Transmitted by the Chair of the Informal Work Group on Quiet Road Transport Vehicles (QRTV)

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Draft Recommendations for a Global Technical Regulation Regarding Audible Vehicle Alerting Systems for Quiet Road Transport Vehicles

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Contents

Page

I. Scope

The UN/WP.29 mandated the Group of Experts on Noise (GRB) to establish an informal working group (IWG), the Quiet Road Transport Vehicle (QRTV), to determine the viability of "quiet vehicle" audible acoustic alerting systems, identify critical acoustic parameters and assess the potential need for their global harmonization.

II. Introduction

The environmental benefits achieved by hybrid electric and pure electric road transport vehicles (HEV and EV) include near zero air pollution, reduced fossil fuel demands and very quiet vehicle operation at low speeds. While quiet vehicle operation provides the potential for significant public health and welfare benefits to millions of citizens, it has resulted in an unintended consequence - the removal of an important source of audible signals that are used by many pedestrians (e.g. blind, low vision and elderly pedestrians) and road users (e.g. cyclists), to signal the approach, presence and departure of these vehicles.

This report presents the findings and recommendations of the QRTV / IWG with regard to the future development of a globally harmonized regulation that would specify the applicability and performance of an 'Audible Vehicle Alerting System' (AVAS). The AVAS would provide pedestrians and other road users with information regarding the operation of quiet vehicles at speeds below 20 to 30 kilometers per hour (12 to 20 miles per hour) that is essential to safe movement decisions while also protecting the public from unnecessary increases in environmental noise and the vehicle operator from adverse noise impact. Particular attention should be given to those countries that have programs directed at the reduction of community noise impact.

While an in-depth assessment of the potential growth of the quiet vehicle fleet was beyond the scope of the QRTV terms of reference, there is substantial evidence to support a conclusion that any resulting UN/ECE regulation regarding AVAS must be harmonized as a Global Technical Regulation (GTR) to reduce pedestrian confusion and to minimize diverse regulatory burdens on powered road vehicle manufacturers.

III. Applicability

The QRTV / IWG believes that not all electric (EV) and hybrid electric vehicles HEV) should necessarily be subjected to the installation of a special audible alerting system. The broad range of EVs and HEVs in the market today clearly demonstrates that those vehicles that rely on the combination of electric motor and internal combustion engine drive trains and those that employ combustion engines solely to maintain the electric charge of battery's, may produce sufficient audible sounds as to negate the need for a separate alerting system. Similarly, recently introduced electric motorcycles and scooters have demonstrated that not all models may be candidates for an AVAS. Conversely, the QRTV / IWG believes there are internal combustion engine (ICE) vehicles in the fleet today that in some cases produce less sound than that produced by some HEV's.

The vehicle measurement data, using test procedure SAE J 2889-1 (2011), provided to the QRTV / IWG indicates EVs and HEVs operating in electrical mode produce a sound pressure level (SPL) in a range of 46 to 53 dB(A) at 10 km/h (6 mph) and 20 to 38 dB(A) in standstill condition. Further, measurements of ICE vehicles measured under the same test conditions produced an SPL of 53 to 80 dB(A) at 10 km/h (6 mph) and 45 to 72 dB(A) in standstill condition[1].

QRTV Recommendation:

The QRTV / IWG recommend the GTR be written to apply, in principle, to all low sound level vehicles regardless of their motive power. However, due to the fact that limited vehicle performance related acoustic information is available for vehicles other than electric and hybrid electric automobiles the QRTV / IWG is recommending that initial regulatory specifications be limited to EV's and HEV's, operating in their electric mode.

IV. Definitions

In the course of its investigations the QRTV / WG encountered some confusion in discussions of acoustic parameters and vehicle operating modes.

QRTV Recommendation:

The QRTV / IWG recommends all acoustic terms and parameters be clearly defined in the GTR. However, where such terms and/or parameters are defined in a subsidiary document such as in an ISO standard that can be adopted by reference into the GTR, the QRTV / IWG recommends they not be repeated in the GTR. It is further recommended that vehicle operating parameters such as the speed at which an AVAS is required to operate or turn-off, be clearly defined in universally accepted terms. These recommendations are particularly important in view of the need to translate the GTR into languages other than English..

