Quiet Road Transport Vehicles QRTV

Matching Safety and Environment

September 2023

Foreword - Aim

Consideration on the ongoing development of UN R138 (QRTV)

- This presentation is an approach to match minimum safety aspects with environmental needs.

- The aim of this presentation **IS NOT**
  1. To propose any changes to the operation range of an AVAS.
  2. To propose any new sound pressure values, neither for minimum nor maximum sound or for frequency bands.

- The aim of this presentation **IS**
  1. To convey an understanding for the interaction between vehicle safety and low sound emission.
  2. Both disciplines are important and manufacturer need to integrate both aspects into the vehicle design.

Content of this Presentation

Overview

- Historical background on the development of QRTV regulations
- Scientific approach to determine “safe detection”
- Background noise (BGN) considerations
- Use of NHTSA scientific approach to evaluate “safe minimum sound” for other operation conditions
- Conclusions for UN R138 with regard to minimum safety
- Recommendations

Historical Background

Information and Sources used in this presentation

- The core of this presentation is the NHTSA scientific approach as described in and published with the **N**ew **P**roposal for **R**ule **M**aking (NPRM) Docket No. NHTSA-2011-0148, RIN 2127-AK93
- The US has taken the lead in the development of minimum safety standards for QRTV
  1. Started in 2010 with an informal Working Group of GRB und the Chair of USA (EPA)
  2. Continued in 2012 by the GTR Working on QRTV under the chair of USA (NHTSA)
  3. Continued from 2014 by a parallel Informal Working Group QRTV for drafting an UNECE Regulation (58 agreement) under the chair of Germany
  4. The results were US Federal Law FMVSS 141 and UN-ECE Regulation No. 138
- The scientific background was mainly provided by USA, Japan, OICA and Universities.
- The models used by the various organizations for the evaluation of the sound perception were very similar.
- Therefore, this presentation is built on the NHTSA approach to determine minimum sound levels for a safety detection of vehicles by pedestrians.

Documents published between 2010 and 2016 on the development of QRTV:

- GRB-55-14 - Report Chair of IWG Quiet Vehicles
- Report QRTV Group for Development UN Rxxx on QRTV
- REG58-QRTV-05-04 - WBU Presentation 2015

Outline of the Work presented by this Presentation

Development of UN R138 (QRTV)

- In 2010-2014 the GRB working groups on Quiet Vehicles concluded on the basis of available vehicle technology:

  <u>Vehicles can sufficiently be detected by their tyre rolling sound at speeds above 20 (30*) km/h</u>. *NHTSA conclusion

- These conclusions were made based on C-Label tyres running on an ISO 10844:1994 surface.
- Progress in tyre technology and an increasing use of “quiet roads” in the public have reduced tyre/road noise.
- This raises the question about the impact on the “crossover speed” for safe detection of vehicles.
- Other operation conditions such as acceleration were excluded from the consideration on minimum sound with the option to resume this aspect at a later stage.

Tests according SAE 2889-1 (Mic in 2 m distance)

