HEXAGON

Case study

Travel quietly and sustainably in SNCF trains

Based on an interview with Claire Chaufour, Project Manager at SNCF

The Research & Innovation Department of SNCF, the national railway operator of France, has been exploring Actran for modelling the interior noise comfort of their trains and setting up what-if scenarios for noise reduction solutions.

SNCF (Société Nationale des Chemins de fer Français) is the French National Railway Company and operates one of the largest rail networks in the world, transporting more than 5 million passengers per day as well as cargo. It operates more than 14,000 trains daily across a 35,000 km network, which includes 2,600 km of high-speed lines where the well-known TGV (Train à Grande Vitesse) trains are operating.

While SNCF is not a railway manufacturer, it is paramount that the company ensures a superior noise comfort experience for passengers. This is especially true in the high-speed lines which aim to replace air travel for short distances where expectations are already higher. SNCF buys and operates trains with the long-term use in mind as some trains can be used for decades. As public expectations evolve, trains need to be retrofitted accordingly to match the required levels of noise comfort, as much as possible. This retrofitting most commonly involves new encapsulations for technical equipment and electric motors, replacing energy absorbers or dampers on the wheels and using acoustic treatments on the walls, floors and ceilings of the trains.

Interior design proposal for trains

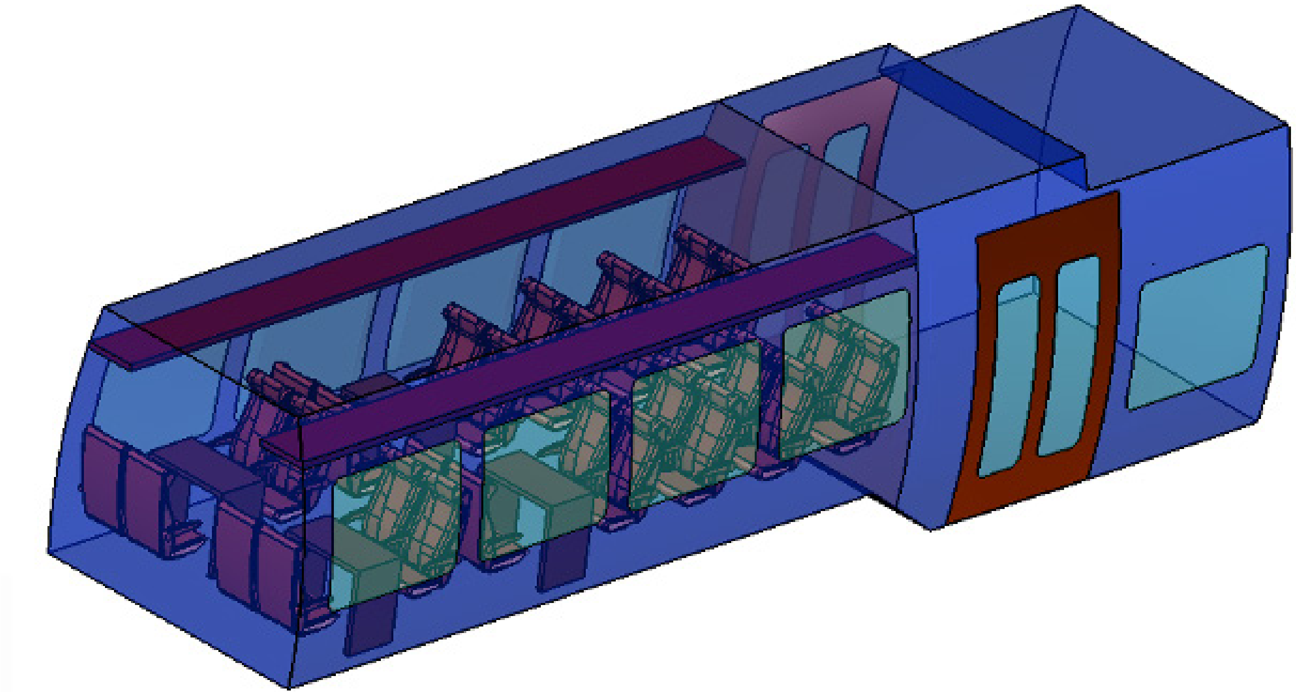
Retrofitting thousands of trains without clear engineering insight can be costly. Therefore, it is vital that engineers working on this task understand the noise propagation path and identify critical areas where treatments will have optimal impact while keeping costs low.