[1] QRTV Meeting 03/06/2011, SAE J2889-1; Data for Quiet Road Transport Vehicles

The QRTV / IWG recommends the list of definitions includes, at a minimum, definitions of vehicles that may be candidates for the GTR and technical or descriptive terminology that is uniquely applicable to the GTR for quiet vehicles. To this end the following vehicle[2] and terminology definitions are presented for GTR consideration

1. Electric Vehicle I (EV-I): A road transport vehicle whose drive-train consists of one or more electric motors that receive their energy from one or more externally charged batteries.

2. Electric Vehicle II (EV-II): A road transport vehicle whose drive-train consists of one or more electric motors that receive their energy from one or more batteries that are charged by an on-board internal combustion engine that is not connected to the vehicle drive-train.

3. Hybrid Electric Vehicle I (HEV-I); A road transport vehicle whose drive-train incorporates a combination of electric motors and an internal combustion engine that powers an electric generator to charge the batteries and also provides direct motive power to the drive-train on demand.

4. Hybrid Electric Vehicle II (HEV-II): A road transport vehicle whose permanent internal combustion drive train can be supplemented by electric motors.

5. Internal Combustion Engine Vehicle (ICEV): A road transport vehicle whose operation relies entirely upon an internal combustion engine to power its drive-train.

6. AVAS - Audible Vehicle Alert System
   System fitted to a vehicle that emits audible sound(s) intended to give information to other road users

7. Attenuation
   Reduction of the sound emitted by an AVAS.

8. Attention catcher
   A special sound produced by an AVAS that indicates to pedestrians and road users the start of vehicle movement.

9. Ready for Movement
   The sound produced by an AVAS that indicates all vehicle controls necessary to initiate immediate vehicle movement are ready for driver action.

10. Pitch shifting
    The variation of the frequency content of the AVAS sound as a function of the vehicle speed.

11. Directivity
    A measure of the directional characteristics of a sound source when mounted on a vehicle.

2

12. Modulation
The repetitive time dependant variation of the sound amplitude produced by an AVAS .

V. General Specifications:

A future Global Technical Regulation (GTR) would establish harmonized operational criteria, acoustic specifications and certification testing protocol(s) to provide vehicle operating mode information to pedestrians and other road users.

The blind citizen groups, vehicle component manufacturers, motor vehicle manufacturers and contracting parties to WP29 are supportive of a GTR. However, these individuals and organizations did raise system design issues, questions and concerns regarding the specific information to be conveyed to the target audience, the acoustic format for communicating this information, functional performance requirements and certification test procedures.

The QRTV / IWG expended considerable effort to align its recommendations with the anticipated U.S. rule. We believe our recommendations incorporate those elements essential to the safe navigation by pedestrians in road traffic environments with minimum adverse impact on the general public and the vehicle operator, and with due consideration to technical feasibility and economic viability.

A. Quiet vehicle "At-Risk" Modes of Operation

The QRTV / IWG obtained, through discussions with blind and low vision persons and a limited number of elderly persons, plus personal experience during a blindfolded - white cane experience, those road vehicle operations that present the highest levels of risk during their typical foot travel. The following modes were the most often indentified:

1. Vehicles approaching at right angles to the direction of pedestrians intended movement,
2. Vehicles initiating movement from a driveway or in a parking lot,
3. Vehicle travelling at low speed in quiet areas.[3]

B. Risks to Pedestrian Situational Awareness

1. Vehicles approaching parallel to the direction of pedestrian intended movement
2. Vehicles in their operating mode but temporarily stationary such as at a stop light or sign,
3. Vehicles with engines located in their rear in relation to their movement

[3] **MLIT;** *Surveys for Standardization of AVAS in Japan* **(**Survey of passers-by, HV/EV drivers & visually impaired)

QRTV Recommendation:

The QRTV / IWG recommends the GTR audibility requirements for the pedestrian alerting systems address at least the 'At Risk' issues listed above.

