

LIFE E-VIA: Electric Vehicle Noise Control by Assessment and Optimisation of Tyre/Road Interaction

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Introduction

Data collected by the European Environment Agency (EEA) shows that more than 100 million EU citizens are affected by noise levels negatively impacting human well-being. Although noise associated with rail and air traffic cannot be ignored, a significant contributor to these high noise levels is the road transportation sector. According to a World Health Organization (WHO) report [1] ca. 50 % of the EU population are habitually subjected to road traffic noise levels above 53 dBA (the WHO guideline value for outdoor sound levels [2]), and roughly 10 % to levels exceeding 65 dBA, which for example have shown to lead to a 20 % to 40 % increased risk for cardiovascular diseases [3]. Consequently, the WHO states that “at least one million healthy life years are lost every year from traffic-related noise in the western part of Europe” [1].

Road traffic noise comprises of the vehicle’s power train noise, rolling noise and aerodynamic noise. Traditionally, rolling noise is the primary noise source for typical internal combustion engine vehicles (ICEV) at common urban driving speeds of roughly 40 km/h to 100 km/h [4]. Below these speeds powertrain noise dominates, and above aerodynamic noise. For electric vehicles (EV) tyre/road noise starts to dominate the overall exterior noise of the vehicle at even lower speeds because of the lower engine noise. Still, at slower speeds EVs exterior noise levels are lower than for ICEVs which is why electric mobility has been identified as an important way to reduce urban noise levels. As an additional benefit also (local) emissions of CO₂ and other air pollutants are reduced.

One of the key focus areas of the LIFE E-VIA project is road traffic noise reduction in densely populated urban areas. Noise mitigation measures are usually most efficient when addressing the problem directly at the source. In terms of the remaining EV traffic noise this means that measures aimed at providing noise optimized road surfaces and tyres have a high noise mitigation potential. Thus, it is one of E-VIA’s objectives to develop noise optimized roads and tyres for future electric mobility traffic scenarios.

For the optimization of a low noise EV tyre different boundary conditions than for an ICEV application need to be considered. For EVs the relative contribution of the tyre noise to the overall vehicle noise is considerably increased because of the drastically lower drivetrain noise. Because of the higher drivetrain efficiency of electrical engines also the tyre rolling resistance has a relatively higher contribution to the energy consumption of an EV than for an ICE vehicle.

Depending on how the electric energy used for charging the EV is created, this also can have a significant contribution to the emission of CO₂ and other air pollutants. More importantly, the tyre rolling resistance has a large impact on the achievable mileage of an EV. A large mileage, in turn, is crucial for the public acceptance of EVs as means of transportation. Therefore, a low noise, low rolling resistance tyre is considerably more beneficial for EVs than for comparable ICE vehicles.

From a purely acoustical point of view, tyre requirements for EV applications also change because typically EVs are heavier than comparable ICEVs and have higher available torque values in a wide range of RPMs. Both increased tyre load, and increased tyre torque are known to lead to higher tyre/road noise [4].

To sum up, the LIFE E-VIA project focuses on noise pollution due to road traffic in a future urban environment in which electric and hybrid vehicles will be a consistent portion of the traffic flow. A major objective will be the development of a holistic low noise tyre and a low noise road surface, both optimized for the special requirements of EVs. Within the project a final version of the pavement will later be used for repaving a section of a road in Florence, Italy. This pilot area will be the centre of further accompanying activities like guideline development, local dissemination and information campaigns, a soundscape analysis, and life cycle (cost) analysis. Finally, the measurement data collected during the runtime of the project is intended to be used to update the CNOSSOS model (Directive 996/2015/EC [5]) for new traffic spectra and new electric- or hybrid-powered vehicles.

