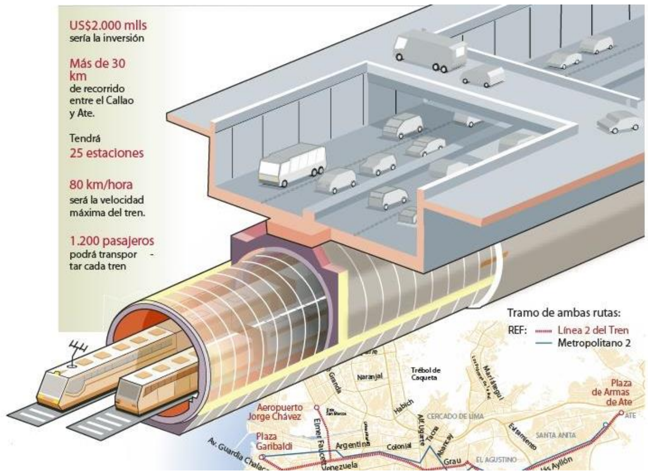
# Case Study

AV ingenieros
Ingeniería Vibroacústica

# L2 Metro Lima (Peru)

2015-2018




## Description

The city of Lima (Peru) has one operational elevated Metro line and is constructing its second line, named L2, which is mainly underground and which will connect suburbs Municipalidad Ate and Callao Harbour.

L2 line, with a total length about 33 km, is being executed using conventional methods (8 km) and 9.2 m inner diameter TBM (25 km). It will have 23 stations, 2 interchange stations and 2 new depots.

## Scope

At a first stage, vibration levels into buildings considering a predefined superstructure composition were predicted using a semi-empirical model.

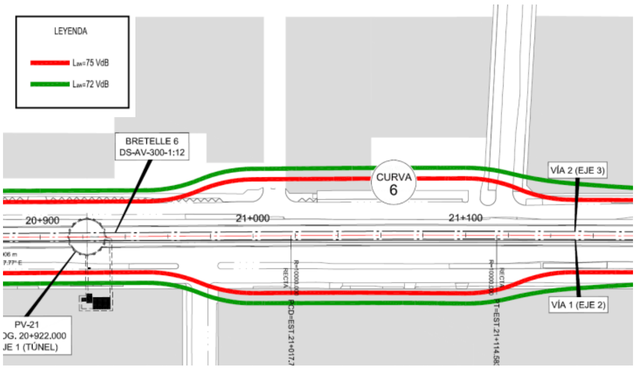
The prediction model considers rolling stock characteristics, track composition, ground geological conditions and building dynamic behaviour.

Areas where vibrations levels are expected to be higher than limits were identified. Vibration excesses were also quantified.

Finally, vibration mitigation solutions to be installed in order to decrease vibration levels were defined down to the last detail. Under-slab mats were considered.

## Objective

Vibration impact assessment project to predict vibration level into buildings due to future railway operation and vibration mitigation solutions design where needed.



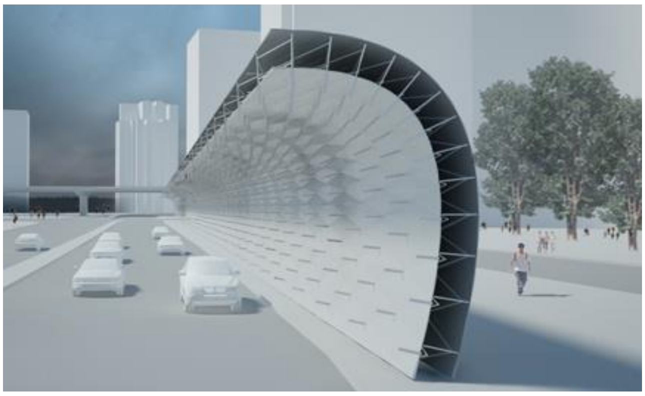


| Inversión aprox. | Duración del recorrido | Estaciones | Pasajeros (aprox.) | Tiempo de ejecución | Beneficiados |
|---|---|---|---|---|---|
| US$ **1.800 mlls** | 45 minutos | 25 | 600.000 diarios | 2 años solo estudios | 4.000.000 de personas |

# Case Study

# High Speed Rail Noise and Vibration feasibility study

2017



## Description

The High Speed Rail Corridor, HSRC, between Delhi and Kolkata consist of two at-grade parallel track, which are mainly ballasted although other track superstructure are considered.