Noise sources and noise reduction

The noise created by the train, both radiating towards the surrounding environment and into the cabin depends a lot on the speed at which the train is travelling. At typical operating conditions, travelling between 80 km/h and 300 km/h, the dominant noise source comes from the rolling noise. This noise is generated by the wheels coming in contact with the lines which may have irregularities from manufacturing or wear; this is the most common noise identified by individuals traveling by train. Secondary sources of noise are attributed to the on-board equipment such as the electric/thermic motors and the air conditioning components. The secondary noise is only discernible at low speeds as it is largely masked by the rolling stock noise as the speed increases.

Finally, as the speed of the train grows beyond 300 km/h, the dominant noise source becomes the aerodynamic noise created by the flow interaction with structural elements, bogies and the pantographs.

To properly identify the noise paths and propose solutions that will increase acoustic comfort, SNCF has been exploring acoustic simulation, an effective utility which can provide engineering insight on what solution will have the optimal impact. Since the company cannot test everything through extensive prototyping, they can go digital with many benefits in terms of cost. As a first step, acoustic simulation is evaluated in the form of an R&D project rather than in a production environment. In this context, a combination of MSC Apex and Actran is used for modelling interior noise. MSC Apex provides an ergonomic and easy-to-learn suite of tools which take an idea from CAD to mesh; easily modify existing geometries, preparing the mesh for a finite element approach, and exporting this mesh to Actran for the simulation. Actran was chosen after a successful benchmark for its ability to model various acoustic treatments and easily identify the best position of these treatments through a what-if analysis/investigation.



