Technical Note

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ADDING NOISE TO QUIET ELECTRIC AND HYBRID VEHICLES: AN ELECTRIC ISSUE[1]

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It has been suggested that hybrid and all-electric automobiles are so quiet at low speed in electric drive that they constitute a safety hazard for pedestrians and bicyclists. This trait has been especially troubling to vision-impaired people who rely on sound cues to avoid approaching vehicles. Assumptions have been made linking the quietness of such vehicles with fatalities and serious injuries. The U.S. Pedestrian Safety Enhancement Act of 2010, requires the use of Audible Vehicle Alerting Systems (AVAS) in hybrid and all electric vehicles. Rules are now being developed and are expected to be issued by January 2014. Similar regulations are being promulgated in Japan and the European Union. The UN/ECE is developing a Global Technical Regulation after extensive preparatory work. SAE International and ISO are developing a method of measuring the lowest accepted noise level for vehicles. This article first notes firm evidence that the noise difference between electric-driven and internal combustion engine (ICE) vehicles exists only at speeds below about 20 km/h; also that AVAS makes vehicles traveling at low speeds detectable from a longer distance, absent masking background noise. Some electric and hybrid cars on the market already have AVAS installed. The author explores the assumptions related to the problem in regard to traffic safety and the harmful effects of noise on humans. One statistical study from the United States seems to suggest that vehicles driven in electric mode cause relatively more accidents involving pedestrians than do ICE vehicles. However, multiple studies in the U.S., Japan and Europe leave this causal relationship unconfirmed. The author then shows that quiet vehicles, very hard to hear when approaching at low speeds, existed in urban traffic already many years before hybrid cars became common, and if quietness would create accidents this should have been apparent already earlier and not be something occurring only when hybrid and electric cars entered the market. A number of non-acoustical ways to alert pedestrians, not the least blind people, of quiet vehicles near them are discussed and suggested in the article. The article also describes the intensive work to explore the problem as well as to develop and specify AVAS systems that has been made from 2008 until now. The author argues that it would be more beneficial to human health and safety to reduce the maximum noise of vehicles rather than increasing the minimum noise of them. Consequently, the article ends with the recommendation to discontinue the work with AVAS, to limit rather than require the use of such systems, and instead focus on limitation of the worst masking noise emissions in urban areas.

A NEW PROBLEM IDENTIFIED

It has been suggested in later years that road vehicles, driven in electric mode, either hybrid electric vehicles (HEV) or all-electric vehicles (EV), are so quiet that they constitute a safety hazard for vulnerable road users (VRU) in traffic, especially to blind pedestrians. Following such fears, EVs and HEVs have sometimes in various documents and press articles been portrayed as "some kind of shark in the water" [1].

The "problem" seems to have been noted first in the United States in 2008 in meetings with the car industry and the US DoT following complaints by the National Federation of the Blind (NFB) against the growing trend for automobile manufacturers to design extremely quiet vehicles. Already in 2007, the SAE International started to work out a draft specification J2889-1 for the measurement of "minimum noise" of vehicles. Due to, among other things, pressure from the California Legislative Counsel in 2009 [2], in 2010 the Pedestrian Safety Enhancement Act was introduced in the US, and approved by the President in January 2011, requiring "means of alerting blind and other pedestrians of motor vehicle operation". This, in practice, requires the addition of artificial sound, also known as acoustic alerting systems, to EVs and HEVs [3].

The Japanese automotive industry, enjoying great commercial success with vehicles such as the Toyota Prius, seems to have reacted quickly to this potential threat to hybrid vehicles and already in 2009 had established own work towards Japanese standards for acoustic alerting systems for HEVs and EVs [4].

Internationally, a special informal group "Quiet Road Transport Vehicles (QRTV)" to deal with this "problem" was established within the UN/ECE/WP29/GRB in 2010 [5]. Japan had then already been working on guidelines for approaching vehicle alerting systems (AVAS), which later were essentially accepted also by the QRTV. Following the QRTV recommendations, the

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GRB (noise) group within the UN ECE [6] accepted them, which is now also part of a present proposal to the European Parliament regarding more stringent vehicle noise limits [7].

Concerning standardisation, the SAE International draft specification J2889-1 for the measurement of "minimum noise" of vehicles is at "Measurement of minimum noise emitted by road vehicles" was initiated also within the ISO; largely based on the SAE draft. The intention is to work out an international standard ISO 16254 for measurement of "minimum noise" of a vehicle.

Never before has the author in his 38 year career in transportation noise seen any subject being so quickly and non-critically accepted by the legislators, vehicle industry, university acoustics departments, acoustic consultancies and other research organisations; and as it appears almost in total agreement. This is in sharp contrast to when it comes to reducing vehicle noise. Vehicle noise standards in Europe and as specified by the UN ECE (accepted by several nations outside Europe) have been unchanged since 1996 and when now, after 16 years, somewhat lower limits are proposed, the industry and some MPs are hesitant [9]. On the other hand, the interest in adding sound to quiet vehicles is enormous.