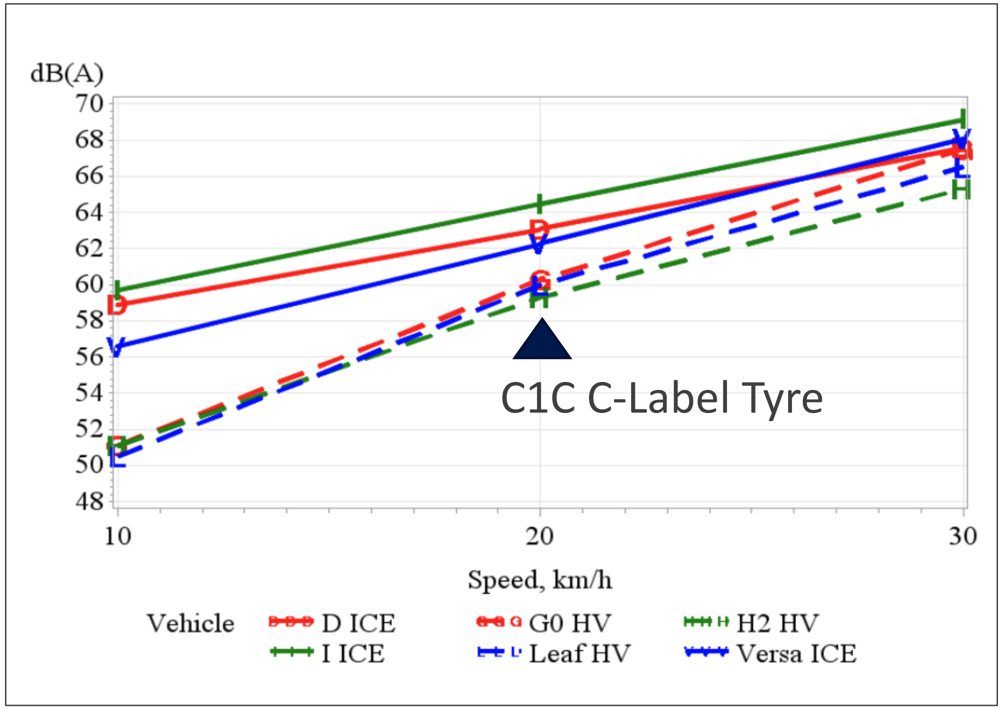


Figure 17. dB(A) Sound Level Versus Speed for Pass-by Tests of HV/EV Vehicles with no alert sound (dashed lines) and ICE Counterparts (solid lines)

Source: NHTSA Research Report July 2010

Parameters that influence the Detection Model of the Operation Conditions

Development FMVSS 141 (NHTSA report 2013)

DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

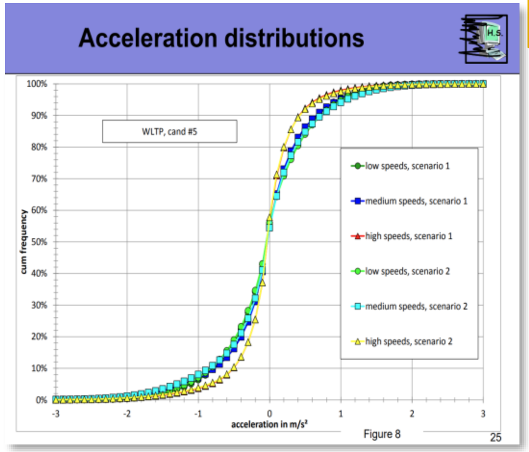
49 CFR Part 571

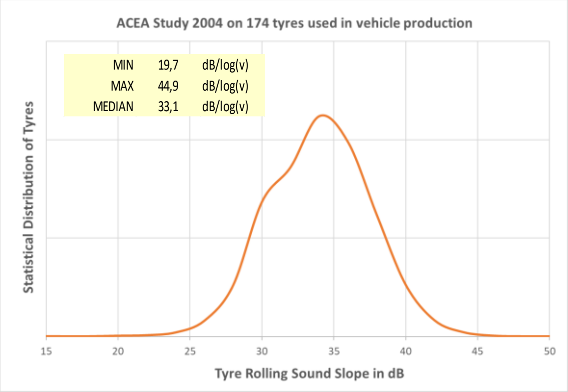
Docket No. NHTSA-2011-0148

RIN 2127-AK93

Federal Motor Vehicle Safety Standards

1. Braking Force ➔ 3.4 m/s² … 5.4 m/s²
2. Reaction time ➔ 1.25 sec … 2.5 sec
3. Acceleration of Vehicle ➔ < 2.0 m/s²; see WLTP results
4. Tyre Rolling Sound ➔ Tyres better than Label C
5. Tyre rolling sound increase over speed (slope) ➔ ACEA study 2004
6. Road Surface ➔ Swiss studies on load noise road surfaces
7. Background Noise ➔ impact on the detection model

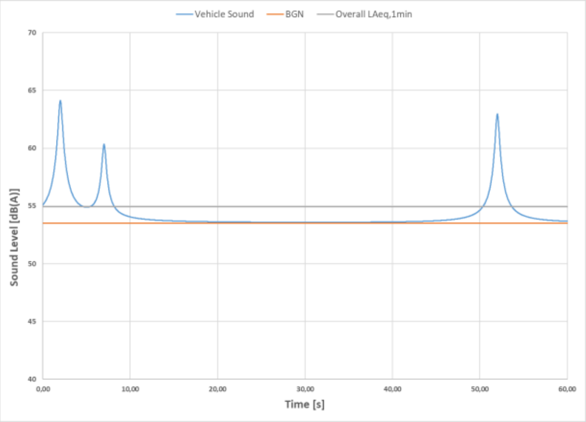




Low-noise pavements Switzerland

Semi-dense asphalt 4mm
After 10 years : - 3 dB(A)

Semi-dense asphalt 4mm
Start : - 7 dB(A)



Background Noise (BGN) – Pedersen Model 2011

Development of UN R138 (QRTV)

- Quieter vehicles, tyres and roads lead of course to a lower ambient noise in the environment.

