EARPA Position Paper

Noise, Vibration and Harshness Research Needs, Priorities & Challenges for Road Transport in Horizon2020

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About EARPA

Founded in 2002, EARPA is the association of automotive R&D organisations. It brings together the most prominent independent R&D providers in the automotive sector throughout Europe. At present its membership numbers 48, ranging from large and small commercial organisations to national institutes and universities.

Noise, Vibration and Harshness (NVH): both deadly pollutant and desired customer attribute

Noise, Vibration and Harshness[1] as a field of vehicle technology has two different scopes:

- firstly, interior NVH aspects, which include the improvement of the interior vibro-acoustic environment for the drivers and passengers and the protection against occupational health issues for the professional vehicle driver and,
- secondly, exterior NVH aspects aimed at the control and reduction of environmental noise emission by road vehicles but aiming also at a sufficient acoustic noticeability of electric vehicles (EV) at low speeds for the safety of vulnerable road users.

The objectives within the first scope are **determined by market needs and customer expectations** as NVH directly addresses two out of five human senses (hearing and feeling). In view of the new challenges of CO_2 reduction with the future propulsion systems and deployment of novel, lightweight materials, it is important to maintain the current noise and vibration levels under the new boundary conditions imposed by the alternative drives (see for instance figure 1 for NVH impact of electrified powered vehicles) in order to ensure the competitiveness of the European automotive industry. The second scope is mostly **determined by the social concern about environmental issues**. Environmental noise emission is an attribute of the vehicle that cannot be perceived and assessed by the vehicle driver alone and is, therefore, governed not only by market needs but also, and even mostly, by governmental and EU regulations.

In April 2014, the European Parliament approved a law to reduce new car noise-levels via a three-phase plan starting in 2016[2]. A new pass-by noise regulation ECE-R51.03 is proposed which will highly impact the vehicle development process. More tests, more test iterations and a more detailed analysis of test results will be required to comply with the new regulation. Firstly, the new ECE-R51.03 is based on a revision of the ISO 362 standard. The revised standard requires more tests in different conditions. The execution of the tests themselves will also become more complex. For instance, more precise driver's guidance and instructions will become necessary. Secondly, and

[1] Definition of Harshness according to FORD NVH principles and diagnosis student reference book: Harshness is a concern that is related to the customer's perception or expectation of a vehicle's ability to absorb vibrations caused by road imperfections

[2] Commission welcomes Parliament vote on decreasing vehicle noise, Press Release, http://europa.eu/rapid/press-release_IP-14-363_en.htm, April 2nd, 2014

most importantly, the new European directive will force car manufacturers to further reduce the pass-by noise levels of their vehicles. Most cars will need to achieve a reduction of more than 6 dBA of their pass-by noise levels in the third phase of the directive implementation (i.e. from July 2024) which is a huge challenge.

According to the communication "Greening Transport"[3], 32% of the EU's population is affected by noise. With noise having become the second most deadly environmental pollutant in Europe[4], the World Health Organization (WHO)[5] estimates 1.8% of heart attacks in high-income European countries to be attributed to a traffic sound level of more than 60 dB, making rail and road noise the origin of 50,000 fatal heart attacks each year in Europe and 200,000 cases of cardiovascular disease[6]. Furthermore, it is estimated that €85bn of healthcare spending could be saved yearly by reducing noise pollution, e.g. 15% of lost workdays are caused by noise[7].