The vehicles operating at exceptionally low noise levels are mostly called "quiet vehicles". The systems that are intended to save the world from the assumed pedestrian road massacres have been named Audible Vehicle Alerting Systems (AVAS), although some documents let the A stand for "Approaching" instead of "Audible".

In this paper, the author presents a review and discussion of the problem, based on his earlier conference papers [10, 11], but with focus on the development during 2011-2012. This article is an abridged version of a much longer article appearing in Noise/News International earlier in 2012 [12].

NOISE EMISSION PROPERTIES

The very low noise emission from electric motors means that power unit noise is almost totally absent for EVs and HEVs in electric mode, and that only tyre noise remains. The effect will be that at low vehicle speeds, approximately up to 20 km/h for cars and up to 50-70 km/h for heavy vehicles, the acoustic environment will improve substantially.

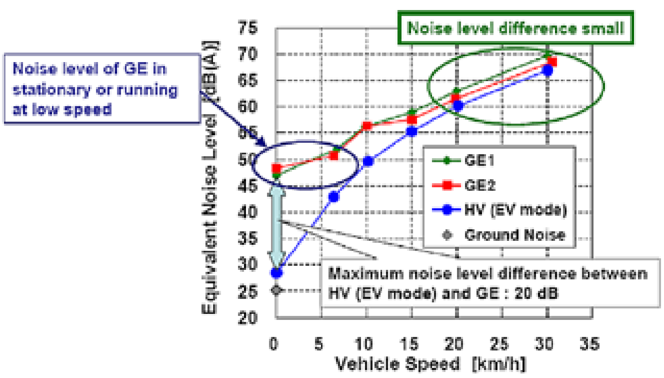

Figure 1. Equivalent A-weighted noise levels from an HEV car, compared to two ICE cars in Japan at low speeds [13]

This subject was the main issue in an earlier paper by the author [10]. It has been shown by many researchers, with consistent results, that it is only at speeds below approximately 20 km/h for cars when there is a significant difference in noise emission from ICE vehicles and vehicles driven in electric mode. The example shown in Figure 1 is typical of most test results.

TRAFFIC SAFETY ASPECTS

Traffic accidents due to lack of sound cues?

There is no doubt that acoustical cues are important in the interactions between road users of all kinds; and in particular among the visually impaired pedestrians. However, this does not mean that the lack of sound cues automatically lead to serious traffic accidents. There are many other things of importance and the lack of sound cues is associated only with very low speeds.

As yet, the lack of sound cues has never been identified in accident statistics as a major cause of accidents; at least as far as this author has found in literature searches and when asking colleagues specialised in traffic accident statistics. The only exception is a study presented by NHTSA, which concluded that [14]:

- *"This study found that HEVs have a higher incidence rate of pedestrian and bicyclist crashes than do ICE vehicles in certain vehicle maneuvers"*
- *"In situations where cars drive slowly (slowing down, stopping, backing up, parking maneuvers) hybrid cars were involved twice as much compared to conventional cars".*

When looking critically at these conclusions, one finds that the evidence of the conclusions is rather weak and that alternative causes for the findings are possible [10, 15]. An update of the NHTSA report when more data had been added became available in 2011, but the conclusions are essentially the same [16].

Other studies of statistics, in the Netherlands and Japan, have been unable to confirm this [15]. Another US study of deaths and accidents of blind people involving Toyota Prius (this car was especially studied as it dominated the US HEV park) gave a different picture [18]:

- *No deaths of legally blind pedestrians 2002-2006 involved a Prius or any other hybrid vehicle (out of an average of five legally blind pedestrians per year killed in US motor vehicle accidents)*
- *For all US pedestrian deaths, a Prius was no more likely to be involved in a pedestrian death than the average passenger vehicle.*

A study in the U.K. to explore the safety aspect of quiet vehicles was undertaken for vehicle accident statistics in the period 2005-2008 and showed that [18]:

- Relative to the number of registered vehicles, for the combined vehicle group of passenger cars, car-derived vans and vans < 3500 kg GVW, EV/HEV vehicles were 10 % less likely to be involved in a collision with a pedestrian than ICE vehicles

- Although the relative number of EV/HEV vehicles involved in accidents is smaller, proportionately more of these vehicles hit a pedestrian than ICE vehicles
- The reason for the latter observation may be that these accident rates reflect different usage patterns of EV/HEV vs ICE vehicles
- There were only two EV/HEV accidents (out of 497) involving a collision with a pedestrian who was disabled in some way (CF810) so it was not possible to make a judgment on the perceived risk to vision-impaired pedestrians.