The alignment has a total length about 1.475 km, the rolling stock design by Talgo (AVRIL) will run at a design speed of 330 km/h and the study area includes more than 2,000 sensitive receivers.

## Scope

Noise and vibration measurements in collaboration with a local partner at 9 different locations to describe baseline levels before HSR Corridor.

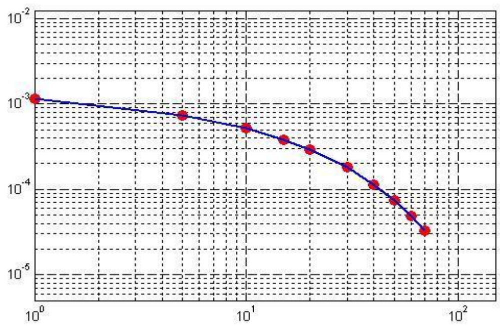
Noise modelling using SRM-II model proposed by the European Directive 2002/49/CE.

Vibration modelling considering Barkan's wave propagation equation.

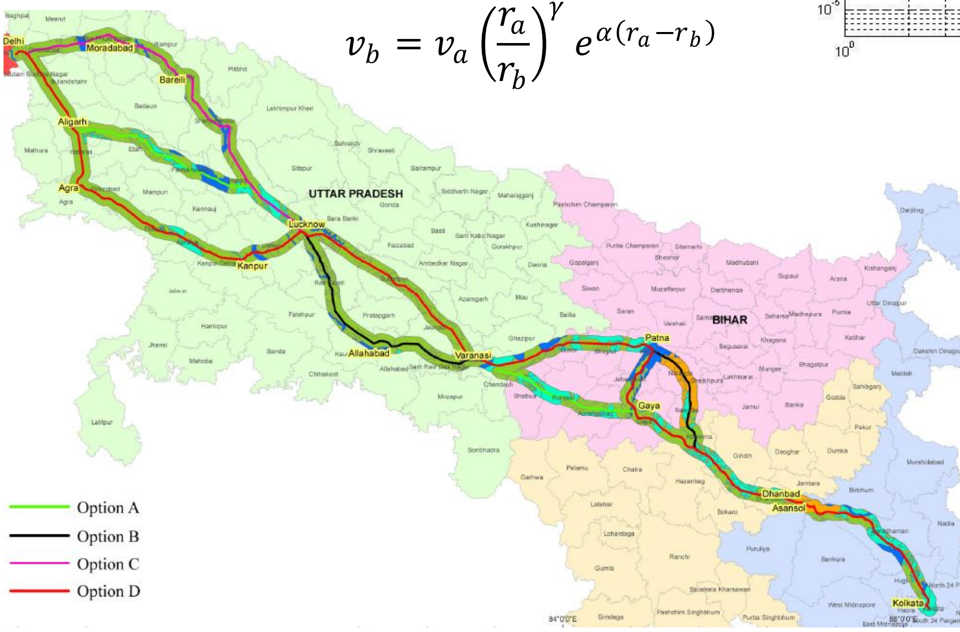
Suggestion of different noise and vibration abatement solutions to be applied to the corridor

## Objective

Noise and Vibration impact assessment project to predict noise and vibration levels due to future operation of HSR Corridor and noise and vibration mitigation solutions design where needed.



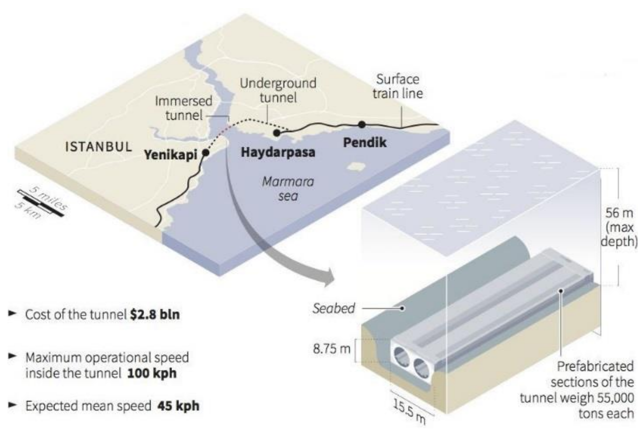

$$v_b = v_a \left(\frac{r_a}{r_b}\right)^{\gamma} e^{\alpha(r_a - r_b)}$$




# Case Study

# Marmary CR3 Project (Turkey)

2014-2015




## Description

The project consist of an underwater railway tunnel under the Bosphorus connecting Halkali on the European side and Gebze on the Asian side in Istanbul.

