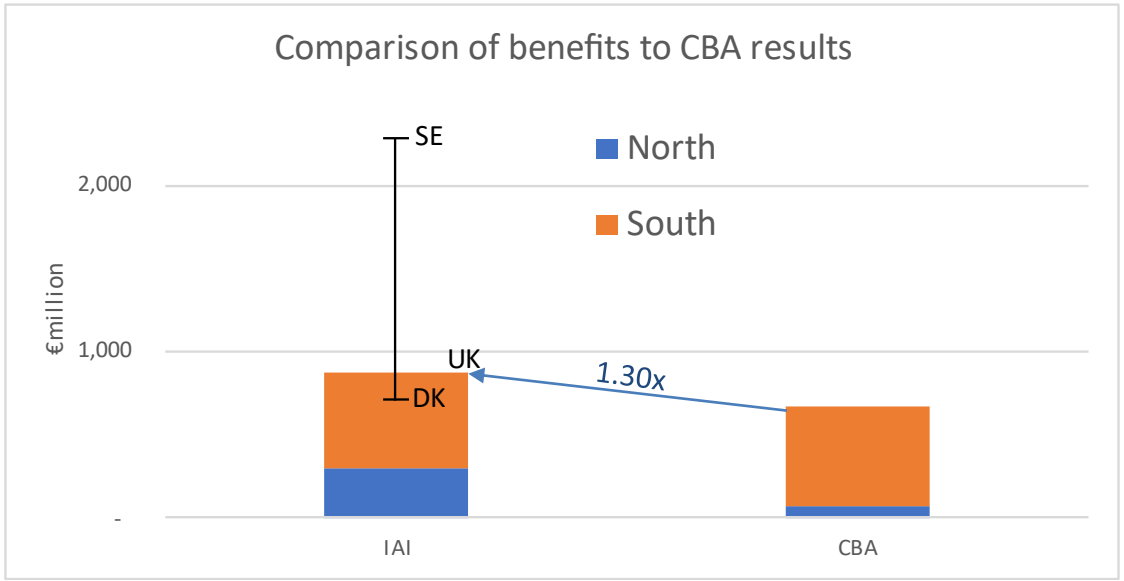


Figure 24: Costs for noise reduction of L-cat vehicles due to tighter sound limits

Benefits: split into blocks for analysis

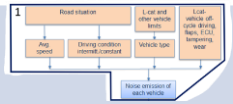
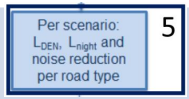
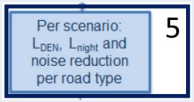
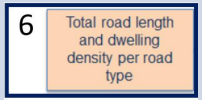
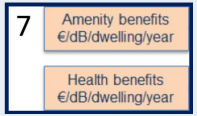


Results – benefits of 2 dB limit reduction (as per report)

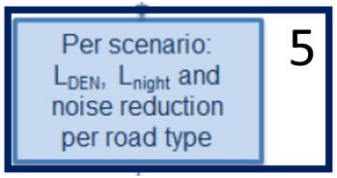


- Overall ratio IAI vs CBA result 1.30x (UK dose-response valuation)
- Sensitivity
  - Max 3.39x (SE valuation)
  - Min 1.15x (DK valuation)
- Similar ratios result for higher limit reductions (up to 5 dB)
- Does not adjust for GDP

Summary – main differences in benefits, IAI vs CBA (illustration -2 dB, Northern Europe, 2040)

	CBA total	IAI total (weighted average)	Ratio IAI/CBA	Comment	Relevant blocks
Sound level reduction $\Delta L_{eq,16hr}$ (dB)	0.19	0.015	0.074	See reconciliation	 
Time fraction	20%	100%	5.0	Excluding use of time fraction	
Exposed households	50.4m/2.4	279.9m/2.4	5.2	Adds non-accelerating road sections & all 6 road types (instead of 2)	
Valuation (€)	59.0	129.6	2.2	Higher variable evaluation from dose-response curves	
Total	**4.2m**	**19.3m**	**4.6**		