? Wouldn't this suggest to considered a lower BGN for determination of a minimum sound for safety?

- The Pedersen Model with 55 dB(A) overall sound level is not equivalent to the environmentally used L_{eq} of 55 dB(A), often used as daytime maximum exposure target level.
- The background noise used for QRTV shall be understood as the background noise at the location and at the time a pedestrian needs to take a decision on crossing a road.
- This background situation is influenced by the general ambient noise, plus the nearby activities of others, plus instantaneous traffic around.
- Background noise might be different for cyclists exposed to additional wind noise at their ear while cycling.

Background Noise Model – Pedersen et al. 2011

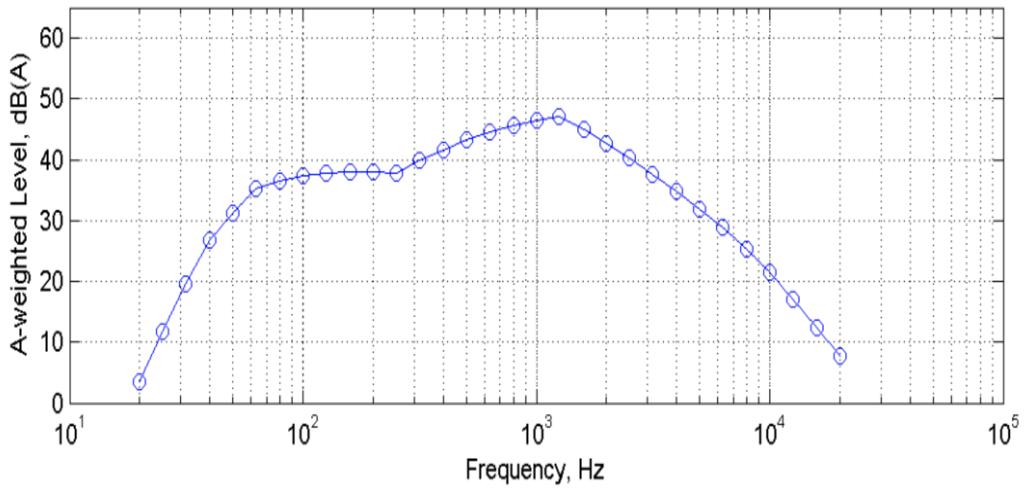


FIGURE 2. A-weighted Spectrum and Ambient at 55 A-weighted dB

Background Noise (BGN) – Recent Studies

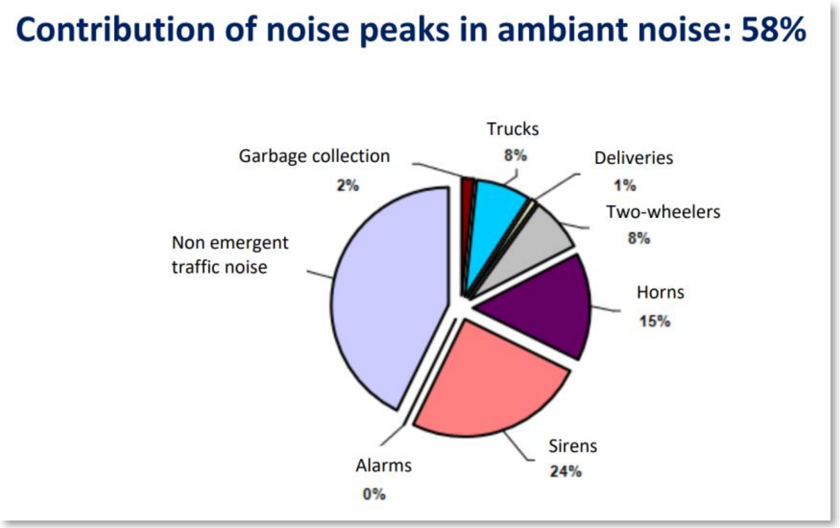
Development of UN R138 (QRTV)

1. According to recent monitoring data, BGN is not only created by road traffic noise. Other sources can have a major impact on the BGN.