It is indeed strange that such extensive activities as started on this subject are not based on robust traffic accident data. As so many pedestrian accidents happen, and we have now had quiet vehicles for a long time; if lack of sound were a problem, it should be relatively easy to identify this in current accident statistics.

The common procedure is that a problem is addressed and solved when the problem has been reliably identified. In this case, the safety problem seems to be more psychological than "real" and yet work is extremely intensive to solve the assumed problem. It seems that one has started in the "opposite end" to what is customary. If legislators and industry had acted with equal speed and efficiency when it comes to high noise emissions from vehicles, it would have been wonderful.

Special fears of the blind

Organisations such as the National Federation of the Blind (NFB) in USA [19] and the World Blind Union (WBU) have put pressure on the NHTSA and the QRTV in order to produce a solution to the problem that they identify as the lack of sound cues for this group of people who depend largely on sound cues. Some national organisations for the blind have also reacted. The WBU was rather critical to the guidelines for AVAS produced in 2011; the organisation thought that the guidelines are not sufficiently strong or far-going [20].

There is of course no doubt that the blind perceive their situation as worrying when the sound cues are becoming less audible. Yet, this does not necessarily lead to accidents. The situations where, the situations where and when the EVs and HEVs may pose a problem due to weak sound are relatively few and not with very serious effects as seen in relation to the entire traffic work.

We have had numerous electric driven vehicles for a very long time and we have had relatively quiet ICE vehicles, some of which are almost equally quiet as EVs, for at least 15 years. Thus, the reaction of the blind organisations should have come much earlier, and be a result of many more encounters than from electric drive, if lack of sound were a "real" accident problem.

However, at the time, it must be recognised that the problem is at least a psychological problem, since the blind see their possibilities to navigate safely as pedestrians in traffic relying on sound cues becoming reduced with the increasing number of EVs, HEVs and quiet ICE cars.

The author has searched very extensively on the web (in English and Swedish) for reports about accidents where blind pedestrians have been injured due to quietness of the car. No such case has been found to date (July 2012), whereas cases when pedestrians are killed due to distraction by using electronic devices in traffic (not involving quiet cars) are frequent.

Distraction due to use or misuse of sound

Especially for the blind people it must seem strange, if not stupid, that a large proportion of the seeing people deliberately choose to totally neglect sound cues from vehicles and from other pedestrians. More and more pedestrians and joggers, in many situations a majority of them, wear some kind of system producing music or speech in earphones, or they use cell phones, which effectively obscure sounds of approaching vehicles. Figure 2 shows an example. It may sometimes be impossible even to hear warning sounds as was, e.g., an observation in the study in [21].

A study conducted by three U.S. universities in 2005 indicated that 48 percent of pedestrians using a cell phone stepped into a crosswalk in what the researchers defined as "unsafe" condition, compared to 25 % not using cell phones [22].

These people have acceptable vision, but often they seem to fail concentration to the traffic as they talk or listen to whatever they use the electronic equipment for. The latest trend is to walk around and read and write text messages. It is not necessary to watch a pedestrian crosswalk many minutes until one will se a situation as the one in Figure 3. This may well be the unsafest behavior of all.

In the Australian state of New South Wales, this is already identified as a serious problem. In the last 12 months 26 Sydney pedestrians died after being hit by vehicles, twice as many as the year before. Experts say that both drivers and people crossing roads are distracted by texting or listening to technology like iPods and mobile phones [23]. "Last week an 18-year-old woman listening to music on an iPod was hit this week as she crossed a road in Marrickville, Sydney. Maybe if she wasn't listening to an IPod she would have heard the horn of a car, the screech of tyres or other people warning her", it was reported [23].

The New York State "distracted walking legislation", first proposed in 2007, would keep pedestrians who are in crosswalks from using handheld cell phones, Blueberries, MP3 players such as iPods, PDAs and similar attention-grabbing devices. The proposal restricts the law to cities with a population of at least 1 million, meaning only Manhattan [24]. However, as far as this author could find, it has not yet materialised into a law.

Figure 2. Woman crossing a street while listening to something in her earphones (Sydney, Australia) (photo by the author)

Since the number of people choosing to neglect sound cues, as described above, may outnumber the blind by several magnitudes, this author wonders if not this would be a far greater accident cause than the missing acoustical cues for the blind. And, sadly, this is a self-chosen situation among seeing pedestrians.