Project objectives

The project objectives are:

1. To reduce noise for roads inside very populated urban areas by implementing mitigation measures based on noise optimized road surfaces and tyres for EV applications. The tyres will be developed with a holistic view which assures that relevant, non-noise related performance requirements like safety, rolling resistance, or grip are met.
2. To estimate the mitigation efficiency and potential of tyres, pavements, and traffic conditions (e.g. noise spectra, speeds, traffic flow) at a higher, comprehensive level. For this, Life Cycle Analysis (LCA) and Life Cycle Cost Analysis (LCCA) will be performed to demonstrate the individual and

- synergistic efficiency of pavement surfaces, tyres, and vehicles.
3. To contribute to effective EU legislation implementation (EU Directives 2002/49/EC [6] and 2015/996/EC [5]) by providing special EV rolling noise coefficients for the Common Noise Assessment Method (CNOSSOS-EU).
 4. To contribute to (Italian) regional and national noise policies, by issuing guidelines for the usage and application of the methodologies developed within the project. The project is supported by the Regional Environmental Agency (ARPAT) of the Tuscany Region, which will see to that these guidelines are applied within its area of jurisdiction. Further candidates for guideline application are the Calabria Region and the City of Reggio Calabria.
 5. To raise people's awareness for noise pollution and possible related health effects. The opportunities provided by EVs will be explained by specific dissemination and promotional events. People's perception regarding noise will be evaluated by soundscape methodology and by involving them in noise data acquisition.
 6. To demonstrate and promote sustainable (electric) road transport mobility by reducing noise emissions by 5 dBA at a receiver's roadside façade while also aiming to achieve a 21 % reduction in CO₂ emissions (based on available data for the current Italian traffic mix).
 7. To encourage low-noise pavement implementation in further EU and extra-EU scenarios, in particular by demonstrating durability and sustainability through in-depth LCA and LCCA.

Pilot character of the project

The LIFE E-VIA project presents all the characteristic of a pilot project. Within a coupled approach a low noise pavement and a holistic low noise tyre will be developed which consider the specific boundary conditions imposed by electric and hybrid cars. Compared to standard roads and tyres, performance and durability shall be preserved while also maintaining cost-neutrality.

To reduce the health effects caused by road traffic noise, the WHO guidelines [1] strongly recommend that policymakers implement suitable measures to reduce noise exposure for populations subjected to L_{den} and L_{night} values which are above the guideline limits. For specific interventions it is recommended to reduce noise foremost by measures affecting the source. Thus, effective mitigation measures, especially for future electrically dominated traffic scenarios, include choosing appropriate low-noise tyres and road surfaces, or reductions in traffic flow or truck traffic.

Another example for source-based mitigation measures is the reduced powertrain noise from EVs, which consequently mainly emit tyre/road noise at urban speeds. Consequently, for EV applications there is a widespread necessity to test,

investigate, and optimize the interaction between tyres and asphalt under EV conditions. Previous research projects on this topic (e.g. FOREVER [7]) were focused on suburban and/or national roads or are rather dated. Projects like LIFE NEREiDE [8] or PERSUADE [9] focus mainly on road surface optimization with little consideration for tyre or powertrain-type influence.

To maximise synergy effects, networking activities and knowledge transfer are carried out with other road noise focused research projects, in particular:

- LIFE NEREIDE about the mixture design for low noise surfaces, and innovative monitoring methodologies,
- FOREVER about electric vehicle noise emission and
- LEO [10] and COMPETT [11] about CPX measurements of EVs.

Although project results are expected to be obtained mainly based on techniques and methodologies already applied in other contexts, the pilot characteristic of the LIFE E-VIA project lies in the holistic, all-encompassing, and multi-faceted approach to road traffic noise optimisation for EVs.