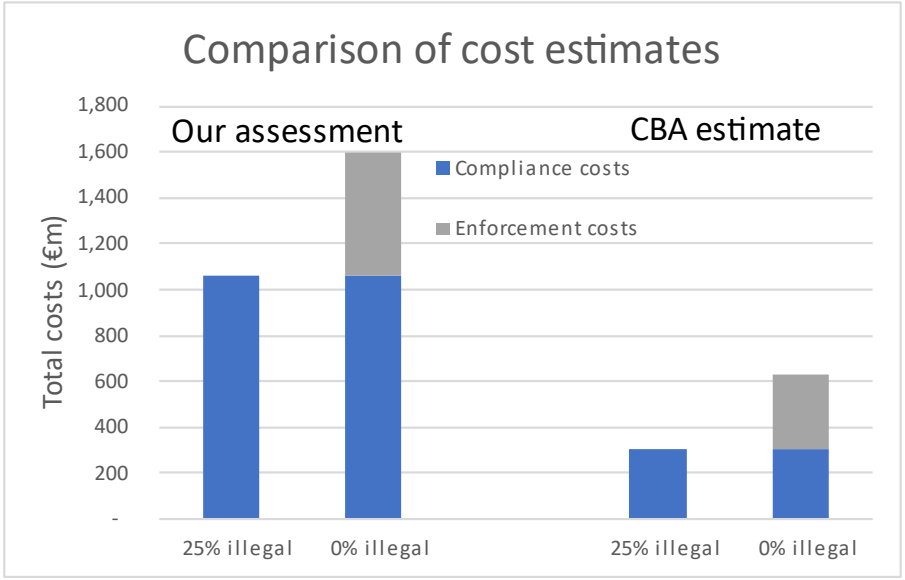
Block 5: Calculation of L_{DEN}, L_{night} and noise reduction per scenario



Reconciliation of noise reduction from CBA to our calculation

ΔL_{DEN}	Northern Europe (dB)		Southern Europe (dB)		Comment
CBA values	**0.19**		**0.39**		
Our calculation, CBA conditions	0.19		0.37		Small discrepancy
Noise increase for accelerating non-L-category vehicles	0.17		0.35		Small impact
Average over accelerating and non-accelerating traffic	0.12		0.29		Reduces average (over a larger population)
+3 dB / +1 dB noise increase for motorcycles/mopeds (instead of +5/+3)	0.11		0.28		Reduces impact in accelerating traffic
2 dB limit results in 1 dB reduction per vehicle	0.062		0.15		Reduced impact by approximately 50%
Altered flow rates ➔ final value	**0.015**		**0.067**		Significant reduction due to lower flow rates

Costs – summary (data from CBA, 2dB limit reduction)



- Higher costs according to assessment of OEM cost figures in CBA:
  - Max 3.5x
  - Min 1.24x (DK valuation)
- Insufficient data available for 5 dB reduction

Benefit/cost ratio

- Based on the changes in benefits and costs according to our analysis, the following range for benefit/cost ratio results (2 dB limit reduction):

	Benefit/cost ratio*		
Valuation:	DK	UK	SE
Costs (high)	0.72	0.82	2.1
CBA	2.18		

*not adjusted for GDP

NSR testing - vehicles

no	manufacturer	model	engine capacity in cm^3	no cylinders	rated power in kW	rated speed in min^{-1}	max torque in Nm	at engine speed in min^{-1}	Trans-mission	vehicle mass in kg	power to mass ratio in kW/1000 kg	L_{urban} in dB(A)	L_{wot_ref} in dB(A)	L_{crs_ref} in dB(A)
1	Honda	Forza 125	124.9	1	10.7	8750	12.3	6500	CVT	162	45.1	74.5	77.8	68.7
2	Piaggio	Vespa 300	278	1	15.5	8250	26	5250	CVT	183	60.1	74.8	80.3	70.8
3	KTM	390 Duke	373	1	32	9500	35		6speed	162	135.0	75.3	77.8	72.5
4	Yamaha	T-Max	562	2	35	7500	55.7	5250	CVT	218	119.5	74.9	81.0	71.4
5	Kawasaki	Vulcan S	649	2	44.7	7500	62.4	6600	6speed	229	147.0	74.4	78.1	68.1
6	Triumph	Street Triple	765	3	86.8	11750	79	9350	6speed	187	331.3	76.7	80.4	73.3
7	BMW	R 1250 GS	1254	2	100	7750	143	6250	6speed	249	308.6	74.2	78.5	69.7
8	Harley Davidson	Street Bob	1745	2	64	5020	155	3250	6speed	297	172.0	74.8	79.3	70.2