C. Vehicle Alerting Signal Considerations

The QRTV / IWG received and reviewed a substantial quantity of information from a large number of diverse sources. The following is a distillation of the most pertinent information and data that we believe must be considered in the development of the performance requirements. The technical recommendations presented in a later section of this report are based, in part, on our consideration and assessment of the following information and data.

1. General Considerations

The role of human hearing in supporting safe pedestrian travel is variable amongst the world pedestrian population yet vitally important. Therefore the following factors merit careful attention:

a) It is not possible to set an audibility threshold due to the very large number of acoustic variables in a typical every-day situation. Put simply: too quiet – not heard; too loud – creates noise pollution and aggravation. In respect of audibility all these are relavent.

b) Regulatory requirements need therefore to be geared to defined high risk scenarios (whilst considering the environment)

c) AVAS should:

   i) provide spatial and directional cues to the hazard location.
   ii) inform the pedestrian and road users of the proximity of a hazard.
   iii) elicit correct and quick avoiding action by exposed persons
   iv) not give false alarms

d) Audibility requires, inter alia, an alerting signal that contains frequencies different from most common ambient frequencies in order to avoid masking effects. Generally, an alerting signal's mid frequencies (0,5 kHz to 2 kHz), higher frequencies (2 kHz to 5 kHz) support audibility and directional cues. Low frequencies (below 500Hz) support earlier detection but in an urban environment are at risk of being masked.

2. Environmental Considerations

Certain noise characteristics can produce adverse human response. The following sounds should be prohibited[4]:

a) excessively loud sounds
b) Siren, horn, chime, bell and emergency vehicle sounds
c) Alarm sounds e.g. fire, theft, smoke alarms
d) Intermittent sound
e) Melodious sounds, animal and insect sounds
f) Sounds that confuse the identification of a vehicle and/or its operation.
g) The sound to be generated by a pedestrian alerting system should be easily indicative of vehicle behaviour, for example, through the automatic variation of sound level or characteristics in synchronization with vehicle speed.

[4] UN / ECE - RE3, Annex 2

3. Critical audible Distance

The critical audible distance is the maximum of two determining factors:

-Vehicle centric i.e. braking-distance

-Pedestrian centric i.e. decisions

a) Vehicle Centric (Braking Distance)

Distance required for a vehicle travelling at the AVAS activation speed to be braked to a stop, can be calculated using the following formulae:

Vehicle stopping distance [meters] = driver reaction distance (R) + vehicle braking distance (B)

where :

R [meters] = (vehicle speed [km/h] /10) x 3

B [meters] = $(\text{vehicle speed [km/h]}/10)^2$

(at 20 km/h this would be ~ 10 m)

b) Pedestrian Centric Factors

-Pedestrian decision time: ~ 2 seconds (estimated)[5]

-Pedestrian travel time for typical 2 lane street ≈ 8m: ~7 seconds (estimated)[6]

(at 20 km/h this would be about 50m)

c) Minimum AVAS Detection Distance

The minimum AVAS detection distance must be greater than the calculations for both distances determined for vehicle braking distance and pedestrian decision.

d) Maximum AVAS Detection Distance

The maximum AVAS detection distance, to provide the highest margin of pedestrian safety, would add the pedestrian travel time to the minimum AVAS detection distance.

QRTV Recommendation:

QRTV / IWG recommends the GTR give careful attention to the above listed minimum AVAS considerations in their development of the acoustic and operational limits of an AVAS.

4. Low Speed Pedestrian Risk Areas

It is natural to conclude that a high-traffic roadway poses a greater pedestrian hazard than a car park because a vehicle / pedestrian collision here, whilst unusual, is generally fatal. However, the likelihood of a vehicle / pedestrian low-speed collision in a busy car park (for example) is high, particularly for children and the elderly. Reasons – driver sightlines are frequently blocked by parked cars, pedestrian pre-occupation, lack of hazard awareness & alertness, false sense of security, toddlers

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running loose and so on; in the presence of a silently moving vehicle these actions can present a most serious injury scenario.

