Sound Design for Electric Vehicle – a step ahead towards a tool-based design methodology

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Abstract

Designing sound for Electric Vehicle is an approach being progressively assimilated in the automotive product development and considered one of the strategic assets for the sustainable future of mobility. Nevertheless, this design process presents several challenges, since it requires multidisciplinary expertise and skills, collaboration and decision-making, among designers, sound experts, engineers, product experts, and other professionals. In this context, the Ircam / Sound Perception & Design group has been collaborating since 2009 with the French car manufacturer Renault. We present our latest project, developed in 2024-25, which allowed us to generate and produce not only solutions but also knowledge on both the manufacturer and the research group sides. The project enabled us to advance the experimentation and implementation of an integrated methodology based on novel and proprietary collaborative sound design protocols, methods and tools, thus making this project a good case of sound-driven design and collaboration. The ins and outs of this fruitful and successful project will then be presented, discussed, and put in perspective for possible future works.

Keywords: *electric vehicle, sound design, methodology*

1. Introduction

Whether electric vehicles (EVs) should be silent or not is not only a scientific, environmental and societal question, but also a political one since the recent introduction of several regulations in several parts of the world (notably North America, EU or Asia). More broadly, this issue also embodies, in its own way, one of the key ideas put forward by R.M. Schafer in his seminal work entitled 'The Tuning of the World', where he predicts a "synthetic soundscape in which natural sounds are increasingly replaced by artificial sounds" [1]. Therefore, the question is: why adding sound to a silent object at the risk of contributing to the increase of background noise in our already densely populated cities and soundscapes, saturated with all kinds of sounds, most of which are unwanted (by listeners) and uncontrolled (by actors)? Why not taking advantage of a (finally!) silent innovation to reduce noise pollution and exposure to the road traffic noise endured daily by millions of people? On the contrary, how can we ensure that silent vehicles are effectively integrated into our sound ecosystems in an effective and sensitive way, while remaining highly environmentally friendly?

As sound design researchers, we believe that a controlled and creative approach to the problem, combined with an expert and responsible sound design process is key to address these non-trivial questions, and to actively reflect on the composition of tomorrow's soundscapes, which are not "… an accidental by-product of society but, on the contrary, a deliberate creation, a composition remarkable both for its beauty and its ugliness" [1]. In this respect, our approach to sound design takes seriously in consideration the concerns relative to the possible unbearable level of cacophony resulting in the uncontrolled overlay of the continuous sounds of electric vehicles [2].

In fact, in the course of technological evolution, electric vehicles have emerged as a particularly relevant and fascinating case for sound design. Unlike traditional cars, EVs naturally reduce one of the most dominant automotive noise sources: the combustion engine. While technologically impressive, the near silence of EVs introduces a new challenge. For reasons of safety, the absence of engine noise cannot be left unaddressed. Pedestrians and other road users rely on auditory cues to recognize the presence of a vehicle. Thus, new, artificial and carefully designed sounds need to be reintroduced. This requirement opens a unique creative and scientific space for sound designers.

At this crossroads, multiple disciplines converge in new ways. Acoustics plays a role in shaping physical auditory textures. Audio technology offers tools for precise synthesis and control. Human-machine

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interaction principles influence how sounds respond dynamically to driving conditions. Interactive sonification provides methods to map vehicle data into meaningful sound cues. Beyond the technical domain, perception studies guide how humans interpret these sounds. Cognitive psychology explores the mental processing involved in recognizing and reacting to them. Sociology and ethnology enter the picture, as the cultural and social meanings of vehicle sounds must be considered. Altogether, EVs mark a turning point where sound design is not merely supportive but central to either safety, identity and sustainability.
Therefore, EV sound design engages with a variety of concerns regarding the role of sound within industrial design practices. These concerns extend across multiple dimensions, including functionality and intentionality, interactivity, usability, and user acceptability. Aesthetic considerations also play a central role, alongside issues of identity and branding, as well as ecological and sustainable requirements.
This complexity makes EV sound design problem multidimensional, thus requiring a multidisciplinary industrial framework. Such a framework involves collaboration between technicians, engineers, project managers, communication specialists, and decision-makers. The intersection of these actors highlights the need for a collaborative design approach that specifically addresses sound. Within this context, EV sound design emerges also as an exemplary case for developing and implementing collaborative methods and tools. These methods are intended to foster ideation processes and support creative decision-making throughout the design stages (see [3] for instance). Importantly, the aim of such initiatives goes beyond the production of sound design solutions only. Instead, they contribute to the generation of new knowledge in sound design as a discipline. This aligns with Findeli's perspective – among others –, which stresses that design research should not be limited to problem-solving outcomes but should also advance the epistemological foundations of the field [4].