Moreover, in EU Directive 2015/996 [5] five new vehicle subdivisions have been introduced for common noise assessment methods. In particular, the fifth category has been provided for any new vehicles that will be developed in the future and which may have such differences in terms of noise emissions as to justify the definition of an additional category. Examples for this which are specifically mentioned in EU Directive 2015/996 are electric or hybrid vehicles. Work towards populating this fifth category with suitable data for EV noise emission modelling in CNOSSOS-EU has been carried out by some projects (e.g. FOREVER). However, these studies need to be carefully evaluated, and potentially be improved, before a future implementation in CNOSSOS-EU seems advisable. In this regard the extensive data on tyre/road noise for EVs which will be obtained during LIFE E-VIA can be an important contribution to the validation and/or implementation of EV noise emission modelling in CNOSSOS-EU.

Scale, output, and ease-of-replicability

The LIFE E-VIA project will assess the efficiency of the mitigation measures in terms of LCA, LCCA, noise efficiency, and soundscape approaches.

The project also aims at testing the combined benefit of electric cars for noise and air pollution in the urban context. Because measures pertaining to the actual design of the low noise pavement and the corresponding testing activities have been carried out in the laboratory and a designated test track in Nantes, France, a pilot area in Florence has in addition also been specifically selected. This allows an evaluation of the road surface, and the optimized tyres, under consideration of the local factors (climate, specific context, characteristics) of an urban environment. Florence was in part chosen because it is one of the most progressive Italian cities with

respect to electric mobility: it was the first Italian city to install charging stations for electric cars and motorcycles; the first with special licenses for taxi drivers working with electric cars only; and the first to offer car sharing of electric vans. Additionally, numerous incentives are provided at the municipal level for the purchase of electric vehicles. Accordingly, the use of electric vehicles is constantly growing (there are currently about 2000 EVs in circulation), along with an increase in available charging stations (currently about 200).

Expected results and outputs

The expected outcomes of the LIFE E-VIA project are as follows:

1. Reduction of road traffic noise levels from EVs and ICEVs with pavements and tyres having life cycle costs comparable to those of standard road surfaces and tyres. Regarding the reduction of CPX noise levels at 50 km/h a target L_{CPX} below 87 dBA should be achieved for the optimized prototype surface. This is with respect to the *comprehensive* criterion for low noise pavements of the EUGPPC. This implies a higher noise reduction at the source (at least 3 dBA to 4 dBA) than a standard state-of-the-art, newly laid dense-graded pavement would offer (at least 2 dBA). Regarding L_{den} and L_{night} , the proposed mitigation action should lead to a reduction of at least 5 dBA at the receiver's roadside façade. This will be achieved by a combination of noise optimized road surfaces and tyres designed specifically for EV applications.
2. At the end of the project about 2000 people living in and close to the pilot area are going to be positively affected by the road traffic noise reductions mentioned in point 1. Observed results and effects which have been measured during the project, will, as much as possible, be modelled for the estimation in future applications. A quantification of health benefits in terms of a reduction in disability-adjusted-life-years (DALY) will be provided.
3. CO₂ reduction from an increased use of electric cars in the mitigated area. Expected are 29 tons CO₂ reduction per year. For this, specific actions are intended to promote electric mobility and raise awareness for noise and other environmental issues associated with road traffic.

Further tangible outputs of the LIFE EVIA project will be:

1. A new emission model for electric cars with the aim of supporting the implementation of EU legislation. Rolling noise coefficients for the CNOSSOS-EU prediction model will be provided in order to evaluate their contribution within strategic noise mapping according to Directive 2002/49/EC.
2. The development of a new testing framework to design road surfaces for mixed fleets with increasing participation of electric and hybrid vehicles.

3. An annual electric car festival in Florence to promote and support electric and sustainable mobility.

Technical solutions

Tires

Within the LIFE E-Via project EV tyres will be developed which are designed to give an optimal holistic relation between low exterior noise and other key performances such as safety, rolling resistance, and wear. This holistic approach is needed because the final tyre needs to be competitive in terms of sustainability and customer acceptance. A low noise tyre with a high rolling resistance, for example, would only shift the focus from one environmental issue (noise) to another (CO₂ emission), and would furthermore not be accepted by customers because of lower achievable mileage.

