CSTB
le futur en construction

CeLyA Summer School
Atmospheric Sound Propagation

June 14, 2018 – Ecully, France

Engineering Models: Noise Maps

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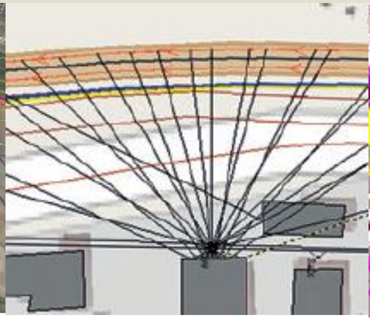
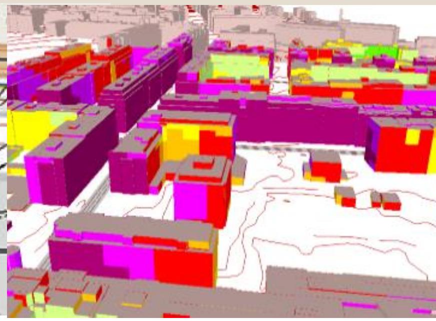
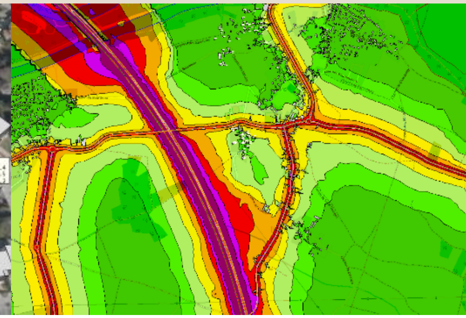
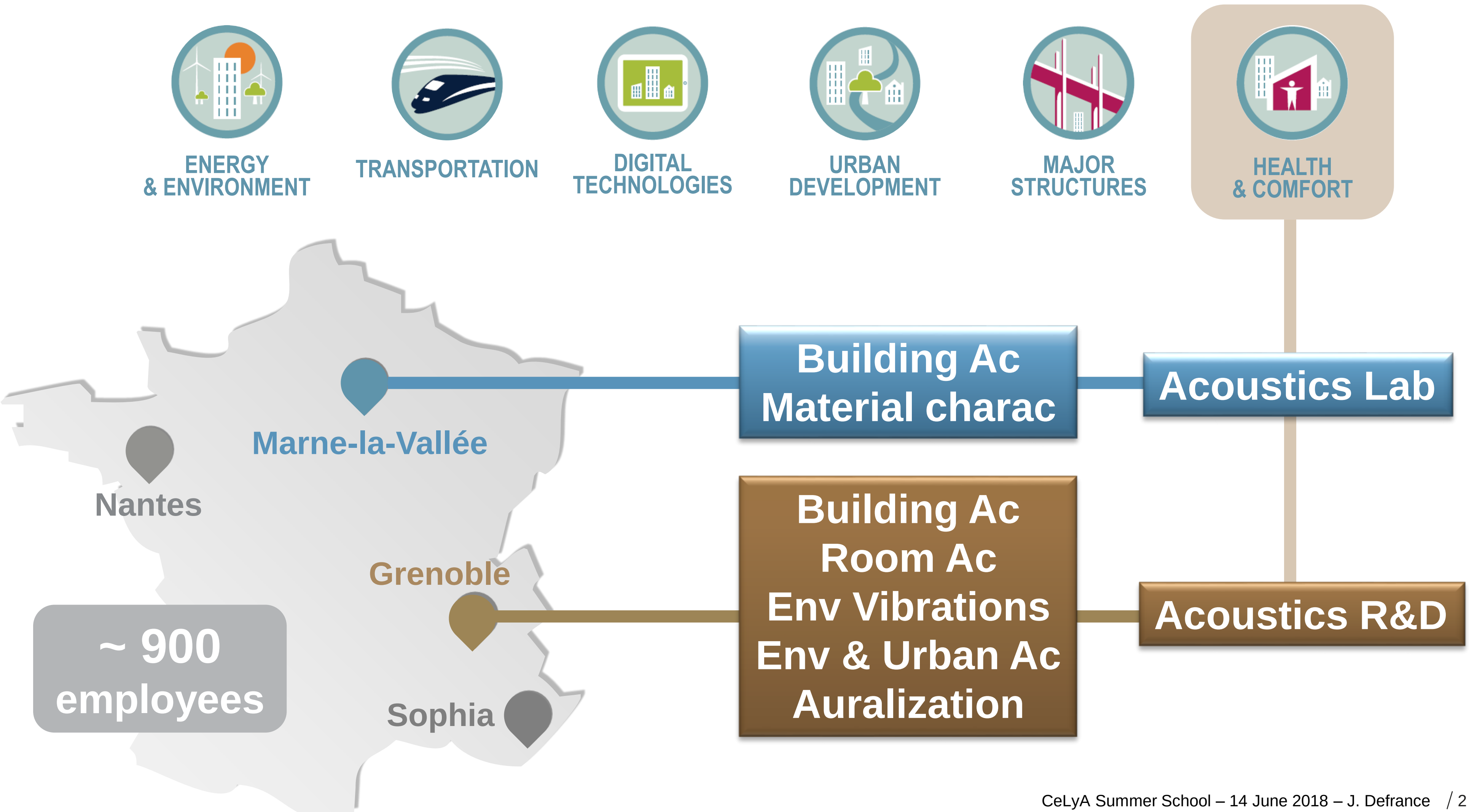