2. An industrial sound design project

In this context, we report an industrial research project we developed in collaboration with the French car manufacturer Renault Group, in the period 2024 - 2026. The project was commissioned by the Project Department, and led by the Design Department of the group. In the rest of the paper, we use the name "EVsnd" to refer to this project, so to move away from branding and commercial considerations, and rather focus on its methodology and implementation aspects. The EVsnd project tackles a range of light commercial vehicles, namely small, medium and heavy vans. The current stage of the project focuses on medium vans, articulated in 3 original models that will be marketed towards end 2026. We characterise the main features of the EVsnd project in the following sub-sections.

2.1 Context of collaboration

The EVsnd project is embedded in a long-lasting culture of applied sound design collaborations with the commissioning car manufacturer since 2010: working together on the first zero emission model of the industrial partner marked a milestone in the development of strong and shared expertise and sensitivity towards vehicle sound design [5].
Such a fertile industrial context provides a significant advantage integrating sound early in the product design and development, thus moving sound design away from being treated as a mere afterthought. This very first industrial research collaboration triggered a virtuous circle and many other projects followed [6,7]. EVsnd represents our last endeavour where the early integration of sound design in the general development workflow allows the team to systematically and methodologically explore solutions and generate novel insights. The currently structured process ensures that essential contingencies are available, such as adequate timeframe for designing, prototyping, developing and assessing sounds, or room for collaborative interactions among designers and engineers. Overall, EVsnd exemplifies how a deliberate industrial framework fosters effective sound innovation.

2.2 Sound design task

Within EVsnd project, our research and development task tackles exclusively the exterior sound of the electric vans, although it has been shown that interior EV sounds contribute to a broader EV user experience [8]. Thus, this work concentrates solely on the exterior sound design process, where the task was to create a single exterior sound for the three models of the medium range utility vehicles.

2.3 Technical framework

EVsnd is implemented using a unified technological platform that integrates multiple components: 1. an input module that receives vehicle data (eg. car speed); 2. a central processing unit that encodes the sound synthesis engine, based on a multi-layer wavetable synthesis, supplemented by sound transformation modules (filtering, mixing, mastering, etc.) in order to precisely control the desired auditory output. The sound diffusion chain consists in a digital-to-analog converter, an amplifier, and a loudspeaker. Contrary to other types of vehicles, the loudspeaker is positioned below the front bumper on the bottom right-hand side with its membrane facing the ground.
The platform is developed by a subcontractor of the vehicle manufacturer and represents a significant aspect of the industrial integration process for EVsnd project. Overall, the platform adheres to implementation and development protocols which differ substantially from the flexibility characteristic of conventional sound design tools. The procedures involved specialized skills that have been acquired during previous projects. Porting a prototype solution to a pre-industrialized version is therefore not a trivial task. The platform represents both a technical foundation and a procedural constraint in EVsnd's development.

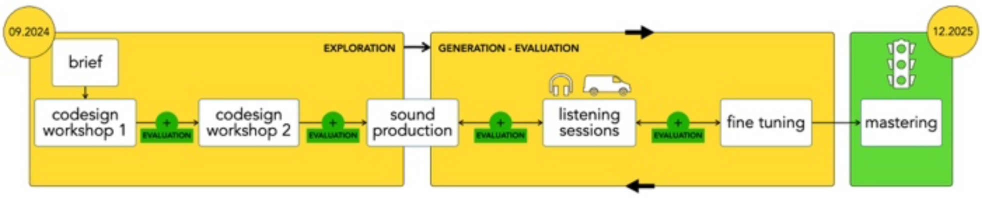

Figure 1. The EVsnd workflow of design activities.