The audible performance of an alerting system or counter-measures must consider the consequences of:

a) Sound too loud:
   i. high false alarm rates,
   ii. masking important auditory cues,
   iii. annoyance
b) Sound too quiet:
   i. high risk in high ambient noise environments
c) Dangerous sound:
   i. tones subject to giving false hazard direction cues
   ii. being masked by similar ambient frequencies, thus unheard

VI Acoustic Performance

1. Frequency Content

It is best that the frequency content includes at least two one-third octave bands, whose level exceeds the corresponding bands in the ambient noise[7]. It has been further suggested, that a minimum of four one-third octave bands may serve to improve the acoustic performance of an AVAS system[8]. Recent practical experiences on various aspects of vehicles that are available in the Japanese market were reported by the Japan Automobile Standards Internationalization Center (JASIC)[9]. The investigation centered on Information from 4 vehicles: 3 EV/HEV with AVAS compared to 1 ICE. The following sound frequency aspects were reported:

Frequency components (according to SAE J2889-1: 2011):

i. EV/HEV show two different, but obvious peaks, low (250/500/630Hz); high (2 kHz/ 2.5 kHz/2.5 kHz) respectively.
ii. No peak frequency was detectable from the ICE
iii. The results from 10 km/h pass-by testing of EVs and HEVs with and without AVAS showed that both results differ significantly only at or around the detected peak frequencies.
iv. Uncertainties in sound level on frequency basis were observed. In the case where the levels of frequency components are specified the following uncertainties should be considered:
   (1) Dispersion of each measurement
   (2) Errors which are made in 1/3 octave band frequency analysis
   If the tested frequency is off-centre in its one-third frequency band, analysis reveals an under reading of up to 3 dB(A) compared to the SPL measured at centre frequency
   (3) Variation of frequency characteristics in loudspeakers

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[7] **JASIC;** "AVAS Sound Specification," reported at the 9th UN/GRB/QRTV Meeting, 5 December 2011, Bonn, Germany

[8] **NHTSA**; "Quieter Cars and the Safety of Blind Pedestrians," Phase 2: Development of Potential Specifications for Vehicle Countermeasure Sounds (Phase 2 Volpe report), p. XVii

[9] See footnote 8

QRTV Recommendation:

Based in part on the information and data obtained from multiple sources, both verbal and published, and extensive debate within the Work Group, the QRTV / IWG recommends the following operating frequency specifications be considered:

1. Frequency range of audible signal: between 50 Hz and 5 kHz [10] [11]
2. Frequency content:
   a) The frequency content should include at least two 1/3 octave bands within that range[12]
   b) In the case where the AVAS produces only two frequencies, they should differ by at least 15%.
   c) An alerting signal's mid frequencies (0,5 kHz to 2 kHz), higher frequencies (2 kHz to 5 kHz) support audibility and directional cues. Low frequencies (below 500Hz) support earlier detection but in an urban environment are at risk of being masked.

2. Alerting Signal Audibility

a) **Determination of Audibility (Masking) of EV Sounders in Traffic Noise**

The success or failure of sounds added to EVs depends largely on their audibility when in a mix of EV and ICE traffic, in which the number of EVs is considerably less than the ICEs. Therefore it is necessary to investigate EV sound in the presence of ICE sound. A characteristic of traffic noise is that it fluctuates in level as a vehicle passes a reference point, so that it is normally the nearest vehicle which predominates in the noise. After a vehicle has passed, the pedestrian has to be sure that the following vehicle is far enough away for it to be safe to cross the road.