It covers the upgrading of 63 km of existing railway on both the Asian and European shores to connect with the 14 km Bosporus tube crossing, creating a 77 km cross-city commuter corridor. A third track is to be laid alongside the existing double-track route to accommodate inter-city and freight services.

## Scope

Predictive calculation of ground-borne vibrations caused by actual and future railway infrastructure regular service were carried out. Semi-analytical models and 2.5D FEM approach were used.

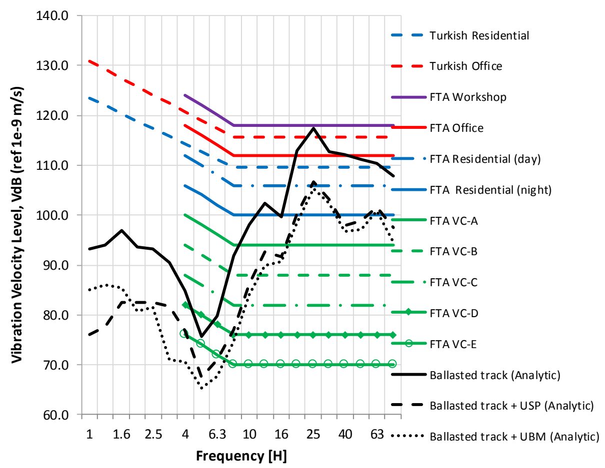
Semi-analytical prediction models consider a fully vehicle wheel-rail contact model to characterise vibration generation, a half-space Barkan model to characterise vibration propagation through soil and a statistic model to characterise building dynamic behaviour.

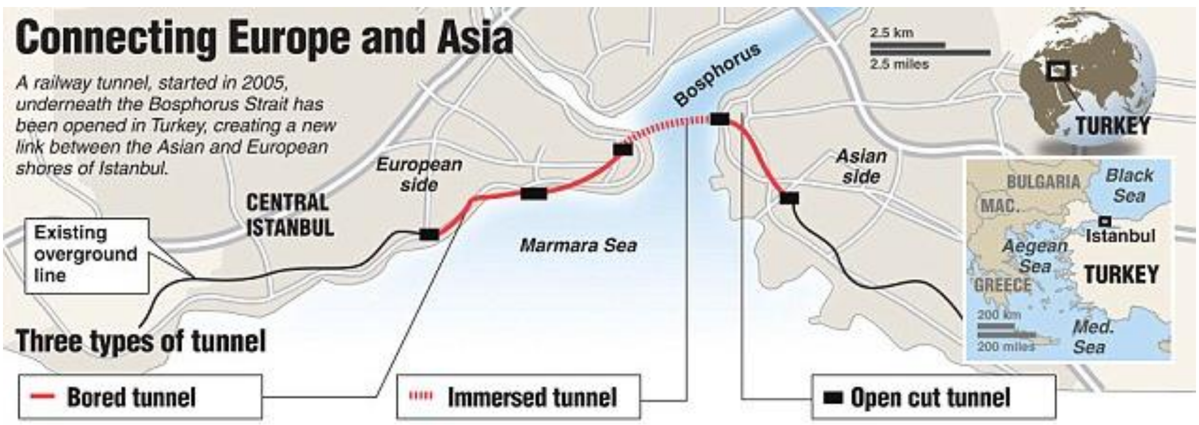
Areas where vibrations levels were expected to be higher than limits were identified and vibration excesses were also quantified.

Finally, vibration abatement solutions to be considered in order to decrease vibration levels were defined. Under-sleeper pads and under-ballast mats were considered.

## Objective

Predictive calculation of ground-borne vibration levels induced into buildings due to future operation of new railway infrastructure and superstructure vibration abatement solutions design where needed.