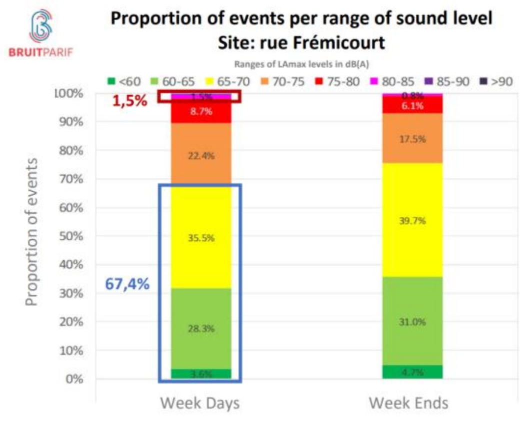
   If road traffic noise is lowered by improved tyre/road noise, the impact on the BGN is not equivalent.

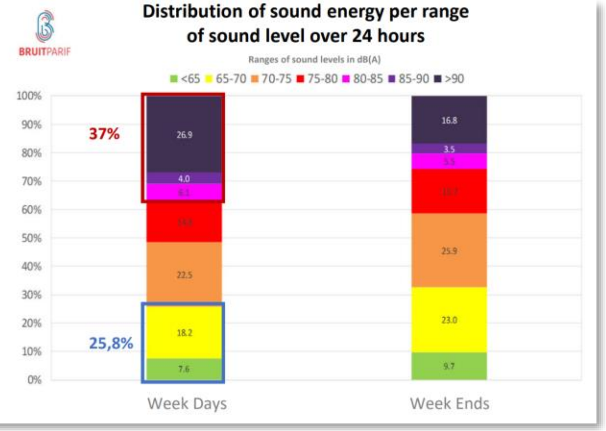
   1. 66% of traffic noises up to 70 dB make 25% of BGN; a reduction of the traffic noises up to 70 dB by -5 dB may lower the BGN by less than 1 dB
   2. 90% of traffic noises up to 75 dB make 50% of BGN; a reduction of the traffic noises up to 75 dB by -5 dB may lower the BGN by less than 2 dB

1. This is a consideration excluding other noise sources, like other transportation means, construction, neighborhood, etc…
2. Especially when road traffic noise is quiet, other sources may dominate the BGN.



Source: TFSL-03-05 (France-Bruitparif) 2021





Source: TFSL-03-05 (France-Bruitparif) 2021

The NHTSA Calculation to determine “Safe Minimum Sound”

Development of FMVSS141

NHTSA Assumption to calculate "safe detection of vehicles"

5.4 m/s² deceleration rate and the 1.5 second brake reaction time

Road Cond	DRY	a_{brake}	5,4	m/s²	3,4 on wet road
		t_{react}	1,5	s	1,25 to 2,5
		$a_{vehicle}$	0	m/s²	up to 2 m/s² ==> WLTP datab

$d = (v_f t) + (\frac{1}{2} a t^2)$

where: d = distance at which detection occurred
v_f = velocity at microphone line (i.e., 10 mph or 14.67 ft per sec)
t = time-to-vehicle-arrival (i.e., seconds until vehicle passed microphone)
a = deceleration rate (i.e., 1 m/sec² or 3.28 ft/sec²)

Calculation of the Stopping Distances (NHTSA Approach)

Condition	Speed event	Speed event	t_react	Speed react	t_brake	Stopp_time	X source
	km/h	m/s	sec	m/s	sec	sec	m
Stationary	0	0,0	1,5	0,0	0,0	0,0	0
Backing	6	1,7	1,5	1,7	0,3	1,8	3
Cruise-by	10	2,8	1,5	2,8	0,5	2,0	5
Cruise-by	15	4,2	1,5	4,2	0,8	2,3	8
Cruise-by	20	5,6	1,5	5,6	1,0	2,5	11
Cruise-by	25	6,9	1,5	6,9	1,3	2,8	15
Cruise-by	30	8,3	1,5	8,3	1,5	3,0	19

1. The scientists tasked by NHTSA to develop an approach for determination of minimum sound levels used the Moore-Glasberg model to elaborate a reference sound level under stationary condition in 2 m distance.
2. This did allow to evaluate the frequency bands most correct.
3. Other operation conditions were scaled by a distance consideration at which a driver could still safely stop the car.