b) Conditions Governing Audibility

Audibility is achieved at the lowest SPL when the alerting signal considers the following:

i) it is of a uniquely distinct character which avoids risk of masking
ii) it contains a broad frequency band spanning a minimum of two 1/3 octave bands
iii) two degrees of audibility merit consideration:
   (1) *Detectable*; the point at which a listener ceases to hear a known sound as its loudness is reduced.
   (2) *Adequate*; the lowest level of loudness at which a listener is likely to detect an AVAS.
iv) At 20 km/h, detection at 35m enables a blind person to cross a road lane safely[13, 14]
v) Different sounds require different SPLs varying up to 10 dBA for equal audibility and detectability.[15]

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[10] **OICA;** " Outlook on Candidate Performance Specifications for QRTV," presented at 9th UN/GRB/QRTV Meeting, 5 December 2011, Bonn, Germany

[11] **Nissan;** "Nissan's Audible Vehicle Alerting System (AVAS)," presented at 8th UN/GRB/QRTV Meeting, 18 October 2011, Baltimore, Maryland, USA

[12] **NHTSA**; *Quieter Cars and the Safety of Blind Pedestrians, Phase 2: Development of Potential Specifications for Vehicle Countermeasure Sounds (Phase 2 Volpe report)*, p. XVii

[13] **Western Michigan University**, Blindness and Low Vision Studies; WMU/GM collaboration: *Quiet cards in Yuma Arizona* (slide 10); 6.9 sec "Crossing margin measure" = Vehicle passing time – 6.9 seconds.

[14] **Western Michigan University**, Blindness and Low Vision Studies; WMU/GM collaboration: *Quiet cards in Yuma Arizona* (slide 10); 6.9 sec "Crossing margin measure" = Vehicle passing time – 6.9 seconds.

vi) A small discrete sound at the rear of the vehicle to indicate to a blind person that the vehicle has passed.

vii) The difference between "detectable" and "adequate" ICE/AVAS sound is > 10 dB[16, 17]

QRTV Recommendation:

The QRTV/IWG work-group does not believe that a specific alerting signal sound pressure level can be recommended absent a clear specification for sound frequency and content. The discussions above have identified those elements that must be considered in the specification of alerting signal frequency content.

3. Vehicle Speed Indication[18 19 20]

a) Frequency Pitch Shifting: A monotonic change of the major frequency content is very typical for machinery sound. The use of pitch shifting strongly excludes animal sound. The pitching rate, which is proportional to vehicle speed, ensures a variation of the sound which is readily detected when the vehicle is in transient operation (acceleration / deceleration). Presently used pitch shifting frequencies range from a low of 0.6 kHz to a high of 2.5 kHz.
b) Frequency Modulation: Used to simulate sound of "firing beat" of internal combustion engine. Modulation frequency is generally less than 0.6 kHz.
c) Volume Shifting: Vehicle sound increases or decreases as a function of the vehicle acceleration or deceleration. This is a physical phenomenon produced to varying degrees by most road vehicles. To ensure that this typical characteristic is kept and to avoid masking of the "signal of interest" by tyre rolling sound, a volume increase may be necessary.

QRTV Recommendation:

The QRTV / IWG recommends the sound generated by the alert device monotonically increase or decrease in frequency as a function of vehicle speed. Further, it is recommended that during acceleration or deceleration an increase or decrease of at least 8% be demonstrated between 10 km/h and 20 km/h. This pitch shift should be verified by SAE J 2889-1:2011.

In addition, the QRTV / IWG recommends that if volume shifting of the alerting device is to be required, it is preferable that the vehicle emits higher sound level at higher speeds. A detection of the vehicle operation condition is already covered by the pitch shifting. The volume shifting can provide an enhancement for detection at greater distance.