NSR testing – smaller vehicles

- For the tested scooters (vehicles 1, 2 and 4):
  - By far the highest contribution to the overall sound emission comes from the driveline and/or other sources followed by the engine.
  - In most cases exhaust and intake play a subordinate role.
  - That means an OEM must work on several sources and thus it is not an easy task to reduce the sound emission of these vehicles.
- Standard mid-range motorcycle (vehicle 3) and the mid-range cruiser (vehicle 5): similar results are found.

NSR testing – smaller vehicles

- Comparing the sound emission values for the original vehicle with the fully covered version:
  - The differences for the vehicles mentioned above are between 2 and 3 dB(A).
  - It is not an straightforward task to reduce the sound emission of these vehicles.
- Difficult to forecast the costs for reduction measures.
  - 2 dB(A) reduction will require laborious measures and correspondingly high costs.
  - 5 dB(A) reduction appears to be out of the range of feasibility without extensive intervention into the vehicle and engine concept.

NSR testing – larger motorcycles

- The results for the bigger motorcycles (vehicles 6 to 8) are different:
  - Less uniform than for the smaller motorcycles.
  - Exhaust has a much higher contribution to the overall sound emission.
- The difference in the sound emission values for the original vehicle and the fully covered versions are significantly higher than for the smaller motorcycles, at least for wot conditions.

NSR testing – larger motorcycles

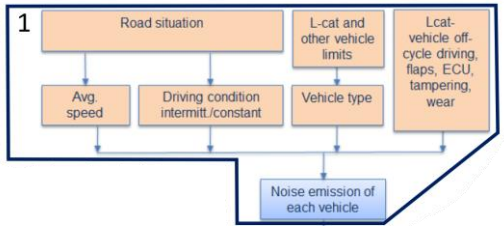
- Values for these vehicles:
  - L_{wot} differences range from 4.4 dB(A) to 7.8 dB(A)
  - L_{crs} differences range from 1.8 dB(A) to 4.6 dB(A).
- But also for these vehicles an OEM would need to work on several different sources in order to achieve a reduction of the L_{urban} values:
  - A 2 dB reduction may be feasible.
  - A 5 dB reduction would require a complete redesign of the vehicles if achievable at all.

Summary – main findings

- Total EU benefits of a 2 dB limit reduction from 2025-2045: €868m (CBA €667m)
- Total EU costs of a 2 dB limit reduction from 2025-2045: €1061m (CBA €306m)
- Benefit/cost ratio with primary assumptions: 0.82
  - Range from below 0.5 to above 2.0 according to other assumptions
- Scenarios for benefit/cost ratio (separate variations on above ratio):
  - Excluding tooling and testing costs: 1.32 (1.04 with new data)
  - Using Swedish / Danish dose-response: 2.1 / 0.72
  - Adjusting for GDP per capita: 0.60
  - EV penetration to 100% by 2045 0.49
- Single event analysis: incoherent analysis in CBA. Average sound level analysis above offers consistent and repeatable results.
- NSR testing:
  - The reduction potential for small vehicles is lower than for big vehicles, but in all cases an OEM would need to work on several different sources in order to achieve a 2 dB(A) reduction of the L_{urban} values.
  - 5 dB limit reduction would require significant intervention on many vehicle systems, likely being out of range for smaller vehicles and questionable feasibility for larger vehicles

Questions, comments?