# Case Study

# FGC line extension in Sabadell

2012- 2013

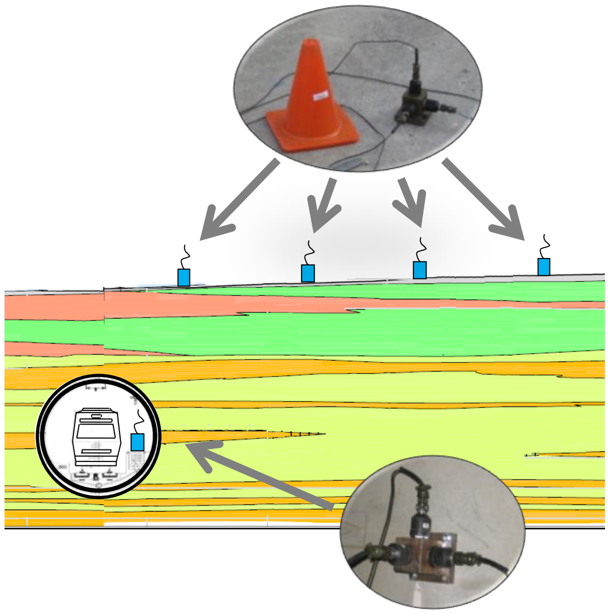
## Situation and description

Catalonian Railways (FGC) line S2 which now is finishing its itinerary at Sabadell-Rambla Station is being extended from South to North bound of the city to connect different suburbs.

S2 line extension is being executed with a double-tube 6 m inner diameter EPB boring machine. The extension total length is about 5.7 km with 4 new stations as well as a new depot.

## Objective

Vibration impact assessment project to predict vibration level into buildings due to future railway infrastructure operation.



## Scope

The project was divided into two phases:
- Phase 1: vibration level into buildings were predicted using a semi-empirical model, which was validated with experimental vibration measurements.
- Phase 2: detailed FEM-BEM models were developed to study locations where phase 1 showed that vibration levels into buildings were near standards limits.

The project results were the vibration levels into buildings due to the future regular railway operation. Different elastic track solutions were studied in order to optimize track behaviour.


## Acknowledgments

To ETSEIAT Laboratory of Acoustics (LEAM) from Technical University of Catalonia.

# Case Study

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# Tram Vibration Assessment

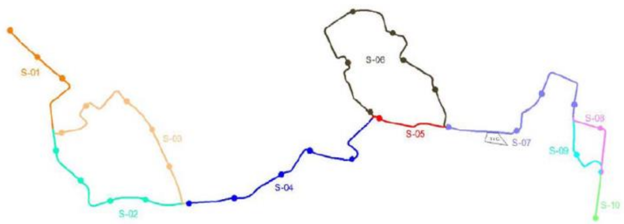
2010

## Situation and description

A new tram line is proposed to join Bellaterra University area with Montcada i Reixac, crossing Cerdanyola and Ripollet.

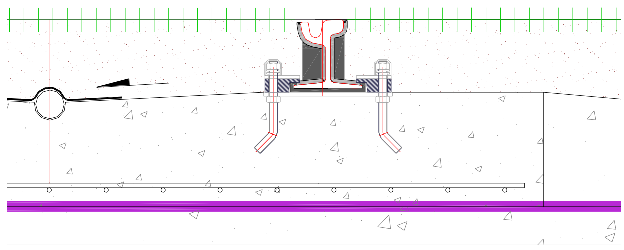
This new line is expected to be a double track railway system with embedded rails and with a total length between 12 km and 15.5 km (depending on the final layout).

The infrastructure mainly runs in urban areas which are really narrow and densely populated.



## Objective

Vibration impact assessment project due to future operation of a new intercity tram line.



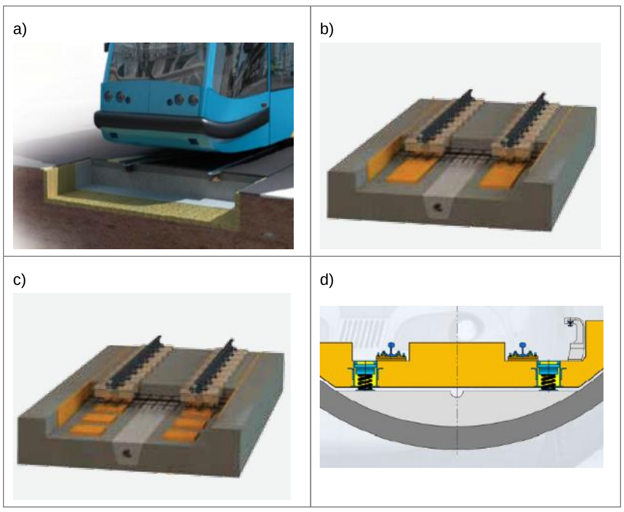
## Scope

Vibration analysis was carried out using a self-developed semi-analytical model.

Input data used in the project was the vibration emission levels of the tram which is being operated in Barcelona. This is because the planned tram had similar characteristics as well as the same superstructure design.