As the noise optimized EV tyres are still in the development phase, no technical details can be given. These will follow in future publications.

Road surface

Following an initial design and laboratory test phase, two asphalt mixtures have been put forth. Both proposals are of very thin asphalt concrete (VTAC) type with a maximum aggregate size of 6 mm. They differ in the presence of two percent crumb rubber from recycled tyres in one of the mixtures.

Road sections at a test track in Nantes which have been paved with these prototype surfaces, see Figure 1, are the basis for a characterization of the two pavements in terms of their physical properties (mean profile depth (MPD), mechanical impedance, absorption, skid resistance, friction, etc.) and their rolling noise performance (CPB, microphone-array CPB, CPX),.

For CPB measurements at constant 50 km/h – and using a variety of different EVs – the new surfaces reduce road noise on average by 3.5 dBA to 4.5 dBA compared to a reference dense asphalt concrete (DAC) 0/10 surface. The surface without crumb rubber has a slight advantage of roughly 0.2 dBA, maybe because of a slightly higher sound absorption coefficients above 1.6 kHz (max. 0.23 vs 0.15). For comparison, the MPD is in the range of 0.3 mm to 0.4 mm (with/without crumb rubber).

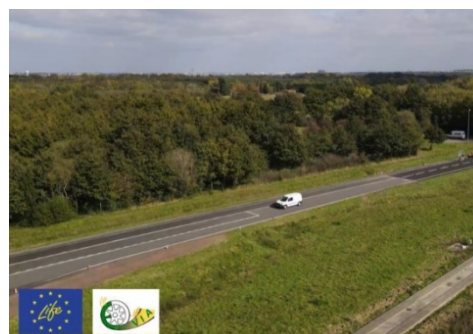


Figure 1: Prototype road surface testing in Nantes.

Based on the outcome of the tests in Nantes, the asphalt mixture with crumb rubber was chosen for further application in the pilot area in Florence. A stretch of approximately 150 m along a highly urbanised road in the city's central district (Via Giovanni Paisiello, see Figures 2 and 3) was repaved using the optimized surface. This area was chosen because of its significant population density, and because of being a busy (due to traffic to/from the city centre), two-way travel road without significant curves. Moreover, it is near to some of the most important and recent urban requalification interventions (e.g. Manifattura Tabacchi) with new dwellings, schools, etc.

Additionally, a second 150 m section nearby in the same road was also repaved using standard asphalt. This section will serve as reference for all further evaluations. Initial road surface characteristics and rolling noise measurements are currently ongoing. Among the planned activities are measurements of surface texture, mechanical impedance, sound absorption, CPX, and CPB. Parts of these measurements will be repeated in three- or six-month intervals to monitor surface wear and ageing. Besides the objective assessment, questionnaires have been handed out to the local residents to initiate the soundscape evaluation.

After the performance tests, three more areas will be identified for experimentation in the city. This will hopefully be followed up by a replication in Italy and Europe.

Finally, the pilot road section will be featured prominently in E-VIA's activities in the Expomove festival [13] which promotes electric mobility and will be held in Florence in May 2022.



Figure 2: Location of the pilot area in Florence: Via Giovanni Paisiello. (Source: [12], © OpenStreetMap contributors).



Figure 3: The pilot area in Via Giovanni Paisiello Florence.

Conclusions

In Europe, the acoustic scenario at an urban level is mainly characterized by road traffic noise. In this framework, the LIFE E-VIA project proposes some prototypal solutions starting with an optimized road surface for the specific context of EV fleets, and tyres designed to give an optimal holistic relation between low exterior noise and other key performances. These solutions are accompanied by policy creation activities, soundscape analysis, estimation of EV rolling noise coefficients for the local fleet in order to support implementation of EU legislation, and Life Cycle Analysis and Life Cycle Cost Analysis to evaluate the track efficiency from a comprehensive point of view.

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