QUIET VEHICLES IN OUR SOCIETY

In a previous paper by this author on this subject [10], a number of vehicle types are described which have operated in traffic since many years ago and which produce no or very low propulsion noise (that list is supplemented here with newer findings by the author):

- Volvo and Scania supplied city busses for the Scandinavian market which met very stringent noise limits already in the early 1970's. These had encapsulated diesel engines at the very rear (Scania) or in the middle (Volvo) resulting in mainly tyre noise being heard towards the front in cruising or coasting conditions.
- Also modern CNG-driven busses with rear engine used in some Swedish cities, are very quiet when approaching and also when leaving a bus stop; propulsion noise can hardly be heard towards the front.
- From 1996, cars in Europe have had to meet the same noise level limits for type approval as today (74 dB(A)). The spread in results has been and is dramatic; some have measured only 68 dB(A). The more fancy variants of these cars are usually designed with quiet (ICE) engines since this gives an impression of a luxury car and is a selling argument. In many countries such luxury cars and limousines have been common for many decades. It is undisputable that such cars are so quiet that it may be hard to hear other than tyre/road noise from them when they approach a listener at cruising or coasting; even at very low speeds.
- Bicycles may not be so much used in most US or Australian cities but in some European cities (such as in the Netherlands, Denmark and Sweden) they are the dominating vehicle types for personal transportation. What you hear from them is weak tyre noise and maybe sometimes chain noise and a bell, but they run very close to pedestrians, even among them. Collisions pedestrian-bicyclist at 20-30 km/h may be fatal.
- Trackless trolley bus networks have existed or exist in e.g. Vancouver, San Francisco, Philadelphia, Zurich, Arnhem, Geneva, and three cities in Poland. In some cases such vehicle types have been used for several decades. They are essentially as quiet as a regular EV. See Figure 4. Note that tyre noise from heavy trucks and buses is sometimes no worse than from automobiles; depending on tyre equipment fitted [25].
- On the 16th Street Mall in Denver, CO, the main shopping and entertainment street, partly only open for pedestrians and busses, hybrid busses which are very quiet have been operating for approximately a decade. No accidents due to the quietness had been reported, according to the Denver transit company in 2010, but the busses have bells that may be activated by the driver when needed, and often is so when starting from a stop.

Increasingly popular, particularly in densely populated urban areas, electric two-wheel vehicles is a category that includes Segways, electric bicycles, electric kick scooters, electric motorcycles, and electric scooters. Walmart sells a range of electric scooters that can run at up to 25 km/h.

None of these vehicle types, busses and electric two-wheelers, which run in quiet mode especially close to pedestrians, have been considered in the work so far by QRTV, although they are not formally excluded, as all attention has been focused on cars.

It is concluded that pedestrians and bicyclists have been exposed to numerous quiet vehicles (where no or very little propulsion noise can be heard) for many years, even before the EV and HEV era; some very quiet vehicle types have been around for decades.

Therefore, the potential problem of missing sound cues is not new and occurring only recently with the modern EVs and HEVs. It has existed for a long time and yet significant accident types caused by the quietness of vehicles have not

Figure 3. Woman crossing a street while “texting” (Braga, Portugal) (photo by the author)

Figure 4. Trolley bus in Seattle, USA, in 2008 (photo by the author)

been reported, as far as this author has found. Also, blind people have of course been exposed to this situation for a long time.

CRITICAL DRIVING CONDITIONS

There is a wide consensus, supported by data in [10], that EVs and HEVs in general are significantly quieter than ICE (light) vehicles only at the following driving conditions:

- At speeds below approx. 20 km/h while ICE vehicles would be using the lowest gear. This hardly ever includes decelerating and stopping at a traffic light, since first gear would not normally be engaged, but it does include the first few seconds of starting from standstill. Whenever 2nd or higher gear is used, tyre and overall noise is approx. the same for EVs/HEVs as it is for ICE vehicles.
- When reversing; for example backing out from a parking lot.

It follows that if artificial sound is added with the aim to make EVs and HEVs equally recognisable in traffic as regular ICE vehicles, this sound shall be in operation only when driving 0-20 km/h and when reversing ("back-up").

It seems that the many proponents of adding extra sound to EVs and HEVs have not yet understood that the assumed safety problem would be potentially greater for trackless trolley busses and other heavy vehicles than for light vehicles, as the "loss" of sound in electric drive versus combustion is much bigger for the heavier vehicles; yet AVAS for these have not yet been proposed (?). If they will ever be proposed, the conditions would include cruising and coasting at speeds lower than 30-50 km/h and accelerations up to probably around 60 km/h, and this would normally mean a dramatically larger effect than for light vehicles, but it depends on how much of the "lost" sound that will be compensated for.

Note that at speeds lower than 20 km/h, stopping distance (reaction and braking times) is shorter than 6 m.

It follows that an accident involving a car-to-pedestrian collision would potentially happen more frequently for EV/HEVs without extra sound than for ICE vehicles only when the EV/HEV is starting or turning from standstill up to about 20 km/h. As stopping distance is less than 6 m in such cases, it means that the driver must be drunk, very distracted or extremely slow in detecting a (blind) pedestrian who is suddenly stepping out into the driving lane, normally displaying his white cane. One situation where the problem may be bigger is if the pedestrian stands hidden behind a large object as seen from the driver's position.