The prediction model considers ground borne vibration propagation through soil and its transmission to nearby buildings, where vibration levels were assessed according to national standards. Therefore, geology and building structure are key data.

The project results are the foreseen vibration levels into buildings during future tram operation and the abatement solutions (if needed) to be implemented in order to meet the vibration limits according to standards.



# Case Study

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# Hotel Ground-borne Vibration Isolation

2016

## Description

Ohla Eixample Hotel is a 5 star hotel located in the heart of Barcelona, where an underground railway is running near the building foundations.

Before the construction of the Hotel, vibrations due to railway were clearly perceptible; hence the hotel direction decided to isolated the building against vibrations and offer fully comfort to its guests.

## Objective

Measurement of vibration levels at the existing building before the construction of the hotel and vibration isolators' design to get low vibration levels induced into the hotel to be constructed.

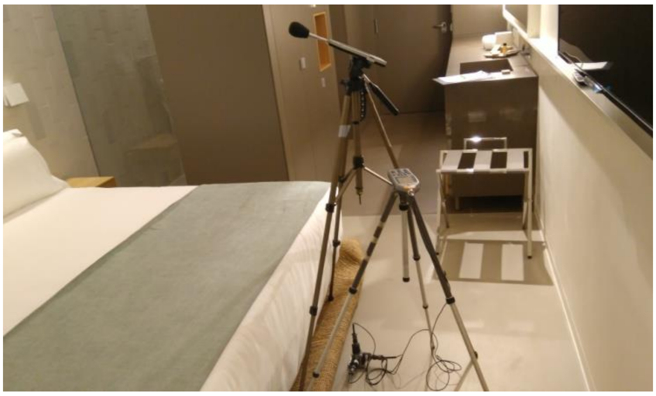
## Scope

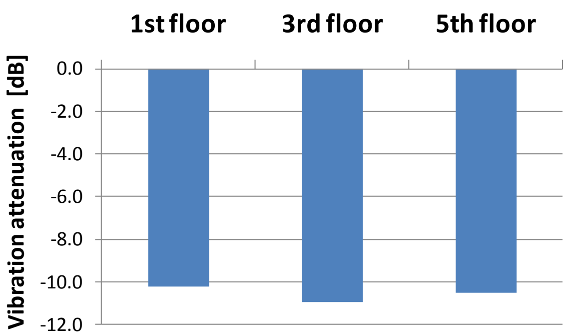
Vibration measurements into existing building before its refurbishment were carried out. Vibration levels and spectra were calculated.

From vibration spectra, dynamic properties of vibration isolators to achieve a proper vibration reduction are defined. A passive isolation system based on high flexibility steel springs is used.

These steel springs are located at top of pillars, some of them at ground floor and others at basement level. Therefore, the building is isolated above this level.

Vibration measurements after the building refurbishment were carried out to check the isolators efficiency in terms of vibration reduction. It was check that reduction objectives were reached.





# Case Study

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# Line L9 Metro Barcelona Dynamic test

2010

## Situation and description

New Barcelona Underground L9 line crosses the whole city, from Barcelona Airport to Badalona and Sta. Coloma, with a total length of 47.8 km and 52 new stations.

L9 is a unique deep line with sections at more than 60 m depth, executed with 12 m diameter EPB boring machine and with two tracks superimpose. The upper track has been laid on an intermediate concrete slab never before executed all over the world.

## Objective

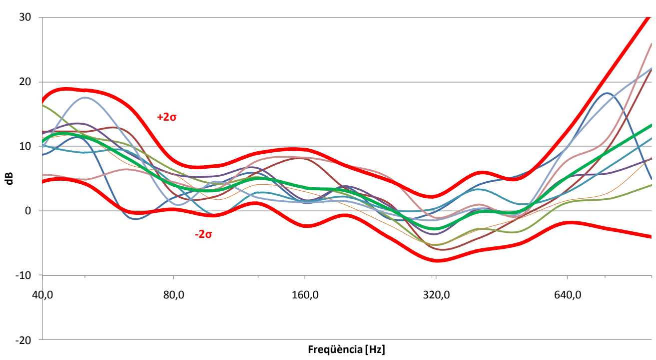
Dynamic characterization of the intermediate concrete slab during rolling stock pass-by.

## Scope

Dynamic test on 8 intermediate concrete slab modules (20 m length each module), using rolling stock as vibration excitation.