4. Vehicle Stationary Alerting Signal[21]

Vehicle stationary alerting signal is the sound emitted when the vehicle is temporarily stopped (vehicle speed is 0 km/h) and in "ready for movement" status. While there is some disagreement for the

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[15] **Katsuja Yamauchi**; *An Examination on Required Sound Levels for Acoustic Warning Devices for "Quiet Vehicles"* (QRTV 04-05, slides 12 to 15)

[16] **Katsuja Yamauchi**; *Psychoacoustic Examination in Germany on Adequate Sound Levels of Possible Warning sounds for Quiet Vehicles* (QRTV 04-03, slide 16)

[17] **Katsuja Yamauchi**; *Psychoacoustic Examination in Germany on Adequate Sound Levels of Possible Warning sounds for Quiet Vehicles* (QRTV 05-03, Fig 2)

[18] **Nissan;** "Nissan's Audible Vehicle Alerting System (AVAS)," presented at 8th UN/GRB/QRTV Meeting 18 October 2011, Baltimore, Maryland, USA

[19] **OICA;** see footnote 9

[20] **ISO;** Draft Pitch-shift standard at http://www.unece.org/fileadmin/DAM/trans/main/wp29/QRTV-08-07.pdf

[21] **OICA;** see footnote 9

need of the vehicle to emit a sound while in a temporary stopped (equivalent to idle) operating mode, blind and low vision pedestrians strongly maintain their need to know the presence of such vehicle operating mode in order to formulate their "go" or "no-go" decision.

In light of the U.S. regulation that may require operation of vehicle alerting system while temporarily stationary, it is necessary to consider the characteristics of the stationary alerting signal, its SPL while in this mode and the duration of device activation.

QRTV Recommendation

In light of the expressed concerns of blind and low vision persons[22] and the U.S. legislation that prohibits any form of on-off or defeat switch, the QRTV / IWG recommends that the GTR require the operation of the alerting system during temporary stops of the vehicle. However, it is further recommended that the sound level be automatically attenuated during these periods to a level that is adequate to be heard by a pedestrian who is at the curb, immediately adjacent to the vehicle, in preparation of crossing the intersection - the specific SPL must be determined based on required signal characteristics. This requirement is not intended to relieve the driver of the vehicle of responsibility for the safety of the pedestrian but rather to acknowledge that some jurisdictions may not require the generation of a sound when the vehicle is temporarily stationary.

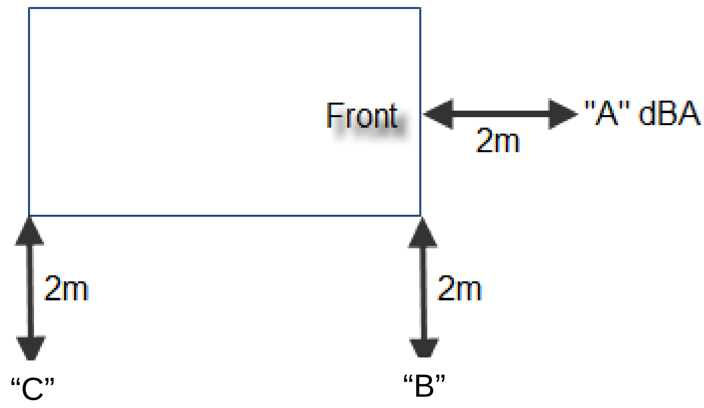
5. Directivity Pattern of Sound Source:

The directivity or radiation pattern of a sound source demonstrates the three dimensional propagation of the sound waves and assists in determining the relative adverse impact of the alerting system sound on third (disinterested) parties. All sources that produce sound waves have an associated radiation pattern or directivity. While the development of a detailed radiation pattern of a sound source requires several hundred measurements in the horizontal, vertical and diagonal planes, such detail measurements are not believed to be necessary for the purpose of determining the directivity of a vehicle mounted alerting system. Since the primary purpose is to convey a relatively simple acoustic signal that does neither contain a verbal instruction nor a complex musical score, detailed knowledge of the uniformity of the radiation is not essential. What is important is the ready detection of a multi-frequency sound and the ability to determine if the sound is stationary, moving toward or away from a pedestrian or approaching from the rear or side. Therefore, a two dimensional test is believed to be adequate with three microphone positions and the vehicle in a stationary mode as described below.