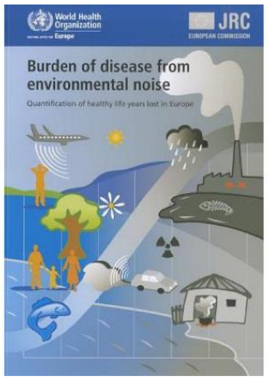
A few words on CSTB

Scientific and Technical Centre for Building

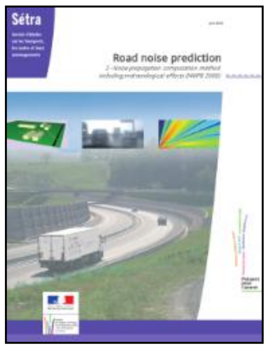


Outline

Context



Models



Noise Mapping

MithraSIG

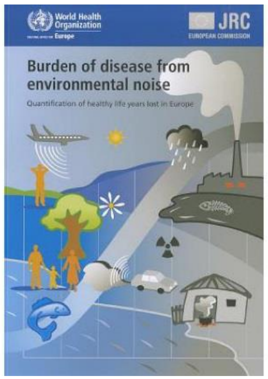
3D Sound Rendering

MithraSON

Perspectives

Outline

Context



Models

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Perspectives

Context

Burden of disease due to noise

An old evidence of annoyance (Caesar, Elisabeth I…)

In Europe 20th C, many surveys → Synthetic guides (WHO, EEA)

- 20% Europeans exposed to levels exceeding WHO thresholds
- 1.6M DALYs: Global morbidity due to Noise
- 1M DALYs: Sleep disturbance due to Noise

In France

- 86% concerned, 45% annoyed (IFOP 2014)
- Social cost of noise: €57 billion/year (CNB-E&Y 2016)

EEA, *Good practice guide on noise exposure and potential health effects*, 38p, 2010

WHO-JRC, *Burden of disease from environmental noise*,126p, 2011

Context

Regulatory development in France

Back in the 1990s…

- ‘Royal’ Law on Noise Control (1992)
- Set of ‘application texts’ (emissions abatement, transport noise, activity noise, urban planning…)
- Development of acoustics consultancy
- IT Development: Scale models → Numerical models → Software
- The acoustical engineer needed new prediction models: simple enough, accurate enough and fast enough / Accessible input data
    - *To meet regulation requirements*
    - *To propose and optimize noise solutions*

CIDB, *Centre d’Information et de Documentation sur le Bruit*, http://www.bruit.fr

Context

Regulatory development in France

Today, a set of regulations…

- Transport noise *($L_{06\text{-}22}$, $L_{22\text{-}06}$, L_{den}, max levels…)*
- Industrial/Facility Noise *(Emergence, max levels…)*
- Neighborhood Noise
- Activity Noise
- Etc. (buildings, noise at work, amplified music …)

Ministère de la Transition Ecologique et Solidaire, https://www.ecologique-solidaire.gouv.fr/bruit-et-nuisances-sonores

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Context

Environmental Noise Directive (END) 2002/49/EC

Objectives

- Determining the exposure to environmental noise
- Ensuring that information is made available to the public
- Preventing/reducing env noise + preserving env noise quality

Requirement every 5 years

- Strategic noise maps
- Noise management action plans (*PPBE* in French…)

Applied to

- Large agglomerations, major roads, major railways, major airports

Assessed through

- L_{night} (sleep disturbance)
- L_{den} (global annoyance)

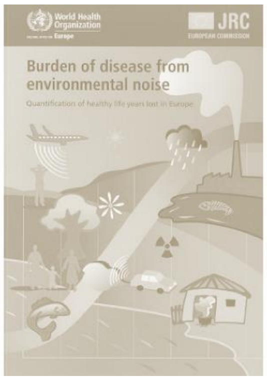
$$L_{den} = 10.\lg\frac{1}{24}\left(12.10^{L_{day}/10} + 4.10^{(L_{evening}+5)/10} + 8.10^{(L_{night}+10)/10}\right)$$

Rec 4m high / LAeq-3dB / No max levels

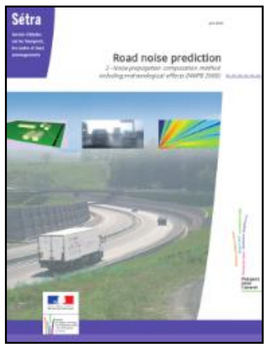
EC, *Directive 2002/49/EC relating to the assessment and management of environmental noise*, http://ec.europa.eu

Outline

Context



Models



Noise Mapping

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MithraSON

Perspectives

Engineering Models

Principles (Ray approach)

Source model (Pt/Lin/Surf/Vol)

Split into point sources

Lw & Directivity of each pt source

Paths determination for a given Rec

(different weather conditions)

Ac attenuations along each path

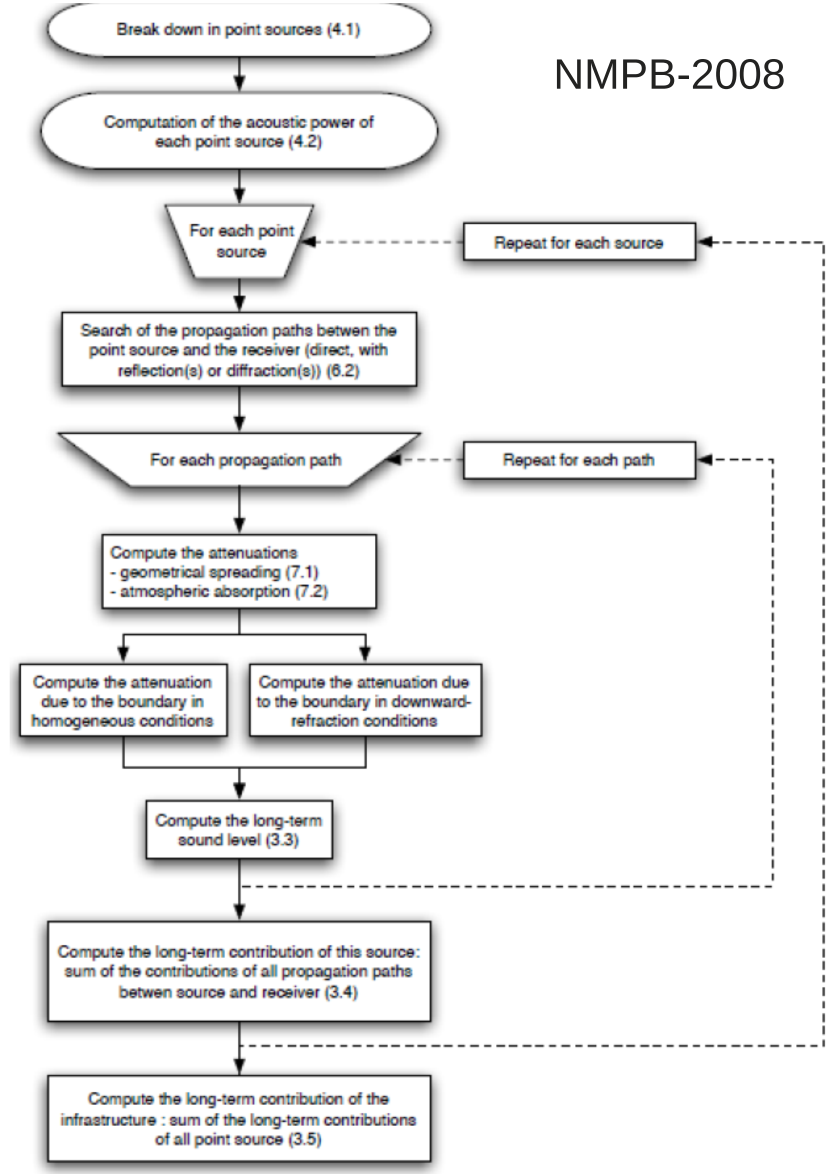
- Divergence & air absorption
- Ground effects
- Diffractions
- Reflections/Absorption
- Miscellaneous..