24 simultaneously high sensitivity seismic accelerometers were used to carry out the test. Vibration levels were recorded at the concrete slab and tunnel walls.

Results showed that the intermediate concrete slab have an homogeneous dynamic behavior along the track length.



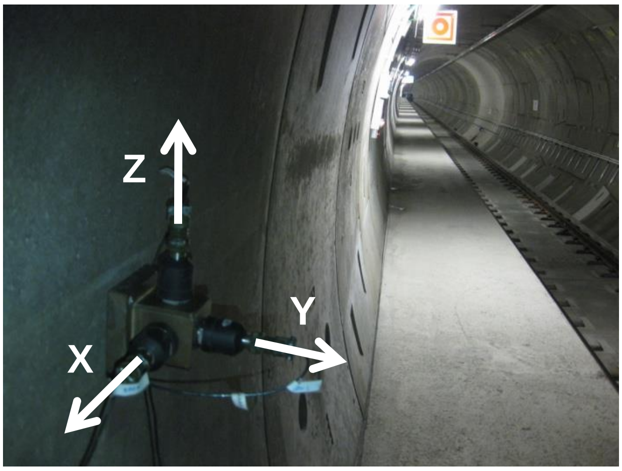

## Acknowledgments

To ETSEIB Vibrations Laboratory and ETSEIAT Laboratory of Acoustics (LEAM) from Technical University of Catalonia.

# Case Study

# Railway tunnel dynamic characterization

2010- 2018




## Description

Since its establishment, AV Ingenieros have been intensely working in the control and prediction of noise and vibration generated by railway infrastructures.

AV Ingenieros have large experience in measurement, control and modelling of noise and vibrations due to railways, into tunnels as well as into buildings

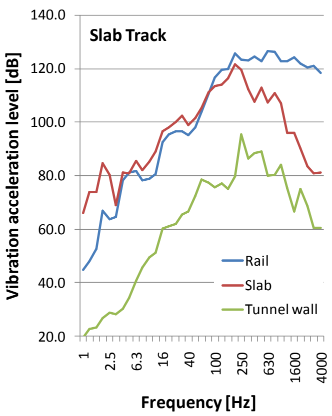
AV Ingenieros have been working for all Barcelona Underground network lines, also in its new double-deck L9 line.

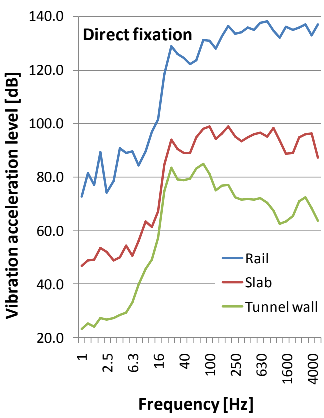
## Scope

Railway tunnels are set up with low and high sensitivity accelerometers, depending on the position of the accelerometer.

According to ISO 10815:2016, accelerometers are placed at the rail, where a low sensitivity vertical accelerometer is attached between two sleepers, the concrete slab, where a high sensitivity vertical accelerometer is considered, and the tunnel wall, where 3 orthogonally high sensitivity accelerometers are placed to measure the vibration vector.

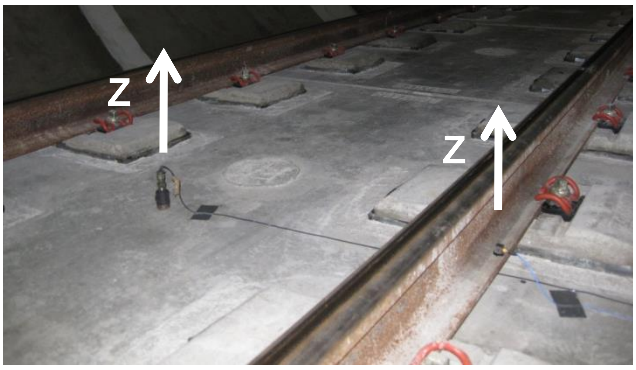
Time-dependant signals from all sensors are simultaneously acquired and later post-processed to obtain vibration spectra.




## Objective

Vibration measurements into railway tunnels to determine the efficiency against vibrations of different types of superstructures, applied vibration abatement solutions, the effect of wheel and rail roughness on vibration generation as well as getting input data for predictive vibration models.




# Case Study

# Vibration vs maintenance: Rail roughness characterisation

## Description

Railway vibration are generated at the wheel-rail contact area due to two main mechanisms: quasi-static excitation & dynamic excitation. Dynamic excitation is mainly driven by rail & wheel roughness.