2.4 Workflow and time course

The EVsnd project kick-started in September 2024 and ended in early 2026. The overall design process involves the following stages, as depicted in Fig. 1: initial brief, collaborative workshops, sound production studio sessions, sound listening sessions (in-studio or in-vehicle), decision meetings, and final fine tuning session for achieving certification. As in a previous recent project, EVsnd follows a rather linear, funnel-like 3-stage model [9], articulated in: exploration, generation and evaluation, with optimized pace for meetings and working sessions for sake of process efficiency.

2.5 Work group

The team composition for EVsnd is a quite ideal case, characterised by a stable work group throughout the project development. The composition of both company and research teams is reported in Tab. 1. The research team (the 3 authors) was responsible for implementation and management of the sound design process. Working through regular (mostly) in person meetings was an added value to the process efficiency

Table 1. The *EVsnd* work group composition.

Company team	2 audio experts
	1 internal lead sound designer
	2 lead designers
	1 design project manager
Research team	1 design project manager
	1 design researcher
	1 sound designer

2.6 Output

Finally, the EVsnd sound deliverable revealed specific structure, sonic properties, and temporal morphology (in interaction with the vehicle dynamics). It could be characterized by:

- a low-pitched, continuous drone component ({1} in Fig. 2), with a fundamental frequency based between 110 and 150 Hz, and a roll-off on the overtone structure, in order to blend with the other components without taking too much energy;
- a drone based on a major third pitch, evolving between 300 and 500 Hz ({2a} in Fig. 2), enriched by a glitchy material ({2b} in Fig. 2), made with a loop of originally random-generated clicks, passed through a series of resonant filters evolving in frequency between 1200 and 3500 Hz (high-pitch for location), and a fixed component ({2c} in Fig. 2) made by a filtered white noise (1200 Hz fixed frequency, and high Q). The interaction between these two components (consonant, then increasingly dissonant) makes the sound calm and reassuring at very low speed, then unusual and attention-getting, at higher speed;
- a slow modulation (a 6-second cycle, evoking a very relaxed breathing sequence), made with a noisy, windy material ({3} in Fig. 2), whose frequency center evolves between 180 and 250 Hz (a narrow zone, giving room for the other components).

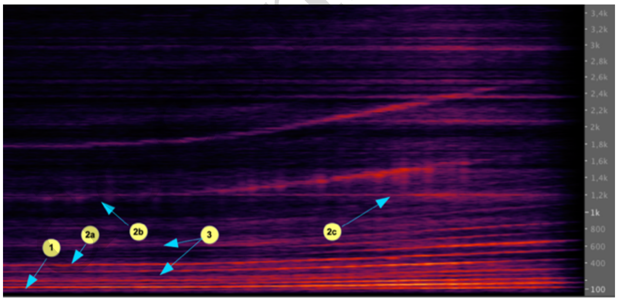

Figure 2. sonogram of the *EVsnd* exterior sound, with its characteristic elements {1, 1a,b,c, 2, and 3}.

3. Integrated co-design methodology

Over the years, we developed a co-design approach resulting in a flexible and scalable research-driven methodology that allow us to generate knowledge in sound design while fine-tuning its process [10]. In this respect, applied and constrained projects, such as EVsnd, also provide the opportunity to experiment and introduce novel, proprietary collaborative sound design protocols, methods and tools.

In automotive sound design projects, co-design approaches are especially relevant in early stages, where exploration activities performed collectively by the work group aim at both producing several sound ideas and distilling them, and creating consensus and shared understanding [11]. We have observed that this last aspect is particularly important for achieving a smooth production process, especially when the work group is faced with possible interruptions, such as team reorganization or changes in project strategy.