For such an accident to be more likely for EV/HEV without extra sound than for ICE vehicles, an additional condition is that the background noise must be low enough not to mask the ICE vehicle's propulsion noise at speeds lower than some 20 km/h. This requires background noise expressed as L_{Aeq} to be lower than approx. 60 dB (which follows from the normal noise levels emitted at such speeds). On a sidewalk in a city, this is rarely the case; one would rather have to be in a suburb or a semi-rural village [26].

Given the conditions mentioned in the previous two paragraphs, it should be obvious that in order for an accident to happen more frequently or more likely for EV/HEVs without extra sound than for similar ICE vehicles, quite rare conditions must coincide. This author believes that occasions outlined above happen, but only extremely rarely, which may explain why this has not yet been identified as a significant type of accident for EV/HEVs in particular.

ACCIDENTS AT LOW SPEED

Despite the quite unlikely case of a car-pedestrian collision at speeds below 20 km/h there will be cases when it happens. How serious would such collisions be? In an international literature review about fatality risk as a function of impact speed, it appeared that below 20 km/h the risk of a fatality is close to 0 % [27]; see Figure 5.

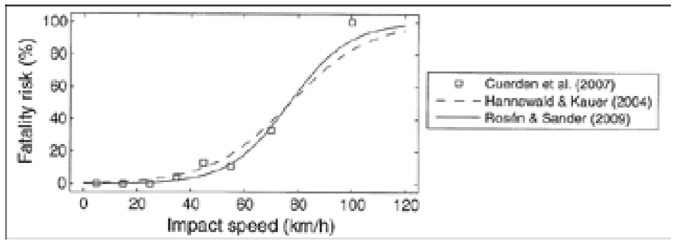

Figure 5. Fatality risk in pedestrian-to-vehicle collisions as a function of impact speed, as determined in three different studies [28]

When looking at risks of severe injury, at an impact speed of 20 km/h, the risk is < 5 %. If risks for a light injury as well as a severe injury are added, the risk is < 25 % [28].

Consequently, making EV and HEV vehicles equally noisy as ICE vehicles, at speeds below about 20 km/h, would have no measurable effect on fatalities and a very limited effect on severe injuries, when a collision happens.

PERCEPTION OF NOISE FROM VEHICLES

There have been numerous studies of how people perceive the noise from EV and HEV versus ICE vehicles. Generally, such studies have been made using a jury of observers who are asked to react when they can hear an approaching vehicle, while the distance to this vehicle is measured. Some studies have been made in laboratories; some have been made outdoors.

There is no point here in mentioning all the studies, since they give rather consistent results; only two of the better will be mentioned. In a German outdoor study using a jury of 12 visually impaired persons, at an approach speed of 10 km/h a Nissan Leaf was detected at distances of 4-7 m while a Lexus IS 250 was detected at 8-20 m (median values). At a speed of 20 km/h, Nissan Leaf was detected at approximately 20 m, while the Lexus was detected at 16-33 m [29]. Thus at 20 km/h there was no distinct difference between the EV and the ICE car; whereas at 10 km/h there was a significant difference. But remember that at 10 km/h (2.8 m/s), stopping distance (reaction time and braking) should be close to the closest detection distance for the EV, and a pedestrian should normally be able to step away from the approaching car before a collision occurs during the 1.5-2.5 s between detection and collision. Rather similar procedures were used in a Japanese study, except that they used more EVs and HEVs as test objects (including AVAS systems), and results were rather similar too [30].

Others have checked whether the use of AVAS will aid in early detection of vehicles running in electric mode. The answer is "yes", provided background noise is rather low and speeds are below 20 km/h [30, 31].

However, it has also been admitted that perception of quiet vehicles was poor already before the EVs and HEVs became common [32]. Thus, it is indeed a problem we have been facing for a long time and without concerns for safety until Americans started to react against the quietness of Japanese HEVs.

Consequently, AVAS will have a positive effect on the detection. But is it really needed and what are the consequences?

ADDING ARTIFICIAL SOUND

So, what is the problem with adding some extra sound in forward driving at speeds below 20 km/h and when reversing? The answer is, in summary, that it neutralises a substantial part of the noise reduction or annoyance reduction that may follow from the increasing use of EVs and HEVs.

To begin with reversing: this would hardly be a significant environmental nuisance if the sound is not of an intrusive kind (such as beeps, see below), since reversing is only a very short driving operation. However, the problem is that the driver may be tempted to rely on such sound and refrain from the discomfort of looking backwards carefully, and vision- and hearing-impaired people as well as young children may then be hit. Some kind of radar would be better.

The safety effect of AVAS may not be as expected. The existence of warning sounds will make some drivers feel more confident that they will not hit a pedestrian or bicyclist, and the attention to this potential danger might be lower than if they would be aware of the danger. Even if only relatively few drivers will react in this way it might be enough to offset the positive effect of the warning sound.