The NHTSA Calculation to determine "Safe Minimum Sound"

Development of UN R138 (QRTV)

NHTSA Assumption to calculate "safe detection of vehicles"

5.4 m/s² deceleration rate and the 1.5 second brake reaction time

Road Cond	DRY				
		a_{brake}	5,4	m/s²	3,4 on wet road
		t_{react}	1,5	s	1,25 to 2,5
		$a_{vehicle}$	0	m/s²	up to 2 m/s² ==> WLTP database 2011

$d = (v_f t) + (\frac{1}{2} a t^2)$

where: d = distance at which detection occurred
v_f = velocity at microphone line (i.e., 10 mph or 14.67 ft per sec)
t = time-to-vehicle-arrival (i.e., seconds until vehicle passed microphone)
a = deceleration rate (i.e., 1 m/sec² or 3.28 ft/sec²)

TABLE 11. Computation of Adjustment of SPL (A-weighted dB) from Source to SAE Microphone Location

Speed, km/hr	10	20	30
X source, meters	5	11	19
Y source*, meters	2	2	2
r0**, meters	2.3	2.3	2.3
r1**, meters	5.5	11.2	19.1
r doubling	1.2	2.3	3.0
Attenuation, dB	-6.0	-12.2	-16.8

* Assume effective source is at center of vehicle since propagation is forward
** Assume Z = 1.2

X represents the distance from the source while Y is the distance from the source to the microphones in SAE J2889-1. Z represents the height of the microphone in meters specified in SAE J2889-1. The values in the Table 11, above, were calculated using the formula below assuming a 1.2 meters value for Z.

$r_0 = \sqrt{y^2 + z^2}$
$r_1 = \sqrt{x^2 + y^2 + z^2}$
$r_{doubling} = \log_{10}(r_1/r_0)/\log_{10}(2)$
$Attenuation = -6 \times r_{doubling}\ dB$

Calculation of the Stopping Distances (NHTSA Approach)

Condition	Speed event	Speed event	t_react	Speed react	t_brake	Stopp_time	X source
	km/h	m/s	sec	m/s	sec	sec	m
Stationary	0	0,0	1,5	0,0	0,0	0,0	0
Backing	6	1,7	1,5	1,7	0,3	1,8	3
Cruise-by	10	2,8	1,5	2,8	0,5	2,0	5
Cruise-by	15	4,2	1,5	4,2	0,8	2,3	8
Cruise-by	20	5,6	1,5	5,6	1,0	2,5	11
Cruise-by	25	6,9	1,5	6,9	1,3	2,8	15
Cruise-by	30	8,3	1,5	8,3	1,5	3,0	19

						MIC Distance 2.0 m	
Ped.Distance r1	Distance doublings	Attenuation	Attenuation	SPL Rounded	NHTSA	MIN SPL	MIN OAL
m	$r_{doubling}$	per $r_{doubling}$	dB	dB	dB	AVAS	NHTSA
2,3	0,0	6	0,0	0	0	44	44
3,6	0,6	6	3,5	4	6	48	48
5,4	1,2	6	6,7	7	6	51	51
8,2	1,8	6	10,1	10		54	
11,4	2,3	6	12,7	13	12,2	57	57
15,1	2,7	6	14,9	15		59	
19,1	3,0	6	16,8	17	16,8	61	61

1. In combination with a propagation model, attenuation levels were calculated which had to be added to the reference sound level.
2. The NHTSA report provides sound level for stationary (reference), backing and the speeds at 10 km/h, 20 km/h, and 30 km/h (shown here by the grey highlighted column).