In practice, our design methodology facilitates the interpretation of design brief into sonically-relevant semantic layers. These are systematically distilled into sound descriptors and guidelines to assist the sound production phase, that is when the specific expertise and sensitivity of the sound designer comes into play. These steps are reported in the next subsections.

3.1 Design brief

EVsnd design brief was given by the Design project manager, who also belongs to the work group (Tab. 1). The brief was built around three main key concepts representing the overall design strategy of the project, conveying functional and aesthetic properties, user experience, etc., and distilled into global values and evocative moods, further detailed into shape, material, color and other features of the three models of medium vans. Interestingly, the brief did not contain explicit indications regarding the sound signature.
Due to confidentiality, the design brief cannot be fully disclosed. To refer to key concepts we will then use the codes Kc1, Kc2, Kc3 and Eu1, ..., EuN, to refer to the elements of understanding attached to each Kc.
To unpack the brief into clear requirements for the exterior EV sound, we designed two sequential co-design sessions (Co-D1, Co-D2) to engage the work group into collective ideation, discussion, comparison and assessment of sonic elements to be used for sound creation. For this purpose, we opted for two specific tools available in our toolkit, that is Soundstorm [12] and SpeaK [13]. We use Soundstorm for warming-up and team building and SpeaK to enable the semantic transformations of the overall design brief into sonic descriptors and guidelines at a verbal level.
However, despite its accuracy, wording sounds does not provide the same level of embodiment and understanding of the experience of listening to them [14]. Instead, it is necessary and beneficial to complement the verbal communication by listening to and creating sound sketches with various degree of detailing. Consequently, for this project, a third tool in the form of a semantics-driven sound synthesizer was specifically conceived to bridge the gap between the ideation and creation phases.
These three components together form an integrated and novel method that allows us to further consolidate our knowledge in the discipline sound design.

3.2 Soundstorm: preparing for ideation sessions

Addressing the temporal and context-dependent nature of sound in multi-stakeholder, collaborative design projects is a challenging activity. Even experts that are experienced in sound design projects have different interpretation of what 'sound' entails for their job [15].
Ideation methods are typically used to generate solutions to a design problem. During idea generation, participants use their creative cognition to generate ideas in quantity, quality, variety, and originality. If this collaboration is managed effectively, a group outperforms its members.
Soundstorm [12] enters the design process to facilitate the construction of a shared ground within a design team or participating experts, before addressing the conceptualization of sound, its embodiment and detailing. Soundstorm is a card-based collaborative board-game to sensitize group-work in sound design ideation sessions (Fig. 3). It acts as an ice-breaker intervention that makes sound-relevant activities more accessible [12]. During a Soundstorm session (less than 10 minutes), participants in turn engage in verbally describing or vocally producing sound, and creatively thinking of alternative functions for a given product based on prompts contained in different types of cards. We slightly modified the prompts in order to include elements from the EVsnd brief. For example, participants could encounter prompts using Kc1, Kc2 or Kc3 to be applied to a bookcase, a fridge, a stroller, and so forth. This warming-up activity served to let the work group practicing and experiencing the complexity of moving from global, high-level design concepts and strategies to their sonic, audible counterparts.
In concrete terms, Soundstorm served to kickstart creativity in sonic ideation, form social cohesion within the work group, practicing iteration and focused attitude sound design, and be ready for verbalization.

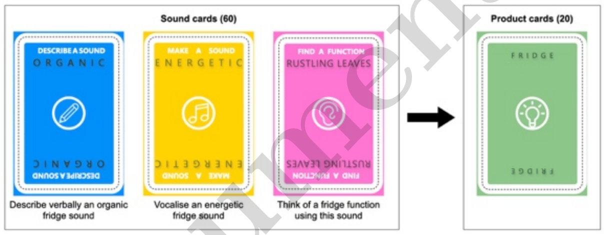

Figure 3. Soundstorm, a card-based board-game.