Sum over met conditions

Sum over paths

Sum over sources

NMPB-2008



Engineering Models

Some well-known ray models in Europe

Model	Some charecteristics of the attenuation part	Complexity
ISO 9613-2	- Empirical formula for ground effects - Not developed for low height sources - Equivalent flat ground, G factor - One rough correction for Met conditions	+
NMPB-2008	- Two fixed weather conditions (H, F) - UiTi Grid approach - Equivalent flat ground, G factor from σ - Not applicable over water and mountain aeras	++
Nord2000	- Fresnel-zone for ground reflections, σ, broken-line - Fresnel-zone for vertical reflections - Weather parameters adjustable (lin-log) 25 classes	+++
Harmonoise	- Close to Nord2000 - Multiple Diffractions: Recursive approach (Deygout) - Weather: curved ground analogy	+++
CNOSSOS-EU	- Similar to NMPB-2008	++

Dutilleux G, Defrance J et al., *NMPB-Routes-2008: The revision of the French method […] noise prediction, Acta Acustica 96(3), 452-462 (2010)*

Salomons E, Van Maercke D, Defrance J, De Roo Foort, *The Harmonoise sound propagation model, Acta Acustica 97, 62-74 (2011)*

Engineering Models

Focus on the NMPB-2008 (propagation part)

Long-term sound level calculated with 2 met conditions *F* and *H*

$$L_{Ai,LT} = 10\log_{10}\left(p_i 10^{0.1L_{Ai,F}} + (1-p_i)10^{0.1L_{Ai,H}}\right)$$

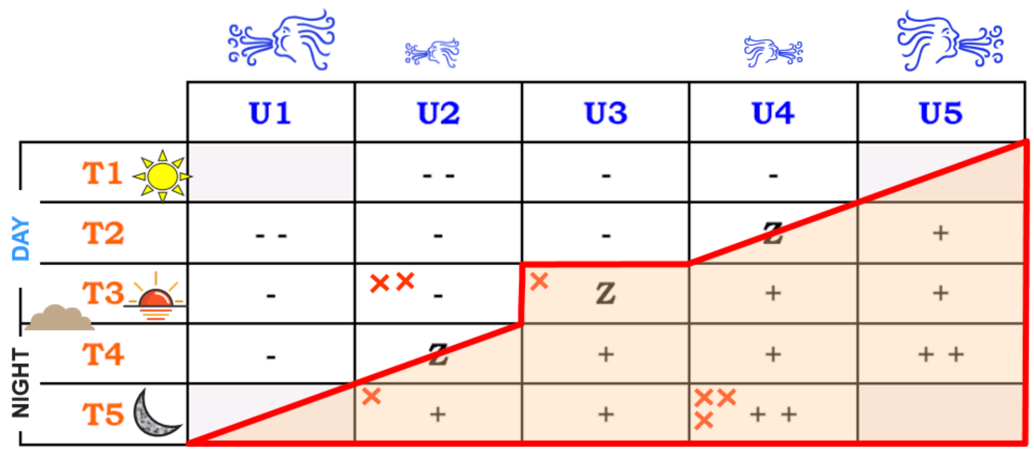
i = 3rd octave band / 100-5000 Hz

Probability of occurrence p_i for *Favorable* conditions given for

- 41 French weather stations / by 20° sectors of S-R direction
- 2 periods (06.00-22.00, 22.00-06.00) and 3 periods (06.00-18.00, 18.00-22.00, 22.00-06.00)

UiTi Grid

T1:	day and strong radiation and dry surface and calm wind
T2:	same conditions as T1 but at least one does not apply
T3:	sunrise or dawn or (overcast and windy and not too humid surface)
T4:	night and (cloudy or wind)
T5:	night and open sky and calm wind



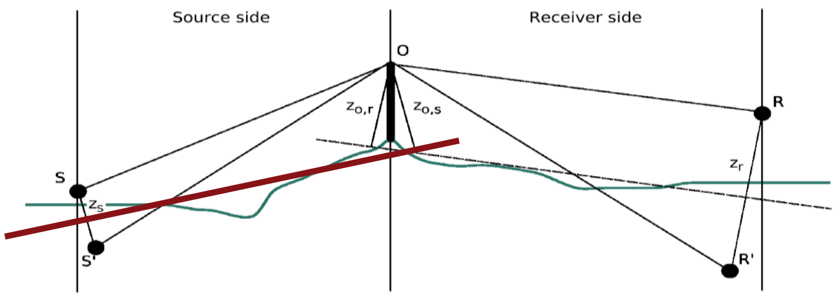
Engineering Models

Focus on the NMPB-2008 (propagation part)