The NHTSA Calculation to determine “Safe Minimum Sound”

Development of UN R138 (QRTV)

Here we flip to an Excel Simulation Tool on minimum necessary sound, based on the NHTSA scientific assessment

The NHTSA Calculation to determine “Safe Minimum Sound”

Result

NHTSA Assumption to calculate "safe detection of vehicles"

5.4 m/s² deceleration rate and the 1.5 second brake reaction time

Road Cond	DRY	a_{brake}	5,4	m/s²	3,4 on wet road
		t_{react}	1,5	s	1,25 to 2,5
		$a_{vehicle}$	1,5	m/s²	up to 2 m/s² ==> WLTP database 2011

$d = (v_f t) + (\frac{1}{2} a t^2)$

where: d = distance at which detection occurred

v_f = velocity at microphone line (i.e., 10 mph or 14.67 ft per sec)

t = time-to-vehicle-arrival (i.e., seconds until vehicle passed microphone)

a = deceleration rate (i.e., 1 m/sec² or 3.28 ft/sec²)

	Tyres according UN R117			
	C1C-B	C1C-B	C1C-A	
tyre slope	36	36	36	dB/lg(v)
Ltyre@80 km/h	69	69	67	dB(A)
	Ref Road	LOW NOISE Asphalt		
Adjustment	0	-3	-3	dB
Adj WET road	0	0	0	dB
	Tyre Rolling Sound on Road			
	69	66	64	dB

BGN Change: -2

Calculation of the Stopping Distances (NHTSA Approach)

Condition	Speed event	Speed event	t_react	Speed react	t_brake	Stopp_time	X source
	km/h	m/s	sec	m/s	sec	sec	m
Stationary	0	0,0	1,5	0,0	0,0	0,0	0
Backing	6	1,7	1,5	1,7	0,3	1,8	3
Cruise-by	10	2,8	1,5	5,0	0,9	2,4	10
Cruise-by	15	4,2	1,5	6,4	1,2	2,7	13
Cruise-by	20	5,6	1,5	7,8	1,4	2,9	17
Cruise-by	25	6,9	1,5	9,2	1,7	3,2	22
Cruise-by	30	8,3	1,5	10,6	2,0	3,5	26
Cruise-by	35	9,7	1,5	12,0	2,2	3,7	31
Cruise-by	40	11,1	1,5	13,4	2,5	4,0	37
Cruise-by	45	12,5	1,5	14,8	2,7	4,2	42
Cruise-by	50	13,9	1,5	16,1	3,0	4,5	48
Cruise-by	55	15,3	1,5	17,5	3,2	4,7	55
Cruise-by	60	16,7	1,5	18,9	3,5	5,0	62
Cruise-by	65	18,1	1,5	20,3	3,8	5,3	69
Cruise-by	70	19,4	1,5	21,7	4,0	5,5	76
Cruise-by	75	20,8	1,5	23,1	4,3	5,8	84
Cruise-by	80	22,2	1,5	24,5	4,5	6,0	92
Cruise-by	85	23,6	1,5	25,9	4,8	6,3	101
Cruise-by	90	25,0	1,5	27,3	5,0	6,5	110
Cruise-by	95	26,4	1,5	28,6	5,3	6,8	119
Cruise-by	100	27,8	1,5	30,0	5,6	7,1	129

Condition	Ped.Dist. r1	Distance doublings $r_{doubling}$	Attenuation per $r_{doubling}$	Attenuation	ATT Rounded	NHTSA	MIN SPL (MIC Distance 2.0 m)	MIN OAL
	m			dB	dB	dB	AVAS	NHTSA
Stationary	2,3	0,0	6	0,0	0	0	44	44
Backing	3,6	0,6	6	3,5	4	6	48	48
Cruise-by	10,2	2,1	6	11,8	12	6	56	51
Cruise-by	13,6	2,5	6	14,1	14		58	
Cruise-by	17,5	2,9	6	16,1	16	12,2	60	57
Cruise-by	21,7	3,2	6	17,9	18		62	
Cruise-by	26,3	3,5	6	19,4	19	16,8	63	61
Cruise-by	31	4,0	6	22,0	22		66	
Cruise-by	37	4,2	6	23,3	23		67	
Cruise-by	42	4,4	6	24,4	24		68	
Cruise-by	48	4,6	6	25,5	26		70	
Cruise-by	55	4,8	6	26,5	27		71	
Cruise-by	62	4,9	6	27,4	27		71	
Cruise-by	69	5,1	6	28,3	28		72	
Cruise-by	76	5,3	6	29,1	29		73	
Cruise-by	84	5,4	6	29,9	30		74	
Cruise-by	92	5,5	6	30,7	31		75	
Cruise-by	101	5,7	6	31,4	31		75	
Cruise-by	110	5,8	6	32,1	32		76	
Cruise-by	119	5,9	6	32,7	33		77	
Cruise-by	129	6,0	6	33,3	33		77	