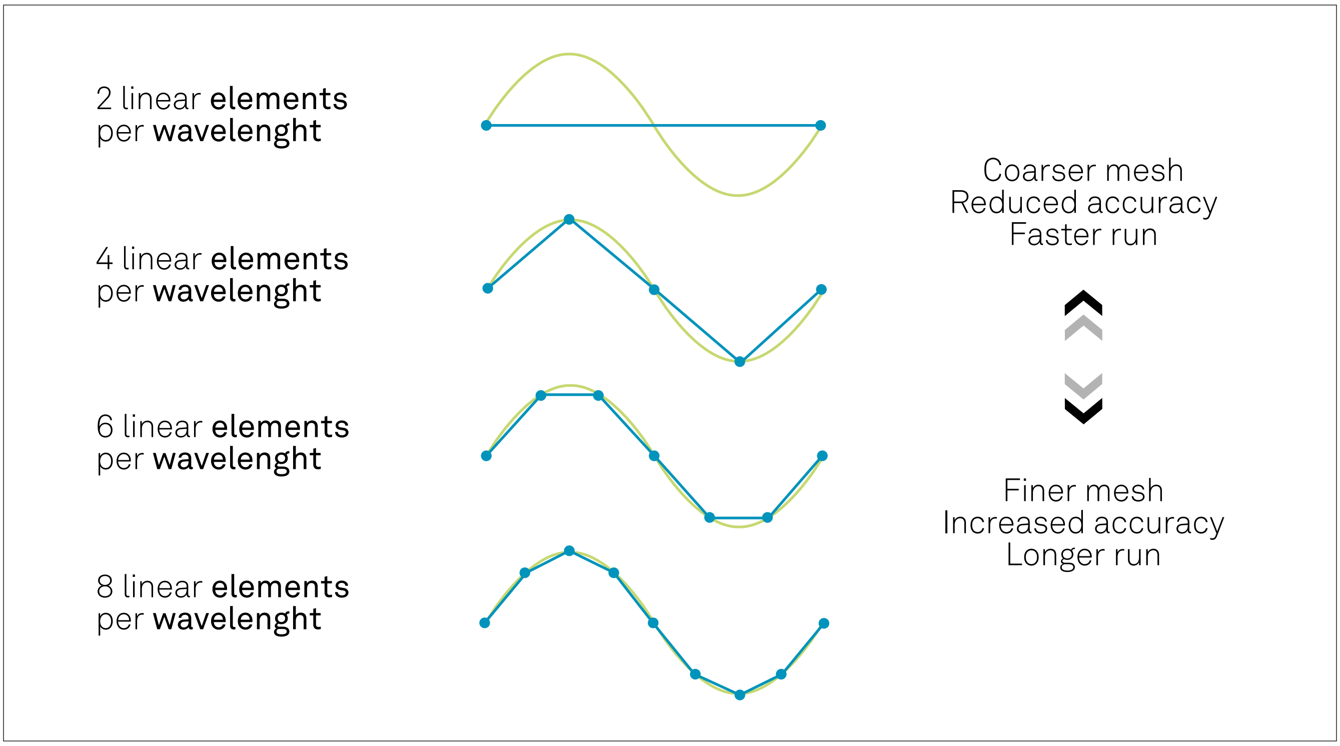
Delivering simulation solutions

A team within the Innovation and Development department was set up in order to deliver a strategy for deploying numerical techniques for noise reduction. Their primary task was to create methodologies identifying how to best run the studies and provide a set of tools that can be used alongside a small amount of complementary experimental tests. Since the exterior noise problem for rolling noise has been well codified, the focus is mostly on interior noise for passenger comfort. To tackle this problem, the team first investigated a simplified train cabin – essentially a parallelepipedon box – in order to derive guidelines for solving the main issue for railway interior noise, the size of the cavity.

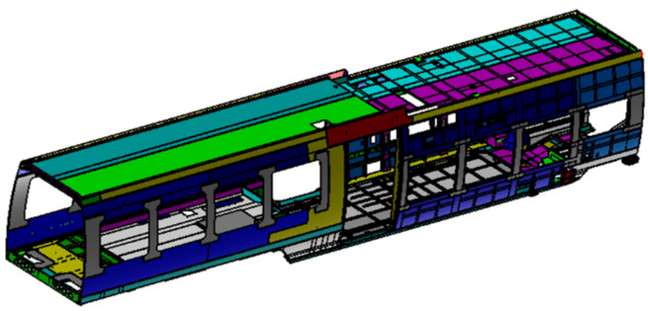
The size of the simulated model is an important factor in the simulation turnaround time. In the case of a large object, more elements will be needed to model higher frequencies and since a train car cabin is quite large, high frequencies (higher than 1000 Hz) are not easy to attain.

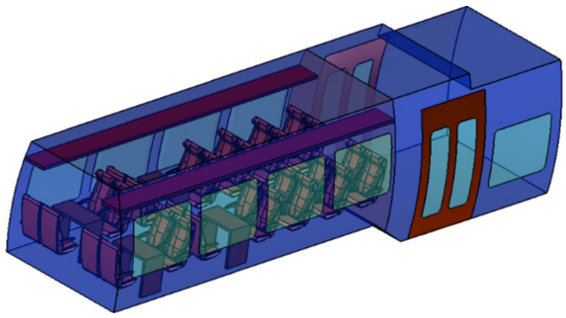
The researchers performed a study on the discretisation criterion which is how many elements are required to properly model a specific wavelength or frequency. They concluded that it is important to have at least five elements per wavelength and that appropriate fluid damping should be defined.

> **"Actran allows a fine simulation of the design as well as the physical mechanisms involved, including absorption and insulation."**



For the next step the researchers worked through a more realistic geometry which was cleaned and prepared in MSC Apex.