Attenuation calculation

$$L_{A,C} = L_w - (A_{div} + A_{atm} + A_{bnd,C})$$

4-ray approach



Mean plane

$$A_{dif} = -20\log_{10}\left[10^{\frac{-\Delta_{dif}(S,R)}{20}}\left(1+\left(10^{\frac{-A_{ground}(S,O)}{20}}-1\right)10^{-\frac{\Delta_{dif}(S',R)-\Delta_{dif}(S,R)}{20}}\right)\left(1+\left(10^{\frac{-A_{ground}(O,R)}{20}}-1\right)10^{-\frac{\Delta_{dif}(S,R')-\Delta_{dif}(S,R)}{20}}\right)\right]$$

Engineering Models

Focus on the NMPB-2008 (propagation part)

Ground effect

$$A_{ground,H} = -10\log_{10}\left[4\frac{k^2}{d_p^2}\left(z_s^2 - \sqrt{\frac{2C_f}{k}}z_s + \frac{C_f}{k}\right)\times\left(z_r^2 - \sqrt{\frac{2C_f}{k}}z_r + \frac{C_f}{k}\right)\right]$$

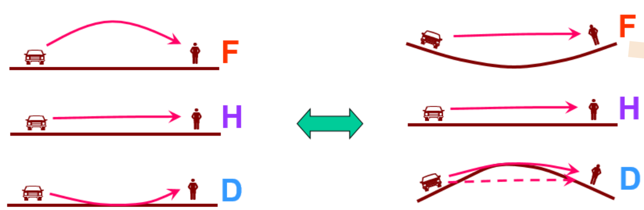
$$Att_{grd} = -20\ log\left|1 + Q\frac{d}{d'}e^{jk(d-d')}\right|$$

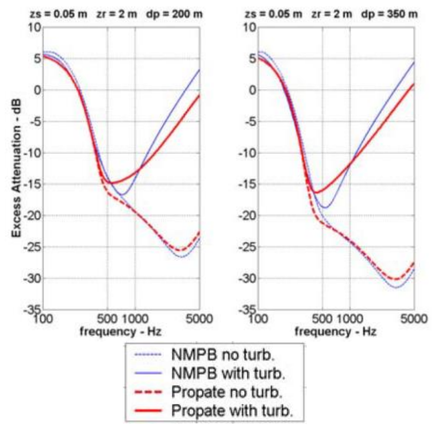
$$A_{ground,F} = -10\log_{10}\left[4\frac{k^2}{d_p^2}\left(\tilde{z}_s^2 - \sqrt{\frac{2C_f}{k}}\tilde{z}_s + \frac{C_f}{k}\right)\times\left(\tilde{z}_r^2 - \sqrt{\frac{2C_f}{k}}\tilde{z}_r + \frac{C_f}{k}\right)\right]$$

$$\tilde{z}_s = z_s + \delta z_s + \delta z_T, \quad \tilde{z}_r = z_r + \delta z_r + \delta z_T$$

$$\delta z_T = \frac{C_T d_p}{z_s + z_r}$$

$$\delta z_s = \frac{b}{2c_0}\left[\frac{d_p z_s}{z_s + z_r}\right]^2$$





Defrance J, Gabillet Y, *A new analytical method for the calculation of outdoor noise propagation, Applied Acoustics 57(2), 109-127 (1999)*

Defrance J, Bérengier M, Rondeau JF, *Validation and evolution of the road traffic noise prediction method NMPB-96. Inter-Noise 2001*

Engineering Models

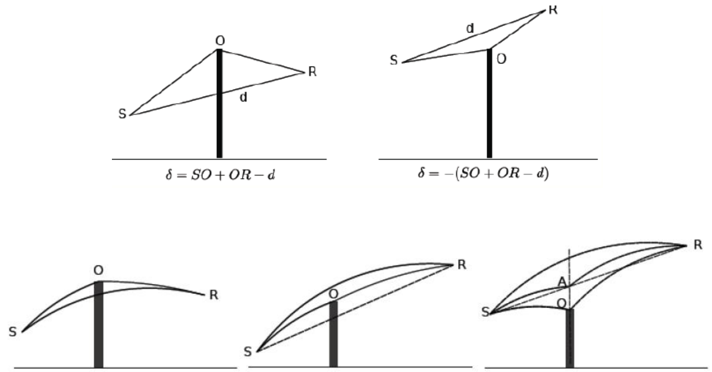
Focus on the NMPB-2008 (propagation part)

Diffraction

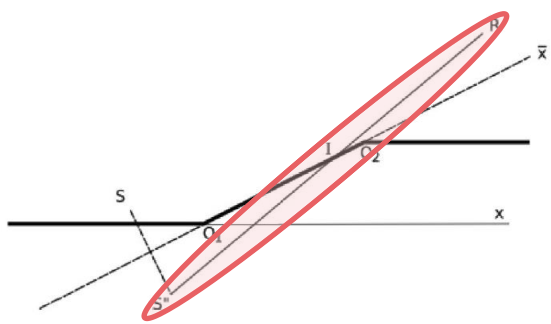
Fresnel Number = **2δ/λ** ≥ -0.1

$$\Delta_{dif} = 10C_h \log_{10}(3 + 20N)$$

Low height



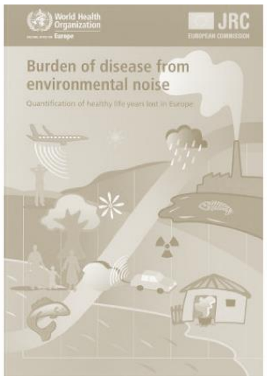
Reflection on embankment slope



$$A_{emb} = -1.5\epsilon(2 - G_{emb})$$

Outline

Context



Models

Noise Mapping

MithraSIG

3D Sound Rendering

MithraSON

Perspectives

Noise Mapping

Building a project

Geometry

- Topography and Land covering
- Buildings, Transport platforms

(+ Weather data)