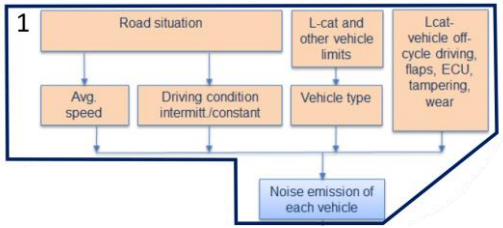
Block 1: Noise emission of each vehicle



- 33% intermittent (accelerating & decelerating) traffic from 2011 Venoliva study – unrealistic (too high) for rural roads and motorways
- 50% of intermittent traffic is accelerating – rudimentary assumption
- Noise impact should also be assessed for non-accelerating traffic
  - Modest reduction in traffic noise reduction in non-accelerating vs accelerating conditions
  - 5/6 of traffic is in non-accelerating conditions – highly relevant to benefits calculation
- Noise increase in accelerating traffic should be applied to all vehicle categories (cars and heavy vehicles as well as L-cat) – small impact

Impact: increase in benefits due to considering non-accelerating traffic

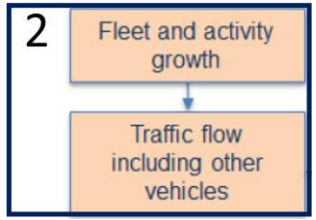
Block 1: Noise emission of each vehicle



- +3/5 dB increase for accelerating vehicles questionable
- Actual vehicle noise reduction ~ ½ of limit reduction – does not appear to be acknowledged in CBA

Impact: modest decrease in benefits due lower increase in noise of accelerating L-cat vehicles and due to lower actual decrease in noise compared to limit change

Block 2: Fleet and traffic flow



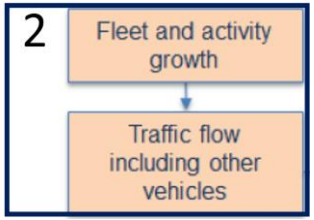
CBA traffic flow data

Table 23: Traffic flow rates for road types considered in numbers of vehicles per hour, left for Northern Europe, right for Southern Europe.

	Northern Europe: Vehicle flow in no./hour			
Day 12 h	Residential	Main	Arterial	Rural
Cars	30,0	302,6	2030,6	356,9
Medium veh.	4,0	11,1	78,9	16,0
Heavy veh.	0,0	11,4	81,0	17,2
Motorcycles	0,0	15,1	101,5	17,8
Mopeds	1,5	15,1	101,5	0,0
Evening 4 h				
Cars	15,0	154,7	1039,4	183,3
Medium veh.	2,0	2,9	21,9	4,5
Heavy veh.	0,0	4,9	34,0	7,2
Motorcycles	0,0	7,7	52,0	9,2
Mopeds	0,8	7,7	52,0	0,0
Night 8 h				
Cars	10,0	50,4	338,2	58,9
Medium veh.	0,0	2,4	16,3	3,4
Heavy veh.	0,0	3,5	24,6	5,1
Motorcycles	0,0	2,5	16,9	2,9
Mopeds	0,5	2,5	16,9	0,0

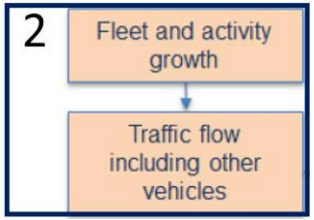
	Southern Europe: Vehicle flow in no./hour			
Day 12 h	Residential	Main	Arterial	Rural
Cars	25,0	236,8	842,5	250,0
Medium veh.	4,6	43,4	154,5	45,8
Heavy veh.	1,7	15,8	56,2	16,7
Motorcycles	2,1	19,7	70,2	20,8
Mopeds	8,3	78,9	280,8	83,3
Evening 4 h				
Cars	28,3	268,3	954,8	283,3
Medium veh.	2,5	23,7	84,3	25,0
Heavy veh.	0,4	3,9	14,0	4,2
Motorcycles	2,1	19,7	70,2	20,8
Mopeds	8,3	78,9	280,8	83,3
Night 8 h				
Cars	28,8	272,3	968,9	287,5
Medium veh.	2,1	19,7	70,2	20,8
Heavy veh.	0,4	3,9	14,0	4,2
Motorcycles	2,1	19,7	70,2	20,8
Mopeds	8,3	78,9	280,8	83,3