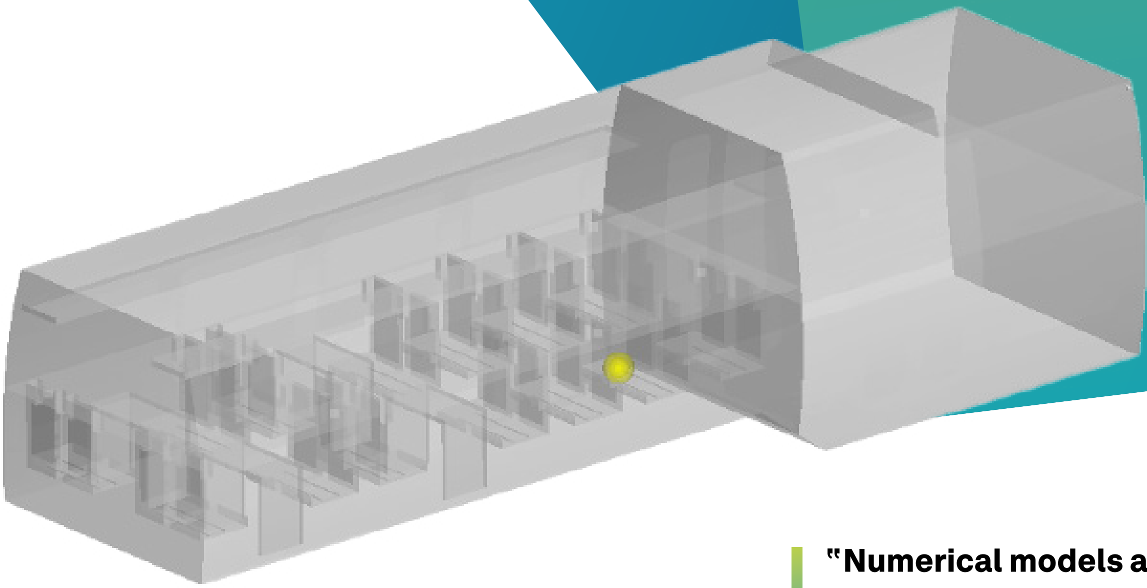




The geometry includes two different compartments (passenger and platform) of a train car as well as the seats, tables and luggage rack. The main noise source considered was rolling noise which was modelled as a monopole source with amplitude defined by a third-octave band spectrum in A-weighted decibels, or dB(A).

The main objectives of the study were to evaluate the propagation of noise within the passenger compartment and further transmission to the platform compartment and the absorption provided by acoustic treatments in the passenger compartment.

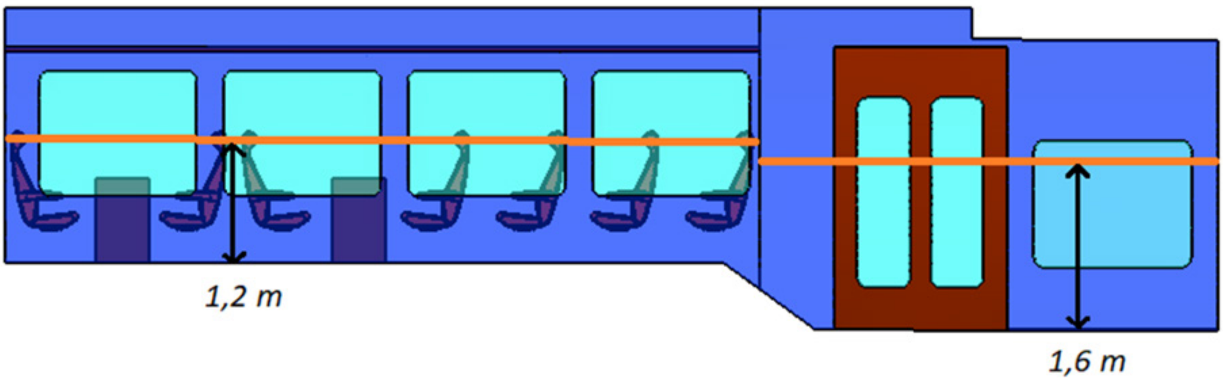
"As we cannot test everything in a real way and model the solutions, we can go digital with many benefits in terms of costs."