Sources

- Roads, Railways,…
- Industries, Activities,…

Receivers

- Maps (H, V, façade)
- Receivers (façade or not)

Noise systems

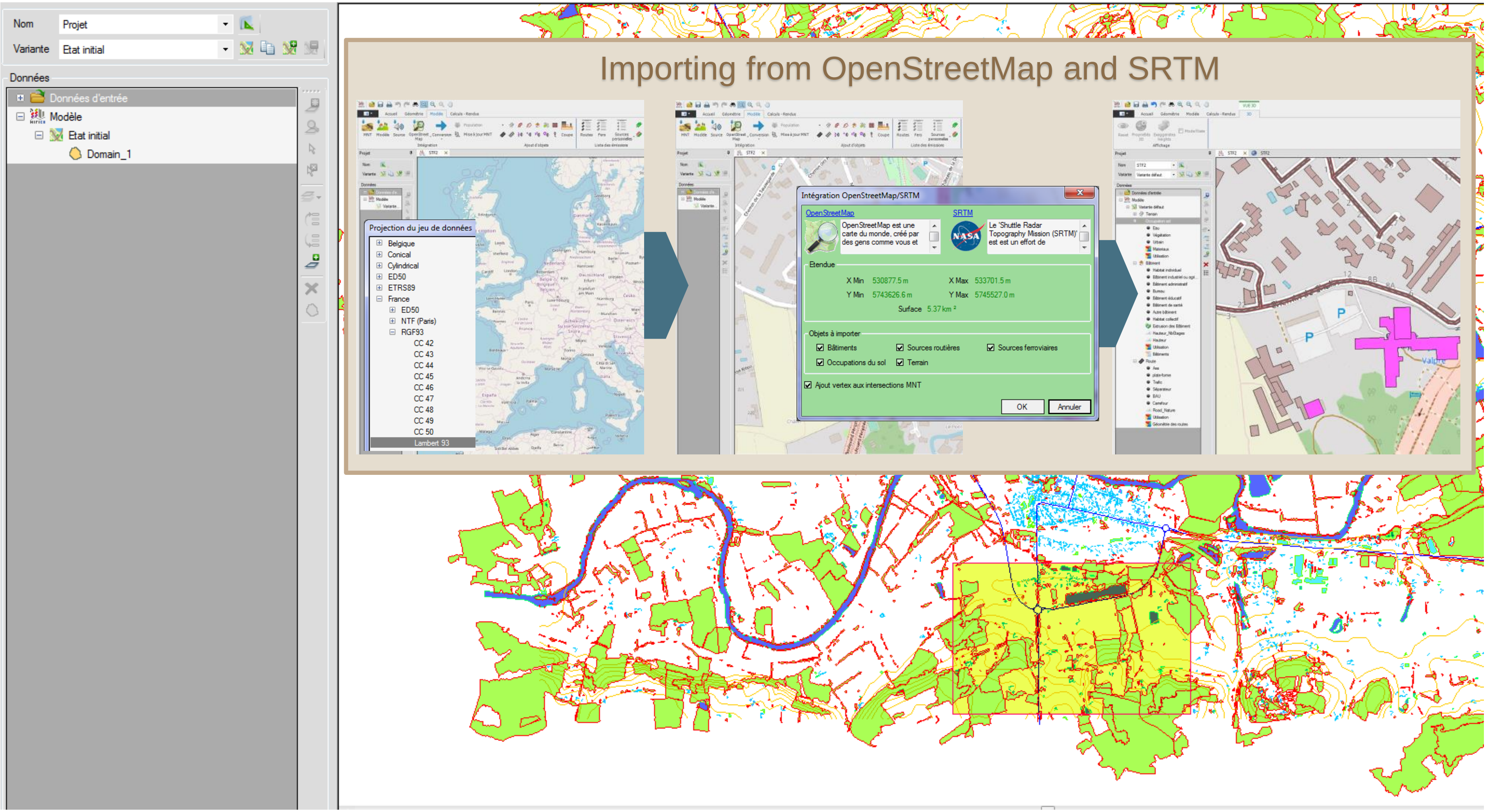
- Barriers
- Berms

Geomod, https://data.geomod.fr/fr/geomatique-terrestre/mithrasig

CSTB, http://logiciels.cstb.fr/sante-confort/acoustique-environmentale-et-urbaine/mithrasig

Noise Mapping

Data collection (many formats, Open Data…)