With reference to the figure below, if the directivity reference point "A" is 2m directly in front and on a center-line of the stationary vehicle:

a) The SPL is measured at position "A" and represents the reference sound level
b) The SPL is measured at 90 degrees and 2m from a front corner of the vehicle - position "B". The SPL reduction should be no more than 10 dB(A) below that measured at "A"
c) The SPL is measured at 90 degrees and 2m from the rear corner of the vehicle - position "C". The SPL reduction relative to the SPL measured at "B" should not be greater than approximately 5 dB(A).

[22] QRTV Work-group; Minutes of 4th Meeting, 27 September 2010, Berlin, Germany



QRTV Recommendation

QRTV / IWG recommends a simplified approach be taken for determining the minimum directivity pattern of the alerting system when mounted in a specific vehicle. To that end, the QRTV believes the above approach should be adequate for verification testing of a sound source radiation (directivity) pattern under insitu conditions.

6. Loudness of Sound Source (Environmental Impact)

A key concern with regard to adding an audible sound to a "quiet" vehicle is the potential adverse environmental noise impact resulting from a possible increase in traffic noise. A measure of sound pressure level is not an adequate metric for assessing adverse impact on the public because human annoyance is a combination of sound level and sound frequency. Annoyance is generally the surrogate for sleep disturbance, speech interference, learning distractions and the degradation of personal peace, tranquillity and overall quality of life and potentially, health[23]. . The metric that provides a good measure of annoyance or the possibility for a negative public reaction is "loudness." Generally speaking, loudness is a subjective metric and is very dependent on personal preference as frequently exemplified by the expression, "one persons music is another person's noise."

a) Significant tonal content is likely to cause environmental annoyance.
b) AVAS with wide frequency ranges and content have lower environmental impact.
c) Adjacent 1/3rd octave bands that are 5dBA louder than their adjacent bands are likely to cause annoyance.
d) Sounds with strong tonal content can be up to 10 dBA higher than an equally loud broadband sound.
e) Care needs to be taken when defining the dBA for a sounder to consider its frequency content to ensure it is neither too loud or unheard.

[23] **WHO/JRC report**; See *http://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf* ; **"Burden of disease from environmental noise"**

QRTV Recommendation

QRTV / IWG recommend the acoustic performance requirements set forth in the GTR for AVAS give careful attention to their potential adverse environmental impact, particularly with respect to loudness and frequency content.

VII. Alerting System Operational Criteria

A key and frequently asked question is "at what vehicle speed should the alerting system be activated?" This question gives rise to a number of secondary issues including the duration of operation, at what vehicle speed should the alerting system be deactivated, should the device remain activated during continuous operation at its activation speed and must the alerting system produce the same sound level during all hours of operation? Clearly, these are all important question that merit substantive assessment and resolution. The QRTV / IWG work-group received diverse suggestions regarding each of these vehicle operating modes and presents a critique below:

1. Alerting System Activation Speed also known as Crossover Speed[24]

Initial quiet vehicle sound level measurements carried out in accordance with SAE J2889-1 SEP2011, verified that the majority of vehicles tested exhibited a change in their acoustic signature at approximately the same speed. It was concluded that this change was due, in part, to the onset of tire-road interaction and aerodynamic generated sound. Manufacturer and U.S. government[25] testing conducted on smaller, lightweight automobiles revealed the crossover speed to be approximately 20 km/h (12 mph) while several other studies suggest the crossover speed to be 25 km/h (15 mph)[26] and between 33 and km/h (20 and 25 mph)[27]. In addition, there is currently a trend for quieter tires and sound absorbing pavement surfaces that can lead to higher crossover speeds in the future.

2. Alerting System Deactivation Speed

The speed at which the alerting system is no longer necessary would be the converse of the speed for system activation. Based on the above suggested crossover speeds attendant to system activation, the deactivation speed would be between 20 and 41 km/h.