If heavy vehicles (trucks and busses) are exchanged from ICE types to EV/HEVs, there will be a substantial improvement in the acoustic environment since at low speeds tyre noise is much lower than propulsion noise. For example, a potential noise reduction of 1 to 8 dB has been measured when comparing an electric to a medium-sized European ICE truck [33]. If compared to the noisier North American trucks, the potential noise reduction is even more dramatic. This would significantly reduce the background noise level in urban areas, and also the maximum levels, and consequently reduce the masking effects (see below).

The conclusions above for light vehicles would, therefore, not hold for heavy EV/HEVs. If these are equipped with extra sounds, they will most probably compensate for a big part of the much lower propulsion noise of these vehicles at low speeds, and thus mean a substantial extra load to the acoustic environment, compared to if extra sound is not generated.

Exchanging ICE types of heavy vehicles with EV/HEV types (without extra sound) in urban settings with average speeds at 50 km/h or lower, will substantially improve the overall noise exposure in the area. It will mean a global breakthrough in noise control; especially in countries having noisy trucks and busses today. This would be much needed in view of the recent WHO report about serious health effects of noise [34]. A couple of decibels of reduced noise exposure may lead to more saved healthy "life-years" than the few injuries from accidents which may perhaps occur due to the loss of sound cues at low speeds for the EV/HEVs. Adding AVAS sound may then cost more lives than it saves.

IMPORTANCE OF MASKING NOISE

The problem of perception of EV/HEVs at speeds in the range of 5-20 km/h is that background noise is masking the tyre noise. If background noise can be reduced by (say) 6 dB, the perception of 6 dB lower (tyre) noise levels from EV/HEVs will be possible. Six dB corresponds to a doubling of distance for a point source, such as an approaching car, to give the same level as without the 6 dB reduction. That would also improve the health situation and reduce general noise annoyance in all areas of this type.

Therefore, it is strange that the focus of the worldwide work on this subject is only to add noise to the lower levels instead of reducing the higher levels of noise. This author thinks that it would be much better to reduce the higher noise levels, in order to reduce the masking effect, than to add extra noise to the low levels.

One way of achieving this is to encourage the introduction at a fairly large scale of heavy EV/HEVs in the urban areas; i.e. to use EV/HEV busses and distribution trucks which are run in electric mode preferably when they are close to pedestrians, bus stops and residential areas.

Another way is to reduce the maximum noise levels allowed at type approval for the vehicles that contribute the most to the general background noise; this would often but not always be caused by the heavy trucks and busses. The European Parliament is currently reviewing and modifying a proposal from the European Commission which will require reduced vehicle noise limits in a few years [35]. In USA such maximum limit changes for heavy vehicles could be especially effective, as the US heavy vehicle standards are approx. 6 dB weaker than corresponding ones in Europe and East Asia, and they have not been changed since the 1980's.

PRESENT STATUS OF QUIET VEHICLES RULEMAKING (JULY 2012)

Work has been and is going on in psychoacoustics at several places in the world to design suitable sounds. The subject quickly became a favorite subject in acoustical departments at many universities.

With the passage in the United States of the 2010 Pedestrian Safety Enhancement Act [3], and the endorsement of the President in January 2011, the US vehicle safety authority is required to issue a formal regulation on this topic no later than January 2014. Before that they should collect comments and explore the consequences in an Environmental Impact Assessment, which is probably what goes on at this moment. The Act requires EVs and HEVs to use AVAS, without the possibility to switch them off. No later than January 2015 the Secretary shall complete a study and report to Congress as to whether there exists a safety need to apply the motor vehicle safety standard also to conventional (ICE) motor vehicles.

The MLIT in Japan, following consultation with the industry and representatives of the blind, in 2010 issued guidelines for audible pedestrian warning systems, already in-force early in 2011 [36]. A summary of the Japanese guidelines appear in [12].

As reported above, the informal working group QRTV operated under the GRB and had nine meetings in 2010-2011. At the GRB, the subject has now advanced to a level when a proposal for a Global Technical Regulation (GTR) is available, as developed by the QRTV [6] which was discussed at the September 2012 meeting of GRB. This proposal is partly based on the previous Japanese guidelines that had already been submitted to GRB [36], but is substantially less specific in its performance specifications; yet contains quite exhaustive explanations and discussions.

To summarise the guidelines [6], the main issues are listed in Table 1. It is recommended that the UN GTR be written to apply, in principle, to all quiet vehicles regardless of their type of propulsion. However, due to limited performance information for other vehicles than EV/HEV it is recommended that initial regulatory specifications be limited to EVs and HEVs, operating in their electric mode.