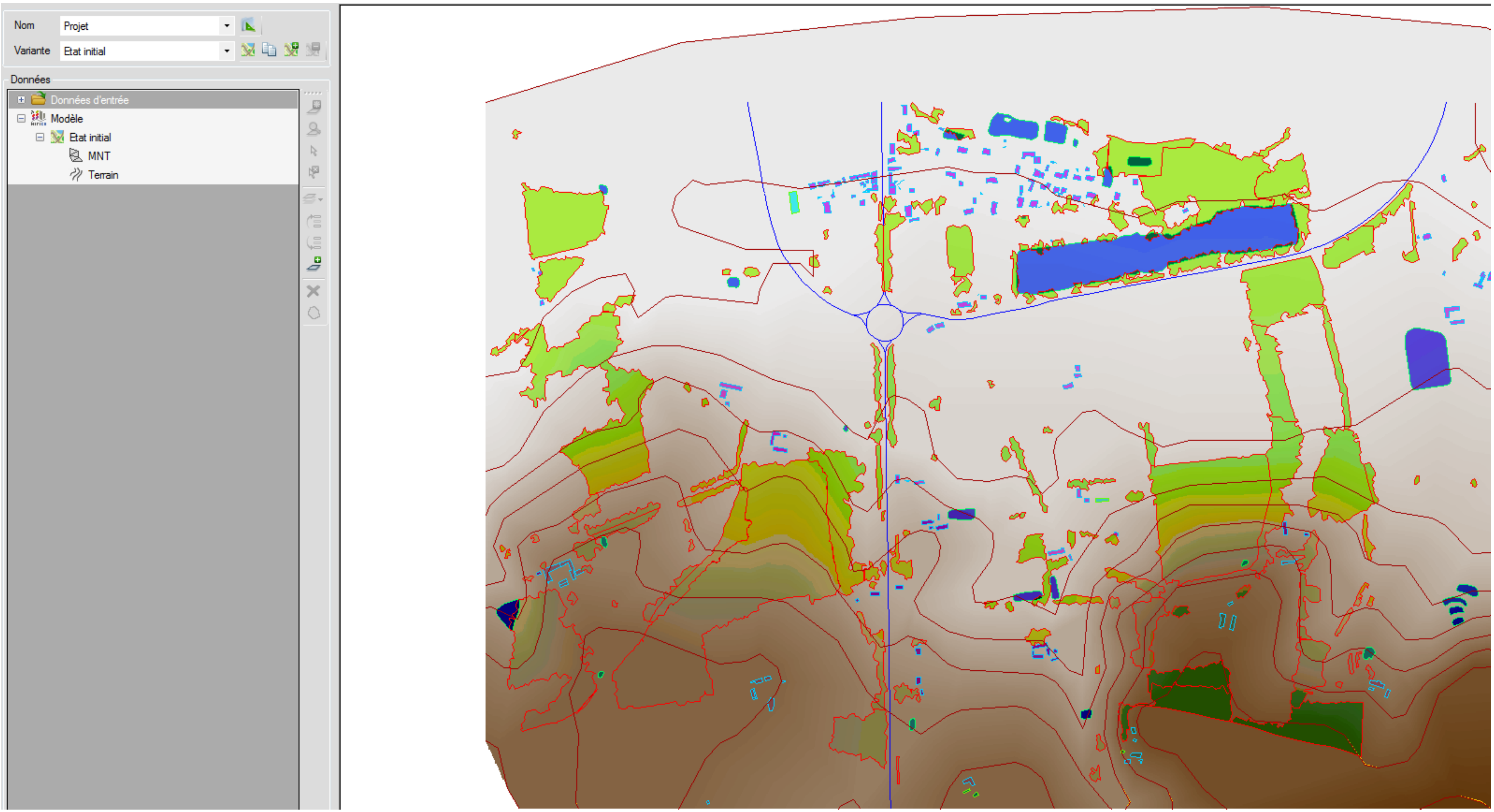


Noise Mapping

Site selection

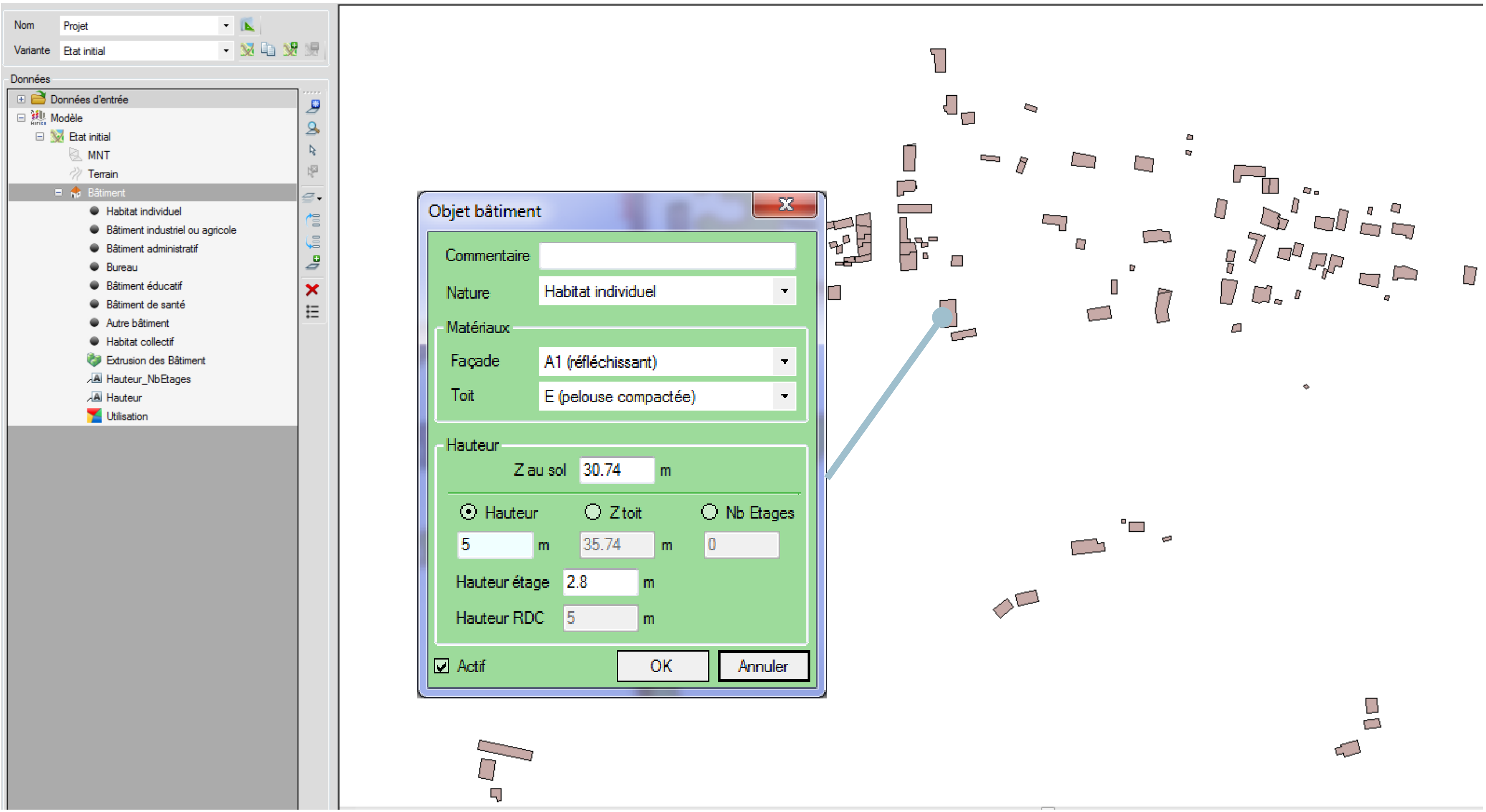
Noise Mapping

Ground (DEM)