*Technical Specifications for Interoperability, TSI*, specify limits for rail roughness and it is well known that maintenance is directly related to rail & wheel roughness.

AV Ingenieros have been working since its foundation in research on the relationship between railway maintenance and vibration.

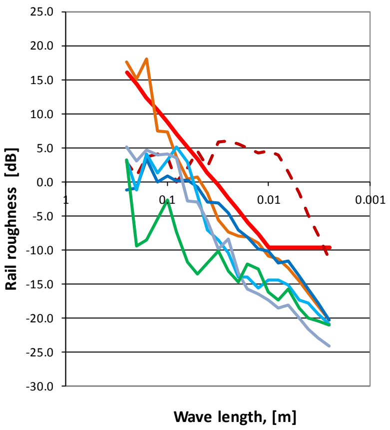
## Scope

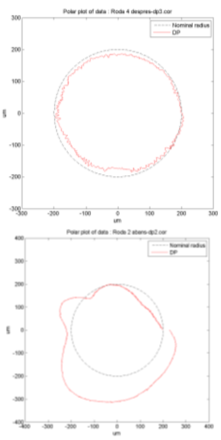
Rail roughness is measured in 6 different sections per rail. Six different rail wear conditions are characterised. Wheel roughness is measured in each wheel of a defined unit, before and after wheel maintenance.

Wheel out-of-roundness and rail & wheel roughness 1/3 octave band spectra are obtained.

Accelerometers are placed at the rail and the tunnel wall, where 3 orthogonally high sensitivity accelerometers are placed to measure the vibration vector.

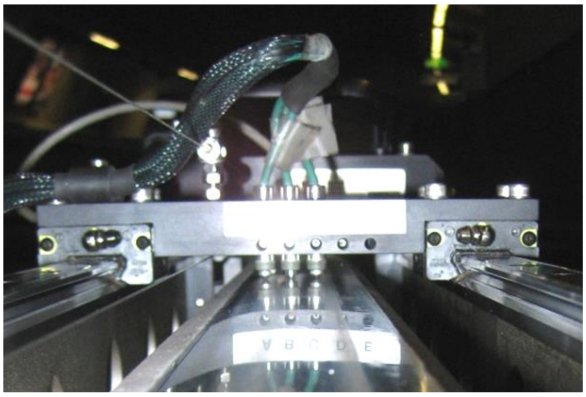
Time-dependant signals from all sensors are simultaneously acquired and later post-processed to obtain vibration spectra.

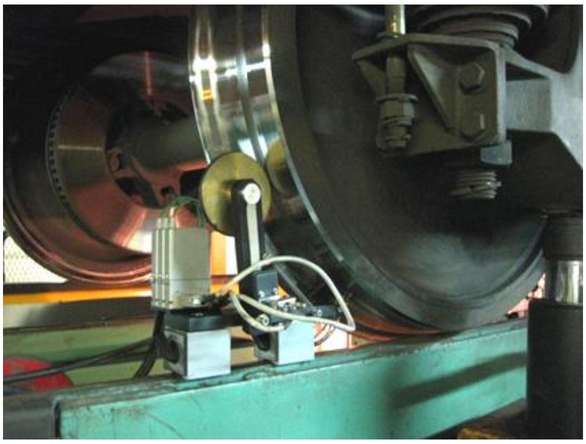


## Objective

Rail & wheel roughness characterisation along with way-side vibration monitoring to obtain relationship between rail and rolling stock maintenance and vibration levels.