3.3 Speak: verbalizing sound ideas properties

SpeaK [13] is a collaborative sound design environment developed from doctoral research [16] and refined through diverse applications. It is a practical and creative framework for sound design that has been used in diverse industrial applied projects, such as for exploring crossmodal sound–taste interactions [17], or translating the institutional identity of a university into an appropriate sonic communication [18].
The SpeaK rationale is to address the challenge of communicating about sound, particularly in multidisciplinary projects or contexts beyond the sound domain. It supports the semantic transformation of design intentions (e.g., brand identity) into terms that generate sound design insights. In SpeaK, semantic transformation is facilitated by mediation objects such as a lexicon of sonic properties and a card-based system. These tools support the translation between brand-related language and sound-related descriptors, enabling stakeholders to engage with complex, polysemic notions within a structured framework.
The lexicon is composed of 35 attributes associated to either general sound qualities (eg., natural/artificial), timbre (eg., bright/dull) or sound morphologies (eg., constant/fluctuating). The lexicon is enriched with sound examples in several categories (instruments, voices, etc.), which help to clarify and align interpretations. The main goal of Speak approach is the semantic transformation, in which participants collaboratively associate target-words to sound-words by placing cards on the game board (Fig. 4). This process fosters discussion and interaction, leading to the construction of semantic portraits that link concepts to sonic attributes.

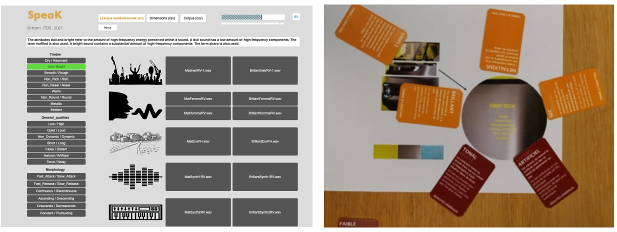

Figure 4. the SpeaK environment composed of lexicon (left), cards and board (right) – as used in *EVsnd* project.

3.4 Bridging creation from words to sound.

In order to bridge the gap between sound ideation and creation, we specifically developed a semantics-driven synthesizer. In fact, in EVsnd workflow, Co-D1 generated initial semantic portraits of Kc1, Kc2, and Kc3, that is layered sets of verbal descriptions coupled with sound attributes. For instance, among other attributes, Kc1 was portrayed by 'round' and 'dull', Kc2 by 'metallic', and 'bright', and Kc3 was protrayed by 'warm' and 'resonant' attributes (see Fig. 5).

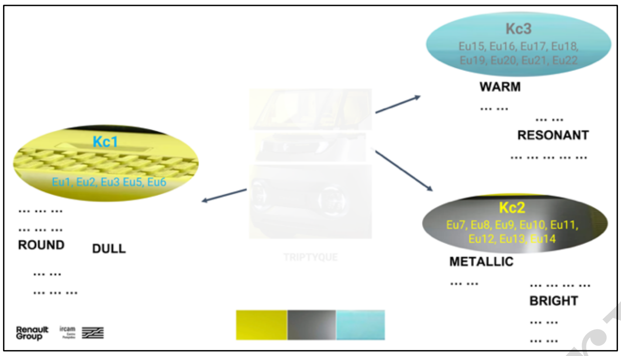

Figure 5. output of the 1st co-design session. Semantic portraits: relations between key concepts (Kc), elements of understanding (Eu), sound attributes (mostly masked).

We then used the full semantic portraits as interpretive guidelines to create a set of audible sketches to propose in Co-D2. Therefore, Co-D2 was instrumental to consolidate a shared consensus on the sound attributes, by listening and discussing the sound examples, on top of which exploring and developing variations and combinations collectively. To do so, following insights of the 2nd author (sound designer), we developed a sound synthesizer that makes use of basic sound processing to translate, manipulate and modulate Kc1, Kc2, Kc3, and their respective sound portraits.

Our semantic approach to sound design is reflected in the rationale of the EVsnd synthesizer: the sound processing is organized in two classes: 1. a top layer, called (G)enerator, to define the boundaries of the sound design space according to Kc1, Kc2, and Kc3 portraits; 2. low level layers, called (T)ransformers, to navigate the resulting design space. (G)enerators make use of looped playback of audio textures, and parametric sound synthesis, (additive, substractive). (T)ransformers make use of audio filtering, and various effects such as distortion, flanger, etc. that operate on the (G)enerators' output.