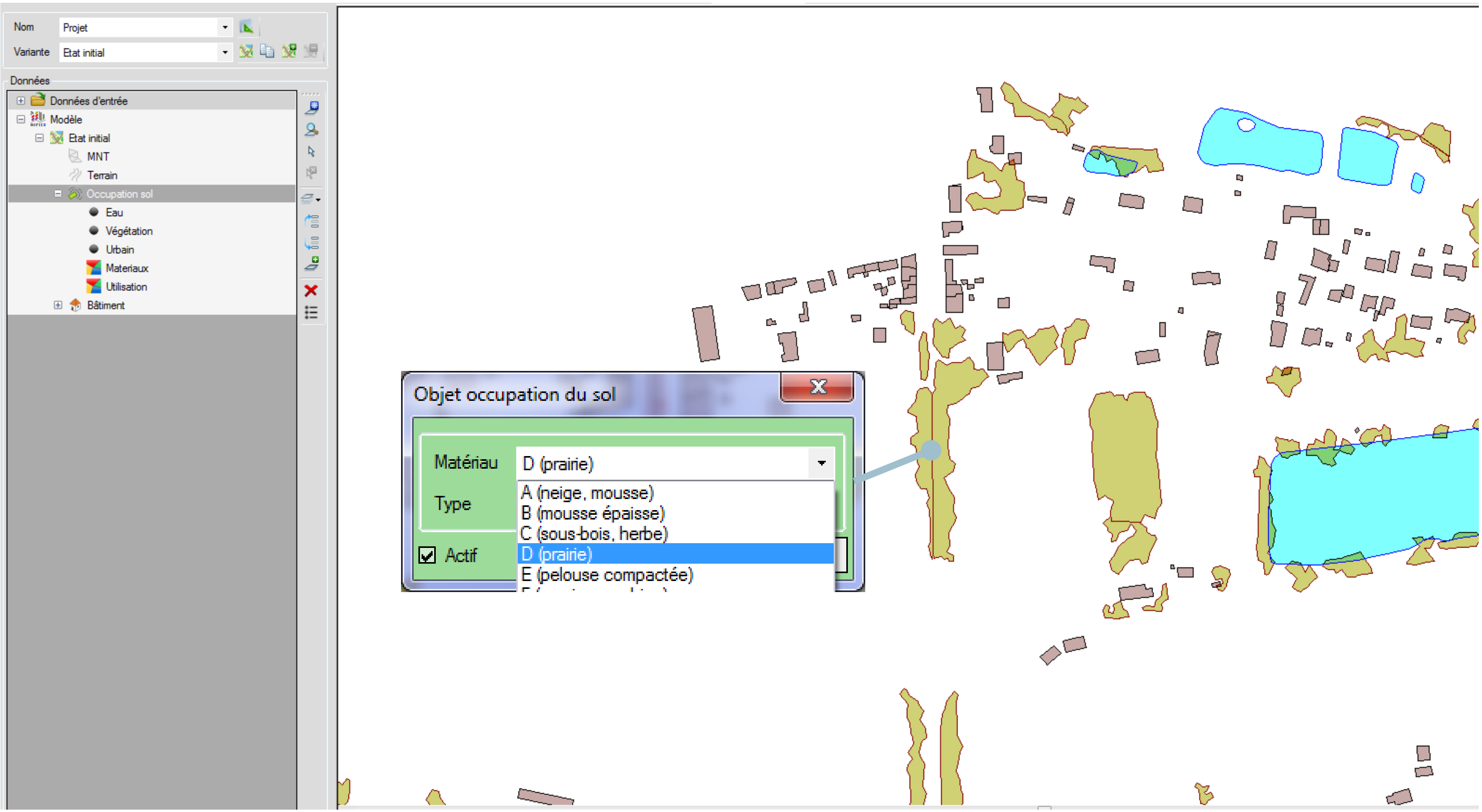
Noise Mapping

Buildings



Noise Mapping

Land cover



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