3. Alerting System Duration of Activation at Constant Speed and Late Night Travel

A key concern arises when we consider that the typical flow of traffic is frequently intermittent or constant at low speed, particularly during peak morning and evening commutes to and from work. In addition, there is the question as to the need for alert system activation during prolonged slow speed operation on highways or boulevards where pedestrian traffic or crossing is prohibited. Finally, there is the issue of the alert

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[24] **United States of America**; "Pedestrian Safety Enhancement Act of 2010" (Public Law 111-373 - January 4, 2011) defines the crossover speed as "...the speed at which tire noise, wind resistance, or other factors eliminate the need for a separate alert sound ..."

[25] See footnote 12; Volpe 20 km/h

[26] Delta 25 KPH

[27] Dr. Rosenblum

system sound level during sleeping hours - both WHO[28] and U.S.[29] guidelines recommend noise levels in residential areas not exceed a time average (L_{night}) of 45 dB(A) from 10:00 p.m. until 7:00 a.m (these night-time restrictive periods may differ based upon national laws).

This issue was given only cursory attention by the QRTV / IWG. However, several suggestions were put forth during discussions that ranged from manual deactivation to automatic sound attenuation with a preset attenuation level if an activation period exceeds a predetermined period. A similar automatic sound attenuation might be applicable when the vehicle is operated during sleeping hours.

QRTV Recommendation

The QRTYV / IWG makes the following recommendations with regard to AVAS operational criteria:

1. The alerting system is automatically activated when the vehicle slows to or below the crossover speed,
2. The alerting system will automatically deactivate at vehicle speeds in excess of the crossover speed.
3. The GTR work-group gave serious consideration to automatic sound attenuation during prolong periods of system activation and during sleeping hours. The technology to achieve automatic sound attenuation is readily known and available. A possible GTR requirement could state that "the alerting system shall automatically attenuate its audible sound by [X] db (A) when sustained vehicle speeds at or below the crossover speed exceed [X] minutes and shall automatically resume its operation upon acceleration of the vehicle to a speed in excess of the crossover speed.
4. It is strongly recommended that a GTR contain explicit language that prohibits the alteration or disabling of an alerting system installed on a vehicle, by any party except for repair or maintenance by a designated authority.
5. It is recommended that manual deactivation of the alerting system be an option that may be adopted by a Contracting Party to the future GTR[30]. However, based upon strong opposition expressed by the blind and low vision community, and the U.S. legislative prohibition[31] of such manual defeat devices, the GTR should give consideration to automatic sound attenuation of the AVAS as an alternative to the manual activation/deactivation switch.

VIII. Economic Considerations

The QRTV / IWG did not conduct an investigation of the potential costs of an AVAS. However, during discussions of system performance requirements it became clear that as additional technical features are added to the system, the cost can be expected to increase, at least initially. Once an AVAS design is finalized it is anticipated that system cost may decrease due to the economy of production.

[28] World Health Organization; " **Burden of disease from environmental noise. Quantification of healthy life years lost in Europe**," ISBN 978 92 890 0229 5

[29] U.S. Environmental Protection Agency; "**Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare With An Adequate Margin of Safety,**" Report No. 550/9-74-004, March, 1974

[30] UN/ECE; – RE-3

[31] See footnote 24

QRTV Recommendation

The QRTV / IWG strongly recommends that the GTR drafting group give consideration to cost effectiveness of the performance requirements.

IX. Conclusion

The Quiet Road Transport Vehicle Informal Work-group extends its appreciation to the many persons and entities that provided valuable information and guidance during its nearly two year work program. It must be noted that at the inception of the QRTV / IWG, an expression of interest to participate was received from approximately 11 persons. At the conclusion of our work we have a mailing list of interested parties that exceeds 104 persons and organizations. The importance of this work, to provide an alert to pedestrians when confronted by a "quiet" vehicle, is obvious by the increased level and diversity of participants. Clearly, this report represents a starting point in the development of next generation alerting systems that will save lives around the world. The QRTV / IWG is proud to have had the opportunity to foster an awareness of this important work which serves as the precursor of a global technical regulation that will grow in importance with the anticipated growth of the electric and hybrid electric vehicle fleet and the continued reduction of noise from internal combustion powered vehicles. Thank you.