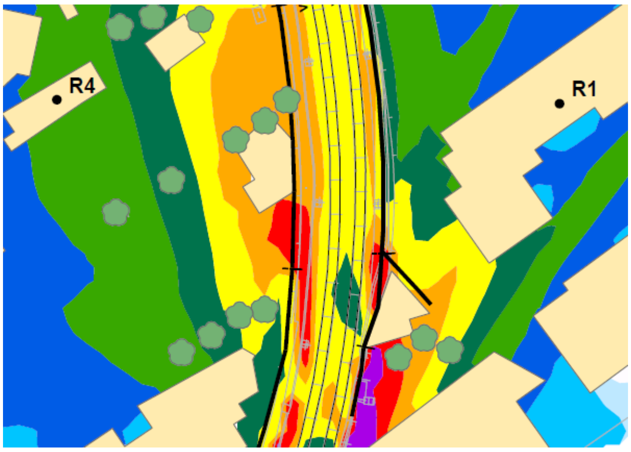


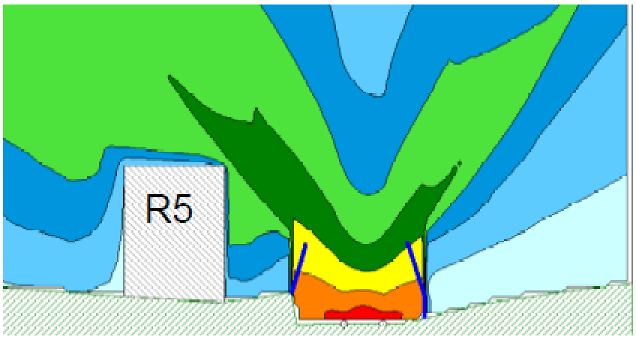


# Case Study

# Noise Abatement Solutions Design

2010- 2018



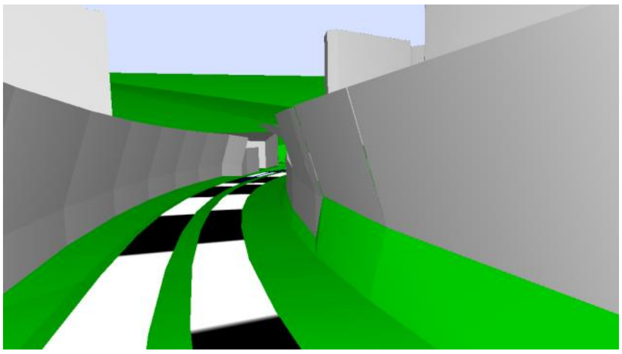

## Situation and description

A railway infrastructure is running through a high-density populated area, close to residential buildings. The consequence is that annoying outdoor noise levels are induced at building façades.

As a consequence, Railway Administrator have to enhance outdoor noise conditions using noise abatement solutions that minimizes those noise levels at building façades.

## Objective

Acoustic model of the area and noise abatement solutions' detailed design in order to improve outdoor noise landscape near railway infrastructure.



## Scope

In a first stage, as it's done in all noise abatement solutions' design projects, in situ experimental noise measurements are carried out during the operation of the railway infrastructure.

A virtual model of the railway infrastructure surroundings is developed using the predictive noise software CadnaA, properly validated with experimental noise measurements.

Simulation results allow to calculate the noise abatement solutions' efficiency in terms of dBA reduction.

Adequate noise barriers are designed and defined down to the last detail in order to construct them. After its construction, noise levels are measured to check the noise reduction efficiency.

# Case Study

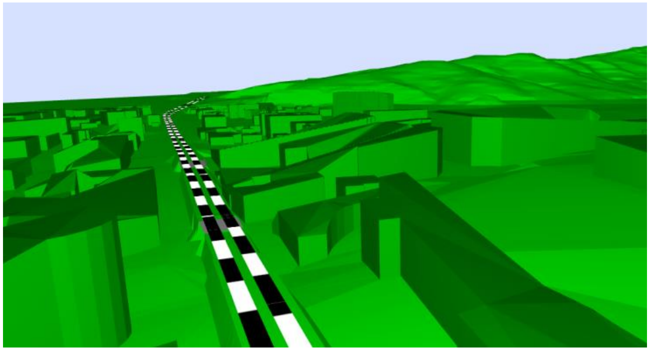
# Railway Noise Action Plans

2008- 2018

## Situation and description

In Europe, the responsible of transportation infrastructures has to elaborate noise strategic maps in order to assess the population exposition to noise levels generated due to infrastructure's operation.

The results of the noise strategic maps are the current noise situation and the population affected to those levels. As a consequence, noise action plans has to be defined and applied to get the appropriate acoustic quality in each area.



## Objective

Detailed outdoors noise levels at nearby buildings and noise abatement solutions' design to minimize the railway infrastructure noise impact.

## Scope

First of all, an experimental noise measurement campaign is carried out in order to determine the current outdoors noise levels at specific points during railway operation. Noise levels for different types of rolling stock are measured.

A virtual noise model is developed using the predictive noise software CadnaA.

Simulation results allows to calculate outdoors noise levels, the areas where noise levels are higher than those permitted and, therefore, the noise reduction objectives to be achieved using noise abatement solutions.

Design of the noise abatement solutions (mainly noise barriers) in order to reduce noise levels under those permitted.