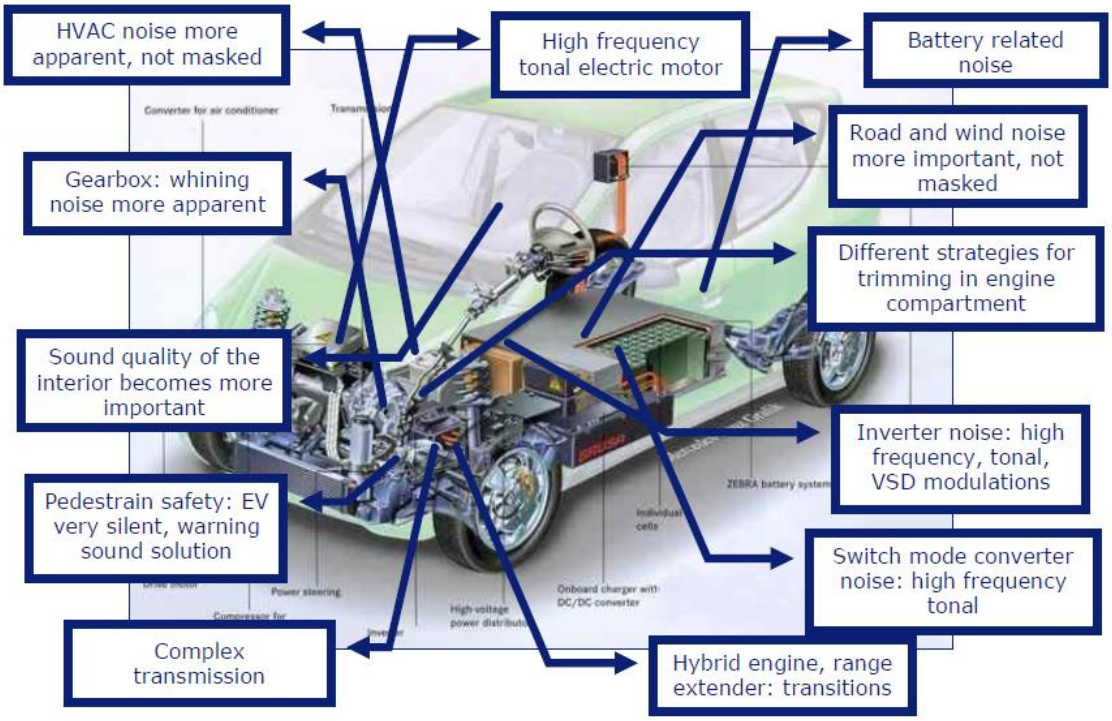

Figure 1: ***The increasing complexity of NVH in HEV (summary of SIA papers [8])***

NVH Research Needs, Priorities & Challenges

Recent developments in next generation combustion engines, alternative drives as well as in new materials and technologies for lightweight design offer a huge potential of vehicle emission reduction (both noise and CO2). However, the electrification and lightweighting of vehicles causes a radical change in vehicle NVH. Decades of experience in designing brand-specific sound, based on noise and vibrations generated by combustion engines in conventional vehicle layouts, cannot be simply transferred to vehicles including new breakthrough material technologies and/or novel powertrains[9].

[3] SEC(2208) 2206: Commission Staff Working Document on Greening Transport, Brussels, 8.7.2008.

[4] M. Paviotti (2013), EU Policy Officer, Keynote lecture at Internoise2013, Innsbruck, The EU noise policy after the second round of noise maps and action plans

[5] WHO (2011): Burden of disease from environmental noise - Quantification of healthy life years lost in Europe

[6] T&E (2008): Can you hear us? Why it is finally time for the EU to tackle the problem of noise from road and rail traffic

[7] The Parliament Magazine's Research Review, June 2013 – Noise Pollution in transport

[8] SIA International Congress on NVH of Hybrid and Electric Vehicles, Feb. 4, 2010, Saint-Ouen, France

[9] Eisele G., et al., (2010), Electric Vehicle Sound Design - Just Wishful Thinking?, AAC Conference, Aachen, Germany

The EARPA Task Force NVH[10] brings together experts in the field of automotive NVH from European research organisations working on the next generation of NVH technologies: innovations in the fields of noise and vibration analysis techniques, measurement approaches, simulation methodologies, subjective assessment, infrastructure interaction, material science, product design, etc. Together, these experts drafted the **EARPA vision on NVH Research Needs, Priorities and Challenges** discussed below:

1. **Test, simulation and development tools for NVH design, analysis and optimization** of vehicle components/systems and their integration. Whereas most current NVH tools are based on conventional Internal Combustion Engine (ICE) powered vehicle behaviour, nowadays alternatively driven (often electrified, electronically controlled) vehicles exhibit a completely different behaviour with respect to noise and vibration issues, as do new two- and other multi-wheel vehicle types. As time is lacking to build up experience on the ground (it has taken over 50 years to develop this for ICE NVH), an urgent need for new NVH tools is arising, especially for novel NVH source components such as electro-motors, range extenders, gears and power electronics. Breakthrough innovations developed over the past years in (academic) research environments hold huge potential to completely change the analysis/design/optimization of the NVH behaviour of tomorrow's vehicle. Hybrid Numerical-Experimental approaches (such as virtual sensing) and Design approaches coming over from software-design (such as Model-Based System Engineering (MBSE)) provide the inspiration and the building blocks in upgrading NVH from a performance attributed – often assessed late in the design process when first prototypes become available – to a true design attributed included frontloaded to early design stages.
2. **Material technologies for both noise and vibration mitigation** try to reduce (annihilate) the impact of noise and vibration sources from the vehicle and its components. Recent advances in manufacturing, material science, electronics and control engineering pave the way towards the development and deployment of a next generation of smart materials solutions: passive solutions such as new metamaterial concepts hold potential for developing very NVH performing, yet low-weight structural components; advances in both mechatronics (actuator and sensor design) and control engineering make actively controlled materials reality; new physical insights and supporting CAD/CAE tools allow including final product noise and vibration behaviour already in conceptual design phases; etc.
3. **Symbiotic technologies for NVH adaptation** hold great potential in improving the NVH behaviour of full vehicles and individual components. With the growing technological complexity of modern systems, also the availability of inherently present (electronic) intelligence follows. Resulting in vehicles with embedded sensors, actuators, control units, CPUs, etc., typically not for NVH purposes, but for safety, performance, comfort and entertainment. By exploiting the already available technologies in a symbiotic manner, the NVH behaviour can be adapted, opening up a completely new range of applications: exploiting (distributed) powertrain components as inherent NVH sensors/actuators for reducing noise and torsional vibration levels without adding additional systems nor material; optimizing (semi-)autonomous and assisted driving scenarios to positively influence overall urban noise levels; deploying existing entertainment systems in combination with distributed vehicle vibration sources (such actuators and switches) to optimize the interior NVH experience for the driver and passengers; etc.
4. **Customer and road user NVH perception** is still mostly assessed based on engineering biased dB(A)-based metrics, although many have shown that these do not suffice to fully capture subjective NVH perception. Novel comprehensive cost functions are needed to include not only the 'engineering' levels of noise and vibration, but also aspects from human and environment. Such new cost functions will allow for more general road noise assessment and feed also new developments in Vulnerable Road User (VRU) protection for quiet vehicles.

[10] http://www.earpa.eu/earpa/13/3/noise__vibration__harshness.html

5. **Future infrastructure developments** have a major influence on environmental noise evolution. The idea of just reduction of urban noise is now in conflict with safety aspects associated to VRU navigation in cities. Thus a new concept of urban noise design should be considered based on the idea that future cities can have noise maps that are created by managing quiet vehicles with directive warning signals for pedestrians together with generalised use of directive acoustic sources on building façades and other urban furniture sources to generate low, but detectable sound levels suitable for pedestrian navigation safety and urban sound-scape definition. Outside urban areas, technologies are needed to further reduce noise disturbance by tackling both the source (e.g. sustainable low-noise pavements, low-noise tyres with low rolling resistance yet adequate grip) and the transfer path (advanced infrastructure solutions – e.g. intelligent/active/unobtrusive noise barriers).