Condition	MIN SPL (MIC Distance 7.5 m)	Speed	T/R SPL	T/R SPL	T/R SPL	
	AVAS	km/h				
Stationary	33,7	5	25,7	22,7	20,7	
Backing	37,7	6	28,5	25,5	23,5	
Cruise-by	45,7	10	36,5	33,5	31,5	
Cruise-by	47,7	15	42,8	39,8	37,8	
Cruise-by	49,7	20	47,3	44,3	42,3	UN R138.01
Cruise-by	51,7	25	50,8	47,8	45,8	
Cruise-by	52,7	30	53,7	50,7	48,7	FMVSS 141
Cruise-by	55,7	35	56,1	53,1	51,1	
Cruise-by	56,7	40	58,2	55,2	53,2	
Cruise-by	57,7	45	60,0	57,0	55,0	
Cruise-by	59,7	50	61,7	58,7	56,7	UN R51.03
Cruise-by	60,7	55	63,1	60,1	58,1	
Cruise-by	60,7	60	64,5	61,5	59,5	
Cruise-by	61,7	65	65,8	62,8	60,8	
Cruise-by	62,7	70	66,9	63,9	61,9	
Cruise-by	63,7	75	68,0	65,0	63,0	
Cruise-by	64,7	80	69,0	66,0	64,0	
Cruise-by	64,7	85	69,9	66,9	64,9	
Cruise-by	65,7	90	70,8	67,8	65,8	
Cruise-by	66,7	95	71,7	68,7	66,7	
Cruise-by	66,7	100	72,5	69,5	67,5	

UN R51.03 Annex 7
plus extension to GRB-68-03

!

The calculation indicates sufficient “safety” when tyre rolling sound exceeds the calculated minimum sound for safety. While the minimum safety sound is based on frequency band considerations, tyre rolling sound is not validated accordingly. UN R138 accounts for that by specifying in paragraph 6.2 of the main body:

“If the vehicle that is not equipped with an AVAS fulfils the overall levels as specified in Table 2 below with a margin of +3 dB(A), the specification for one-third octave bands and the frequency shift do not apply.”

Conclusions on the minimum Safety Assessment

Minimum Safety under other vehicle operation conditions

1. The application of the Scientific Model (VOLPE for NHTSA) for other operation conditions shows:

    - When lowering the overall sound emission of the vehicle by quieter tyres or/and quieter roads, **the minimum safety needs to be expanded to higher speeds**, as a lowering of the background noise due to quieter tyres/roads cannot be confirmed in the same dimension as an individual vehicle might become quieter.

    - Variation of braking force, reaction time, vehicle operation (acceleration) and tyre variation show that a safe detection of vehicles is not limited to the operation ranges specified in the regulations today (neither FMVSS141 nor UN R138).

- Any considered changes to UN R138 with regard to minimum or maximum sound levels, or the operation range of AVAS need an assessment on impact on safety.

- This presentation and its simulation tools used behind can be used for this assessment.

Recommendation #2

General concept of all Vehicle Noise Regulations

1. All regulations on vehicle noise are based on the sound performance of a vehicle.
2. Vehicle technology has received a fast technology progress between 2000 and 2015 for which older UN R51 series 01 and 02 were not fit for and provided grey zones for abuse.
3. UN R51.03 with all its supplements is explicitly tailored in recognition of the grey zones and leakages of UN R51.02. It is capable to test vehicles and evaluate their sound behaviour independent of the vehicle design.
4. The overall vehicle sound is a complex system to which many components contribute, a lot of them managed by Control Units (CU), which might make them fall under the new proposed definition of “artificial sound”.
   - Systems such as, but not limited to AVAS, pumps, fans, actuators, ventils, anti noise systems are dependent of a CU and work (and make noise) as a function of operation conditions and other factors.
   - How to evaluate, which technology would fall under “natural sound”, “artificial necessary sound”, “artificial useful sound”, “artificial undesired sound”, “AVAS”, and Sound Enhancement Systems “SES”.
5. For the sake of approval authorities, technical services and manufacturer it is strongly recommended to **keep the sound emission regulation as they are today: design neutral as much as possible**
6. RD-ASEP should be followed consequently to bring it into force in the near future.

Thank You very much!