In the proposal to the European Parliament from the Commission in 2011, it is stated that taking into account the discussions and the information provided in the UN ECE it is proposed to amend the current noise legislation with a new Annex harmonizing the performance of 'Approaching Vehicle Audible Systems' if they are fitted to a vehicle. The fitting of such systems, however, shall be voluntary and remain an option under the discretion of the vehicle manufacturers [35]. The current intention is just to harmonize the AVAS.

SOME AVAS IN USE

Most EV/HEV vehicles available on the market already have AVAS mounted; in some cases these are retrofit systems. Here are but a few notes about this.

For the Toyota Prius, the AVAS is an optional speaker setup in the front of the car that makes a “futuristic” humming sound equivalent to that of a standard petrol-driven vehicle. The cost is reported to be approx USD 170, excluding installation. The speaker is activated when the car starts up but can be turned off at the touch of a button if the driver so desires [37]. A synthesised electric motor sound is emitted at speeds up to 25 km/h and rises and falls in pitch based on the vehicle’s speed.

In the Nissan Leaf, the sound system includes a speaker under the hood and a synthesizer in the dash. The driver will be able to turn it off, but it comes on by default at start up. At

Table 1: The most essential recommendations from QRTV to be part of a Global Technical Regulation (GTR) (not a complete list, major items selected by the author)

The GTR shall currently be applicable to all EVs and HEVs in electric mode, but at some later stage also to quiet vehicles with other motion systems than electric. GTR audibility requirements shall address at least the following "at risk" issues: a. Vehicles approaching at right angles to the direction of pedestrians intended movement b. Vehicles initiating movement from a driveway or in a parking lot c. Vehicle travelling at low speed in quiet areas. A specific alerting signal sound pressure level is not recommended. A specific crossover speed, at which the system shall be switched on and off is not specified. The alerting system should be automatically activated when the vehicle slows to or below the crossover speed. The alerting system will automatically deactivate at vehicle speeds in excess of the crossover speed. It is recommended that 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 and 20 km/h. It is recommended that the alerting system is operated during temporary stops of the vehicle. 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.	It is recommended that the acoustic performance requirements give careful attention to their potential adverse environmental impact, particularly with respect to loudness and frequency content. The development of the AVAS shall give consideration to the overall community noise impact. The following operating frequency specifications should be considered: a. Frequency range of audible signal: between 50 Hz and 5 kHz b. The frequency content should include at least two 1/3 octave bands within that range c. In case the AVAS produces only two frequencies, these should differ by ≥15 % d. An alerting signal’s mid-frequencies (0.5-2 kHz), higher frequencies (2-5 kHz) support audibility and directional cues. Low frequencies (< 500 Hz) support earlier detection but in an urban environment are at risk of being masked. The following sounds should be prohibited: a. Siren, horn, chime, bell and emergency vehicle sounds b. Alarm sounds e.g. fire, theft, smoke alarms c. Intermittent sound d. Melodious sounds, animal and insect sounds e. Sounds that confuse the identification of a vehicle and/or its operation (e.g. acceleration, deceleration etc.)

speeds above 30 km/h, the system turns off. The sound is a sine wave sweeping from 2.5 kHz to 600 Hz. At start-up, the sound comes on at its loudest to warn the visually impaired and other pedestrians that a car is about to enter their vicinity. When the Leaf is reversing, the system produces an intermittent “beeping” sound, similar to the back-up warning systems on trucks [39].

The Chevrolet Volt EV has an AVAS that GM calls “pedestrian friendly alert” or “courtesy signal”, which is manually activated by pushing a button on the blinker control stick. It is reported to sound like a soft horn [39].

NON-ACOUSTICAL SOLUTIONS

The author thinks that the acoustic solution in the form of a soft horn applied by GM Volt could be a reasonable compromise, to be applied only when the driver thinks that there is a danger ahead (but it must not be abused by telling pedestrians “keep out of the road, here I come”). Apart from this, non-acoustical solutions are preferred.

In the author's previous paper, several non-acoustical systems for alerting pedestrians or drivers about a potential risk of collision are described [10]. This is not repeated here; nevertheless, a few potential solutions will be mentioned.

Professor Jim Kutsch, President of The Seeing Eye, Inc. (http://www.seeingeye.org/), blind himself (as his family) and an expert on seeing-eye dogs, has expressed in an interview that “We’ve added hybrid cars to our training program. You can’t hear them when they are at a full stop. We now teach dogs that a car is a car, whether it’s making a noise or not” [40].

One may also consider making the white cane sticks more hi-tech with special warning indications, such as a blinking lamp when the cane is pointed straight out or when activated by the user.

Several modern cars are already equipped with Autonomous Emergency Braking (AEB) systems; often in combination with pedestrian detection systems. EuroNCAP describes AEB Pedestrian systems which can detect pedestrians and other vulnerable road users like cyclists [41]. They invariably employ a camera combined with a radar – something called sensor fusion. New technologies are appearing on the market that use infrared which can also operate in very low light conditions. EuroNCAP lists two car manufacturers who have such systems fitted: Lexus and Volvo, where Volvo has it as standard equipment on most of its new models [41].