Key research needs, priorities and challenges

Concerning the safeguarding of both customer and environmental aspects of automotive NVH, EARPA stresses the importance of further research and development on the following elements:

1. Test, simulation and development tools for NVH design, analysis and optimization: virtual sensors, MBSE approaches, multi-attribute design
2. Material technologies for both noise and vibration mitigation: metamaterials, active materials, linking CAD/CAE for early NVH assessment
3. Symbiotic technologies for NVH adaptation: exploiting sensor/actuator systems to reduce NVH disturbances, active systems, deploying entertainment systems for NVH improvement
4. Customer and road user NVH perception: new comprehensive cost functions
5. Future infrastructure developments: smart infrastructure, tackling at the source and the transfer path

Expected impact

Looking at Horizon 2020 Grand Societal Challenges, the innovative, breakthrough research priorities discussed in the previous section will impact directly within the challenge of providing **smart, green and integrated transport** by:

- Reducing traffic noise pollution, as such saving thousands of lives every year (see also page 2).
- Assisting the process towards the development of lighter, more energy efficient transport vehicles, maintaining both interior and exterior NVH behaviour (fuel economy, comfort and safety).
- Safeguarding European vehicle industry's competitive advantage in human-centred, ecologic, economic and safe products and developing new NVH technology products with high intrinsic added-value.
- Further reducing development time and costs adopting a model based design paradigm and bringing NVH issues to early design stages.
- Assisting in the development of new, green materials with enhanced functional and ecological performance.
- Providing tools and a baseline for further noise legislation for electrified vehicles.
- Increasing customer acceptation and hence speeding up the introduction of new vehicle types.
- Assisting cities and governments in better assessment of noise issues for improved planning and city and infrastructure development and implementation with new standard tools.

Relation to other roadmaps

Given the strong involvement of EARPA Task Force NVH members in other Task Forces (such as especially in the groups on *Materials, Design and Production* and *Modelling and Simulation*), this NVH Position Paper is fully aligned with needs, priorities and challenges posed in the other EARPA position documents. Furthermore, additional alignment has been done with roadmap and policy documents of stakeholder organisations such as ERTRAC, EGVIA, CLEPA and EUCAR as best as possible, since most of the recent documents are mainly focussed on CO_2 and fuel consumption, but do hardly consider associated NVH topics. This even further raises the importance of this EARPA NVH Position Paper as one of the few comprehensive NVH documents boosting again the public and stakeholders' awareness of noise and vibration issues.

What makes this EARPA NVH Position Paper additionally unique, is that it is focussing for most at the lower to middle level TRL's leveraging on the DNA of the involved research organisations with both academic and industry background. This results in a science and technology driven Position Paper highlighting the Research Needs, Priorities & Challenges for Road Transport in Horizon2020 and beyond, combining high impact potential, as it links with the priorities challenges posed in industry stakeholders roadmaps and position documents, with novel low TRL technology as genesis for truly innovative research actions.

Additionally, as many of the Task Force NVH members are also active in related sectors, such as machine design and other transport modi (rail, air and water), NVH technologies and expertise from those sectors are feeding into this road transport Position Paper allowing to bootstrap on and maximally benefit from innovations in other sectors as well.

Conclusion

With transportation noise being the second most deadly environmental pollutant in Europe and at the same time one of the driving market factors, engineering for future mobility must be inspired by ecology, economy and health to enable green and silent vehicles for a competitive European industry.

This Position Paper document introduces the expert vision of EARPA's Task Force NVH on Research Needs, Priorities & Challenges for Road Transport for Horizon2020 and beyond. Together with its members and expert specialists from other stakeholders involved, EARPA will continuously work on bringing vision to life. Furthermore, special focus will be given towards the training of Europe's next generation of automotive engineers to leverage on the newly developed technologies in helping to maintain Europe's leading position in NVH technology research and innovation.

For further information, please contact our contact persons of the Task Force NVH:

Contact

TF *NVH* Chairman

Bert Pluymers

E: bert.pluymers@kuleuven.be

T: +32 16 32 25 29

TF *NVH* Secretary

Manfred Haider

E: manfred.haider@ait.ac.at

T: +43 50 550 6256