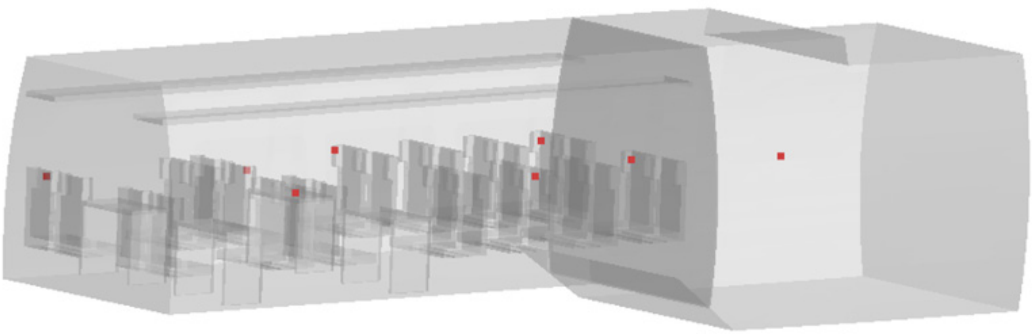


Noise source (in yellow) in the cabin model

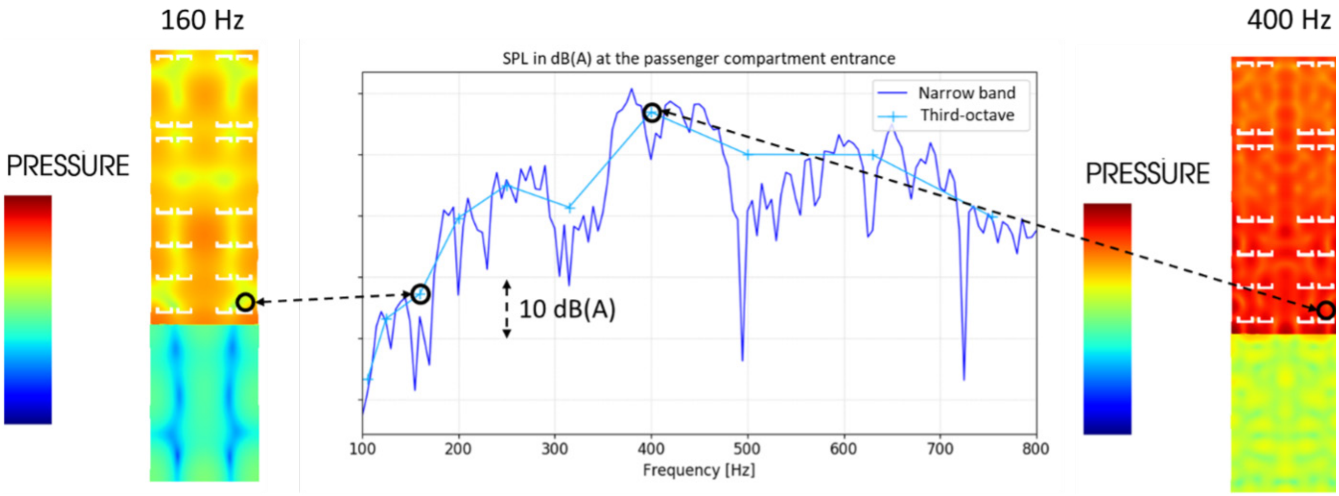
> **"Numerical models allow engineers to imagine different scenarios and quantify the effects in terms of noise."**

The platform and the passenger compartment are separated by a glass panel which is modelled as a thin shell. The absorption inside the passenger compartment is modelled by an absorption coefficient applied on different surfaces as indicated in the figure above. To evaluate the noise, a number of microphones are created to represent the passenger locations as results are evaluated at specific heights within the cabin.

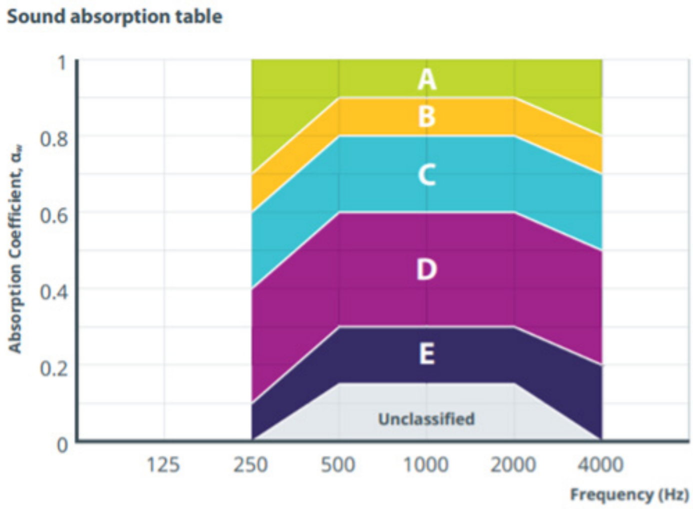


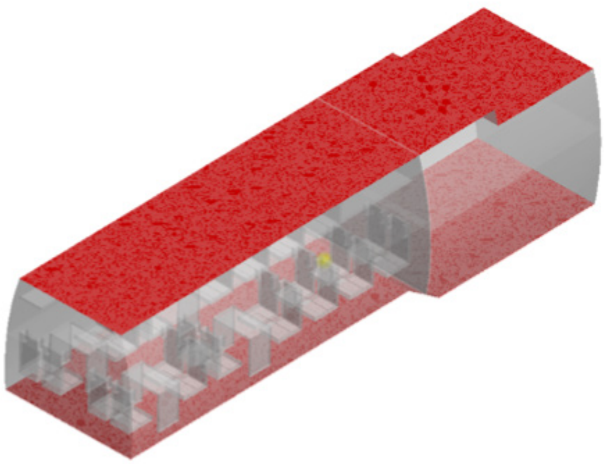


Results of a preliminary investigation identified important frequency ranges to be studied. Several what-if studies are then designed to evaluate potential noise reductions in these regions.