Block 2: Fleet and traffic flow



- Implausible figures in CBA:
  - Vehicle flow/hr higher in rural roads than main roads
  - Figures imply 65-73% of total traffic is on rural roads
- Unrealistic figures for Southern Europe
  - Evening and night time flow almost same as day time – some figures identical
  - Car traffic increases from day-evening-night
  - Daytime flow significantly lower than Northern Europe
  - Above is the likely explanation for 11.5x higher reported benefits (South € 1,113m vs North €97m)
- Inconsistent figures for L-category:
  - No evidence for high values for L-category in Southern Europe
  - Mopeds appear overestimated – inconsistent with other CBA data
  - Distribution over road categories also inconsistent

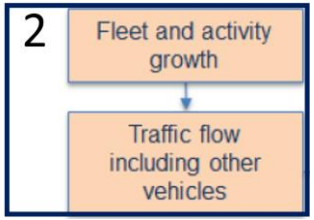
Block 2: Fleet and traffic flow



- Reviewing available data:
  - TRACCS (2010) derived from COPERT provides relevant traffic data
  - Lower L-category flow than CBA
- Assumptions for constructing new flow data
  - Total daytime traffic as in Table 3 above
  - Ratio of total traffic - Day : Evening : Night = same as for Northern Europe
  - Proportion of motorcycles and mopeds taken from TRACCS for Northern and Southern Europe

Northern Europe				**Southern Europe**		
	CBA	TRACCS			CBA	TRACCS
Motorcyles	4.2%	1.5%		Motorcyles	5.0%	5.4%
Mopeds	4.0%	0.6%		Mopeds	20.0%	2.3%

Block 2: Fleet and traffic flow

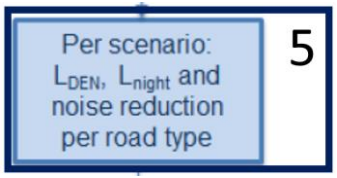


Reconstructed traffic flow data Southern Europe)

	CBA figures / hr				Adjusted figures / hr			
	Residential	Main	Arterials	Rural	Residential	Main	Arterials	Rural
Day 12 h								
Cars/Light duty vehicles	25.0	236.8	842.5	250.0	25.0	236.8	842.5	250.0
Medium vehicles	4.6	43.4	154.5	45.8	4.6	43.4	154.5	45.8
Heavy vehicles	1.7	15.8	56.2	16.7	1.7	15.8	56.2	16.7
Motorcycles	2.1	19.7	70.2	20.8	2.1	19.7	70.2	20.8
Mopeds	8.3	78.9	280.8	83.3	8.3	78.9	280.8	83.3
evening 4 h								
Cars/Light duty vehicles	28.3	268.3	954.8	283.3	14.2	134.4	478.5	141.8
Medium vehicles	2.5	23.7	84.3	25.0	1.3	11.9	42.2	12.5
Heavy vehicles	0.4	3.9	14.0	4.2	0.2	2.0	7.0	2.1
Motorcycles	2.1	19.7	70.2	20.8	1.1	9.9	35.2	10.4
Mopeds	8.3	78.9	280.8	83.3	4.2	39.5	140.7	41.7
night 8 h								
Cars/Light duty vehicles	28.8	272.3	968.9	287.5	8.5	47.0	167.1	49.5
Medium vehicles	2.1	19.7	70.2	20.8	0.6	3.4	12.1	3.6
Heavy vehicles	0.4	3.9	14.0	4.2	0.1	0.7	2.4	0.7
Motorcycles	2.1	19.7	70.2	20.8	0.6	3.4	12.1	3.6
Mopeds	8.3	78.9	280.8	83.3	2.5	13.6	48.4	14.4

Impact: decrease in benefits due lower L-category flow rates and lower evening and night flow rates in Southern Europe