This tool provided an hands-on platform with several degrees of freedom, allowing to explore auditorily the sonic portraits produced in Co-D1 (Fig. 6). For instance, the coexistence of ideas like 'round' and 'warm' (two of the qualities in the constellation of Kc1, and Kc2) were translated into sound by mixing pre-recorded seamless loops (hence, "Generators"):

- a noisy material with main presence around 100-150 Hz and a very subtle hissing component around 4000-5000 Hz for 'warm';
- a low pitched sound with a resonance around 500/1200 Hz., evoking the zone where the nasal cavity resonates, for 'round'.

A quality like 'bright', instead, was evoked using high-pass filter (T)ransformers applied to (G)enerator materials already rich in high-frequency components, in order to modulate this component.

Having grounded the semantic continuity between verbal descriptions and sound parametrization into a shared understanding allowed everyone to propose variations, making the exploration truly collective. In more details, the modularity of this approach allowed direct interventions by other sound experts/designers in the team, who added new/alternate textures and played a role also in the process of the final transformation of the rough sounds produced by the prototyping engine toward more refined timbres.

In this respect the tool acts as an effective intermediary object [19] that facilitates collaboration, understanding, negotiation, and argumentation for the ultimate purpose of designing and manufacturing an artefact, in this case the exterior Electric Vehicle sound.

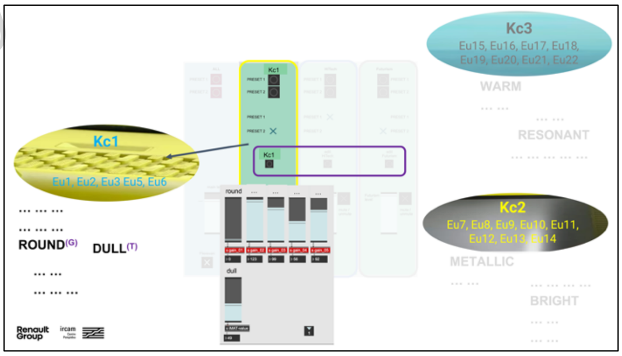

Figure 6. details of the semantics-driven synthesizer for a given set of (G)enerators and (T)ransformers.

4. Conclusion and Perspectives

This paper provides an overview of a typical industrial collaborative research in sound design that makes it possible, in a given context, the conjunction of production of solutions and acquisition of knowledge.

The particular context is the automotive industry and more specifically the need to give a sound signature to electric – so silent – vehicles. We delivered solutions in the form of artificial exterior sound whose design was controlled and thought with regards to all the inherent constrains (technical, commercial, environmental, societal, etc.). But, we also acquired and deepened knowledge about collaborative sound design

methodologies and tools, by implementing an integrated workflow that appeared to be relevant for filling the gap between production of ideas (Ideation) and production of sounds (Creation). In fact, through this workflow, we involved a group of multi-disciplinary experts in listening to sound, producing ideas, verbalizing its properties, and we built the foundations of a semantics-driven synthesizer able to interpret semantic attributes into sound samples and sketches.
The perspective of this work are manifold and could range from addition of new methodological building blocks in the present workflow, to refinement of the synthesizer, including implementation of other instances of this workflow into new applied projects. The long-term perspective of these formal reflection and practical work is to provide the sound designer – and the sound design practice – with a structured workbench where different tools for different situations could be found and effectively used on purpose.
Moreover, these methodological approach and tools could notably be helpful when a project is deployed in less favorable conditions (than the ones described in this paper). For instance, target-values could be more largely ill-defined, stakeholders could be more skeptic and adhere much less closely to the method, or tools developed to prototype sounds could produce sketches that turn out to be out of context. In such cases, adapting paradigms and tools remains the key to preserve the inherently collaborative and human-centered nature of the approach.

5. Acknowledgment

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