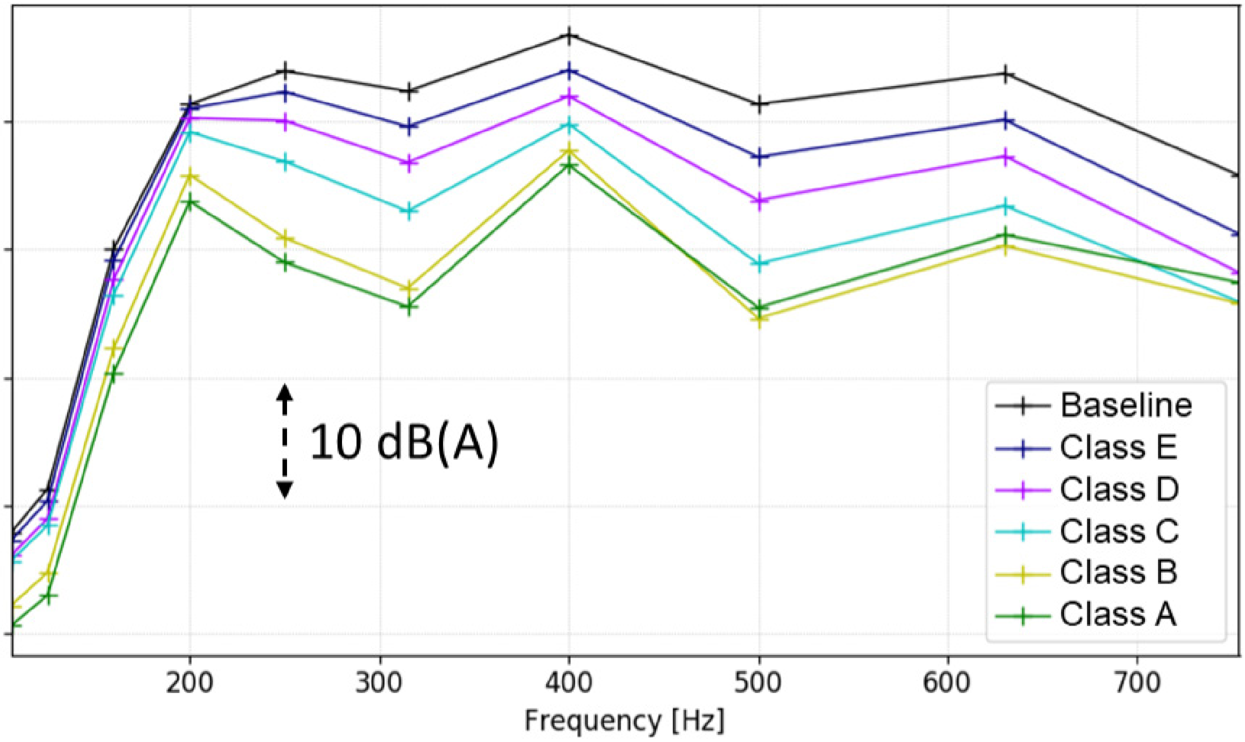


As a next step, it becomes very easy to manipulate the existing model to modify the material properties of the absorbing surfaces. The effect of different materials applied on the floor and ceiling can be viewed below:





"Sometimes we have numerical results that go against what we thought, so simulation allows us to question and better understand results that are not easy to calculate on paper."



SPL in dB(A) at the passenger compartment exit

By performing the two simulations and looking at microphones, they can reach the conclusion that putting the acoustic material at the entrance of the cabin (close to the source) will have a greater impact for noise reduction. The effect can be further visualised by looking at the predicted sound pressure level for specific frequencies. Putting the absorber around the source seems to be more effective as it avoids multiple reflections that amplify the sound level. The main researcher in this study, Claire Chaufour, observed the potential of this workflow as "numerical models allow (the engineer) to imagine different scenarios and quantify the effects in terms of noise."

Moving forward

After achieving valuable insight through this exploration and validation study, the next step is for engineers in the retrofitting teams to embrace this methodology and use it for creating quieter and more comfortable cabins. In environments where adverse noise conditions have been mitigated, passengers can enjoy the ride, relax or work efficiently during their time onboard. Further to that, the methodology will be used for exploring acoustic metamaterials, which could provide large performance gains while reducing the additional weight of the acoustic treatments.

"Numerical simulation allows engineers to compare the ideas with a calculation and to better understand the phenomena so it is a useful tool for the understanding and the validation of what one could have imagined."

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