Block 6: Total road length and dwelling density per road type



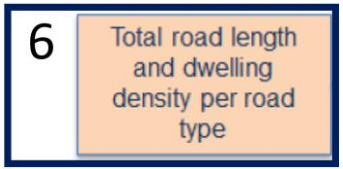
- "Time fraction" applied according to apparently arbitrary considerations

Region	Route	p183
Northern EU	Touring routes (MC only)	20% time fraction (popular touring dates)
	Residential (moped only)	20% time fraction (no explanation)
	Main roads (moped only)	
Southern EU	Touring routes	50% time fraction (=roads with lower proportions of heavy vehicles)
	Residential	
	Main roads	

- Use of time fraction is inconsistent – average noise levels over all times should be considered ➔ 100% of time applied

Impact: significant increase in benefits due to consideration of whole year

Block 6: Total road length and dwelling density per road type



- CBA calculates benefits only for residential, main and rural roads.
  - Other road types should be included. Arterials generate main impact.

Impact: increase in benefits by about 60%

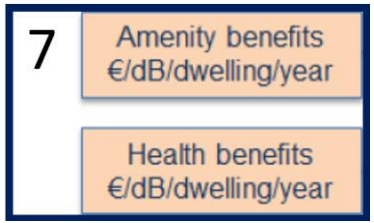
- CBA calculates only for accelerating sections (see also Block 1)
  - All sections should be included as all are relevant

Impact: increase in benefits by factor of ~5

- CBA applies 20% road length fraction
  - Appears relevant - accounts for road and dwelling topology but magnitude highly uncertain

Impact: no change, high uncertainty

Block 7: Monetisation

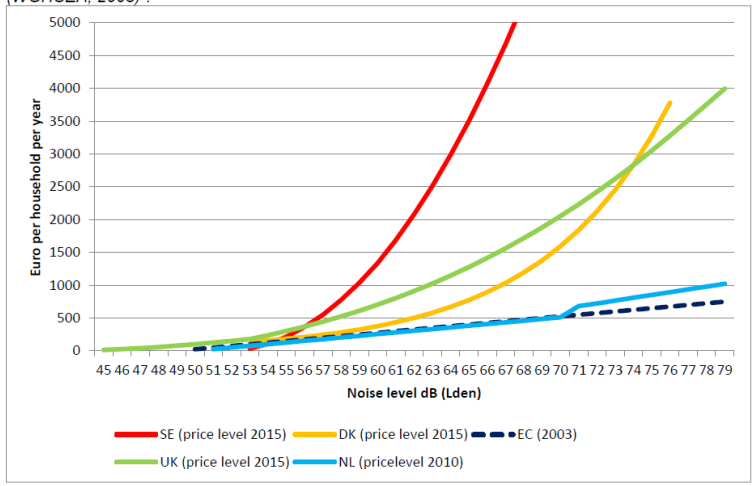


- CBA uses static valuations of benefits
  - Constant value per dB reduction
  - Based on 2003 study
- Dose-response curve not considered
- Subsequent studies update the state of the art
  - Higher costs per dB in general than EU valuation
  - Higher costs per dB at higher dB levels, reflecting scientific consensus
  - At low dB levels (e.g. some residential roads) comparable values to CBA

Block 7: Monetisation

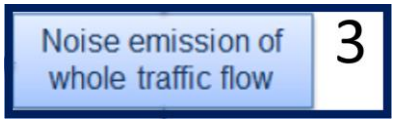
- Three countries have published dose-response curves
  - UK: WebTAG project built up over several years based on annoyance and health impacts
  - SE: hedonistic price study from one town (willingness to pay – disturbance and health effects)
  - DK: based on EU model, applying noise exposure factors for Denmark
- We apply these curves as scenarios for all European countries as an initial estimate

Figure 5: Unit cost for road noise for four different countries and the recommended EC value from (WGHSEA, 2003)[2].