The latest BMW 3-Series has been commended for its pedestrian protection measures following a crash test in Europe, while Volvo has developed an airbag designed to save pedestrians [42]. Volvo's newest pedestrian detection system with AEB is presented in [43]; reading “If the driver does not react to the warning and a collision is imminent, full braking power is automatically applied”.

TRANSFER OF RESPONSIBILITY

The traditional view is that it is the driver who has the main responsibility to avoid a collision with a pedestrian; probably also with a bicyclist. This is natural since the driver has a reasonable protection against injuries in his vehicle while the former are totally unprotected.

A driver being aware of that his vehicle emits dedicated sound that has the expressed intention to inform pedestrians that the vehicle is coming may be tempted to think that this moves some of the responsibility from him over to the pedestrian. This may create a situation which is even worse than with no warning signal, where it is obvious that the driver has the full responsibility. Especially, a vehicle backing out of a parking lot, where it is inconvenient and uncomfortable to look behind, may be an example of this.

CONCLUSIONS

The occurrence of electric driven vehicles on the market promises a unique breakthrough in reduction of urban community noise. The very low noise emission from electric motors means that power unit noise is almost totally absent for such vehicles and that only tyre noise remains. The effect will be that at low vehicle speeds (approximately up to 20 km/h for cars and up to 50-70 km/h for heavy vehicles) the acoustic environment will improve substantially.

However, the supposed problem of quietness of vehicles operating in electric mode has resulted in concerted actions by a number of organisations at a pace which is unique within the subject of traffic noise; the justification for which is questionable. Firstly, the actions have not been based on robust evidence of serious traffic accidents; secondly, the problem (if any) seems to be potentially greater for other types of vehicles than for the cars which have been in focus so far and, thirdly, correspondingly quiet vehicles have been used for decades already without noticing a specific accident problem due to the quietness.

It is suggested in this article that the quietness of cars driven in electric mode may not be a major safety problem. There is simply no robust and consistent traffic accident data that says that quietness of vehicles is a significant cause of accidents.

Nevertheless, for the blind community the quietness of vehicles driven in electric mode must be recognised as a psychological problem, making the blind feel unsafe and experiencing more serious restrictions when the sound cues have been reduced. However, it must also be noted that this situation has existed for a long time due to several types of quiet vehicles operating in our traffic, and did not occur only due to HEVs becoming common on the market.

It is suggested in the article that reducing maximum noise level limits is a much better way for promoting health and safety than adding extra sound to the quietest vehicles. The problem is not that vehicles are getting too quiet; the problem is that background noise masks the noise of the quiet vehicles.

The addition of AVAS to EVs and HEVs, or even to quiet ICE cars, may be directly counter-productive, as it is likely to provide only a marginal safety improvement (if any at all), which may easily be balanced-out by an increased feeling of safety for both pedestrians and drivers, transformation from responsible driving to a belief in AVAS, as well as the impaired health issues due to missing an opportunity to efficiently reduce noise exposure.

The perceived unsafety of the blind due to vehicle quietness should be addressed primarily by reducing the masking of sound cues by noisy vehicles, which would have other substantial benefits, and by other measures than the acoustical. Training of seeing-eye dogs to care about vehicles in the same way irrespective of sound level may be one; another one may be the collision-preventing systems rapidly being introduced on the market.

When it comes to sound cues in traffic, the most effective measures for accident prevention would probably be to reduce distraction of pedestrians and bicyclists by limiting the use of portable audio systems and cell phone talking as well as texting in traffic environments.

The author suggests discontinuing the work with AVAS, limiting rather than requiring the use of such systems, and instead focusing on limitation of the worst masking noise emissions in urban areas. It may not be as exciting and fashionable to work with noise reduction as with sound production, but it would have more benefits to the safety and health of society.

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NSW Road Noise Policy: Application Notes

The *NSW Road Noise Policy* (RNP) was published by the former NSW Department of Environment, Climate Change and Water and replaced the *Environmental Criteria for Road Traffic Noise* from 1 July 2011. The RNP contains strategies to address the issue of road traffic noise from existing roads, new road projects, road redevelopment projects and traffic-generating developments. The policy defines criteria to be used when assessing the impact of road traffic noise.

The NSW Environment Protection Authority (EPA) has been asked to clarify the intent of some sections of the policy and has published Application Notes to explain the intended meaning. Application Notes prepared to date cover:

- Relative increase criteria
- Applying the assessment criteria to additional traffic on existing roads generated by land use developments.

The Application Notes can be accessed at http://www.environment.nsw.gov.au/noise/roadnoiseappnotes.htm