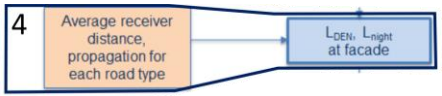


Impact: significant increase in valuation of benefits

Additional observations on benefits



CBA rhetoric on total noise reduction does not match to figures used



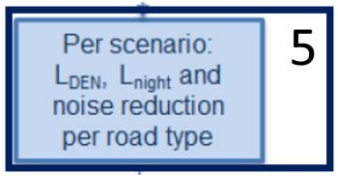
No reference for distances from road to dwelling façade (15m residential/main, 50m rural)

Omitting soft ground effects in rural roads will result in overestimate

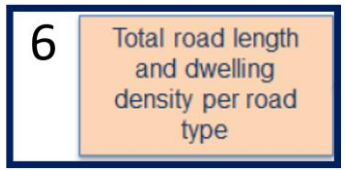
- We assume intermediate ground for rural areas → higher attenuation

Conflicting figures for breakdown of L-cat vehicle activity

Additional observations on benefits



- No derivation of results nor reference to calculations



- Unclear definition of road types (e.g. “touring routes”)
- 62%/38% North and South distribution from 2016 study but not backed up with evidence and equally applied to all road types

- Final calculations and derivation not presented

1. Additional unit production costs (data from CBA)

- Figures are difficult to compare. Total costs per unit are reported in the table.
- Company 2 appears most representative – applied to overall analysis.

Source	Model	Limit value reduction		
		1 dB	2 dB	5 dB
CBA	Motorcycles	/	€ 43	€ 111
Company 1	Model A	€ 0	€ 0	€ 2,290
	Model B	€ 571 (€ 353)	€ 916 (€ 698)	€ 2,470 (€2,252)
Company 2	L3e-A2 and A3	€ 43 (€ 20)	€ 78 (€ 39)	/
	L3e-A2E/A3E (Enduro)	€ 99 (€ 76)	€ 151 (€ 114)	/
Company 3	100-250cc single	€ 0.5 (€ 0.3)	€ 1.2 (€ 0.8)	/
	251cc single twin tri four	€ 29 (€ 22)	€ 34 (€ 26)	/

Figures in brackets are without tooling costs

3. Total additional annual costs

- The CBA figures indicate that costs approach zero around 2034
- This appears implausible since vehicles will still require noise-reduction components to be fitted
- Add-on costs for noise reduction can be expected to be valid out to 2040 and beyond
- Assuming cost incurred until 2040 ➔ estimated increase by factor 1.65

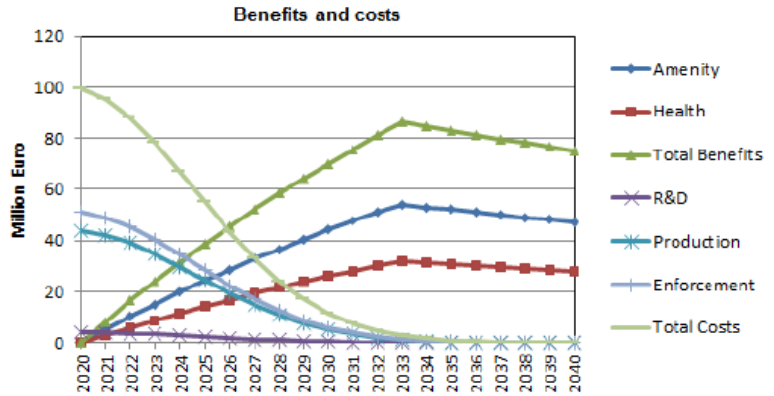


Figure 27: Annual benefits for amenity and health and additional costs for R&D, production and enforcement, and totals, for 2 dB lower L-category sound limits, 2040 traffic noise levels, 0% illegal exhausts and no off-cycle noise and baseline market growth (BAU).

Benefit/cost ratio (adjusted for GDP)

- Based on the changes in benefits and costs according to our analysis, the following range for benefit/cost ratio results (2 dB limit reduction):

	Benefit/cost ratio		
Valuation:	DK	UK	SE
Costs (low)	0.64	1.07	1.95
Costs (high)	0.40	0.66	1.21
CBA	2.18		