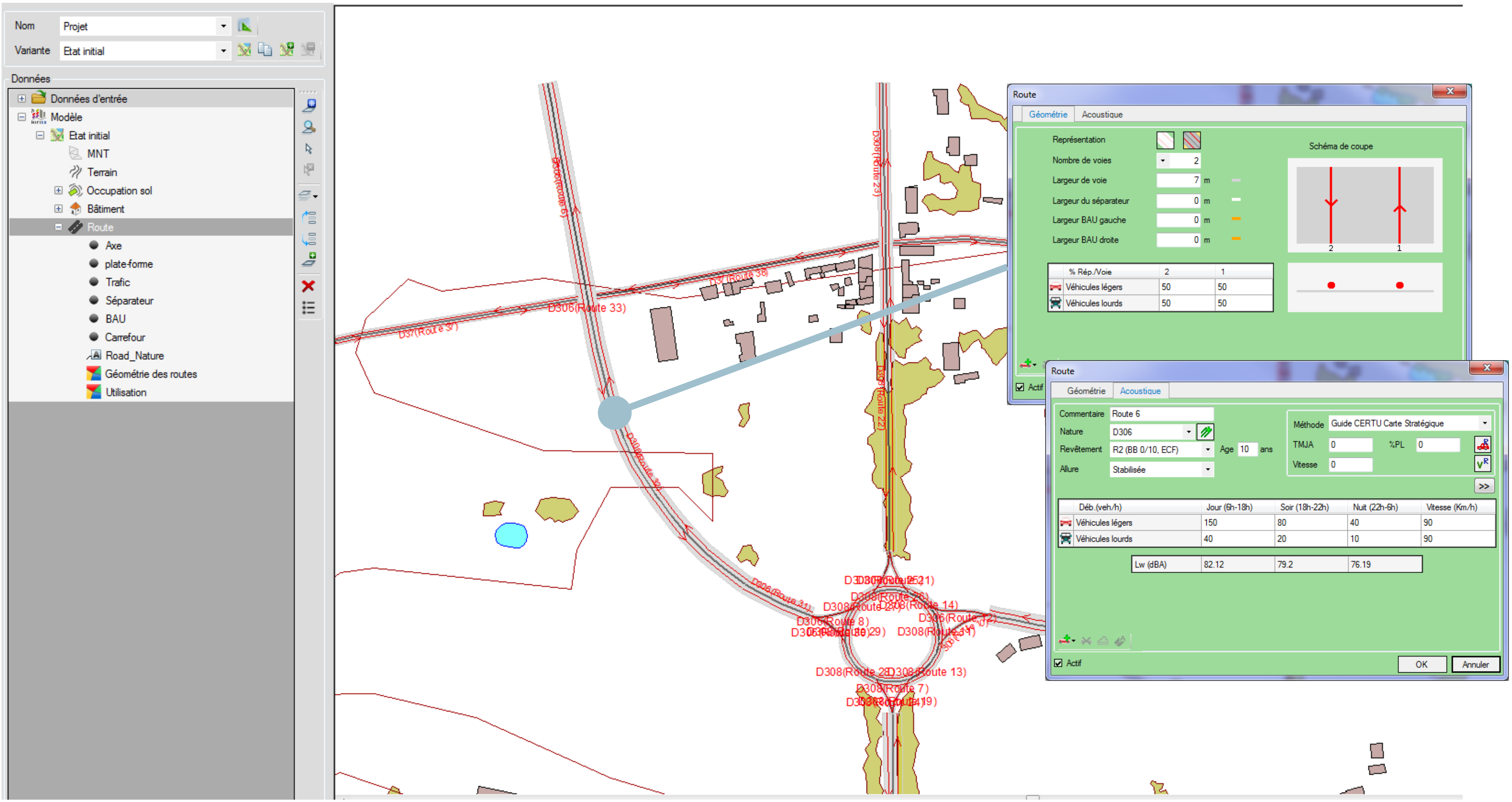
Noise Mapping

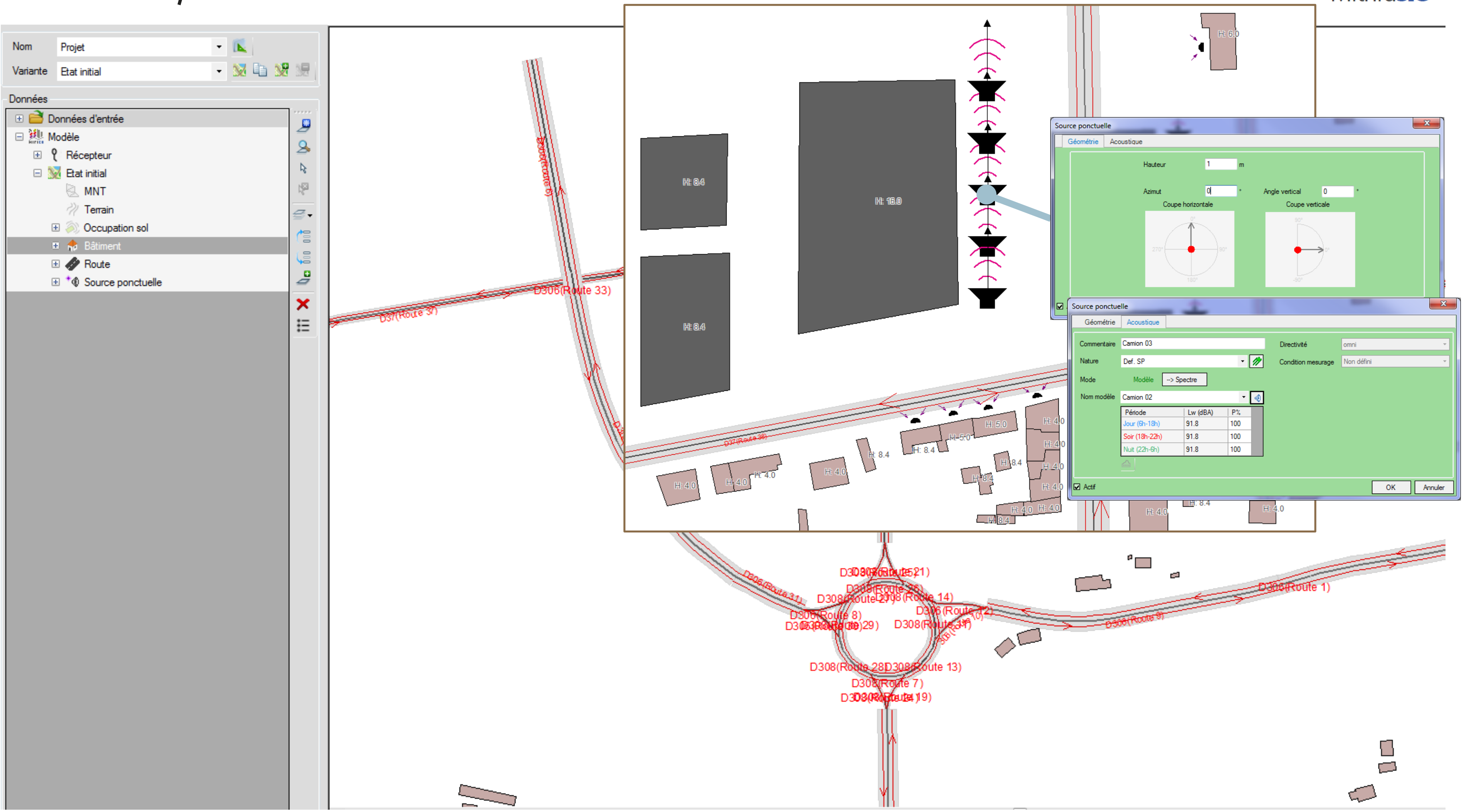
Traffic: Roads, Railways, Tramways…

MithraSIG



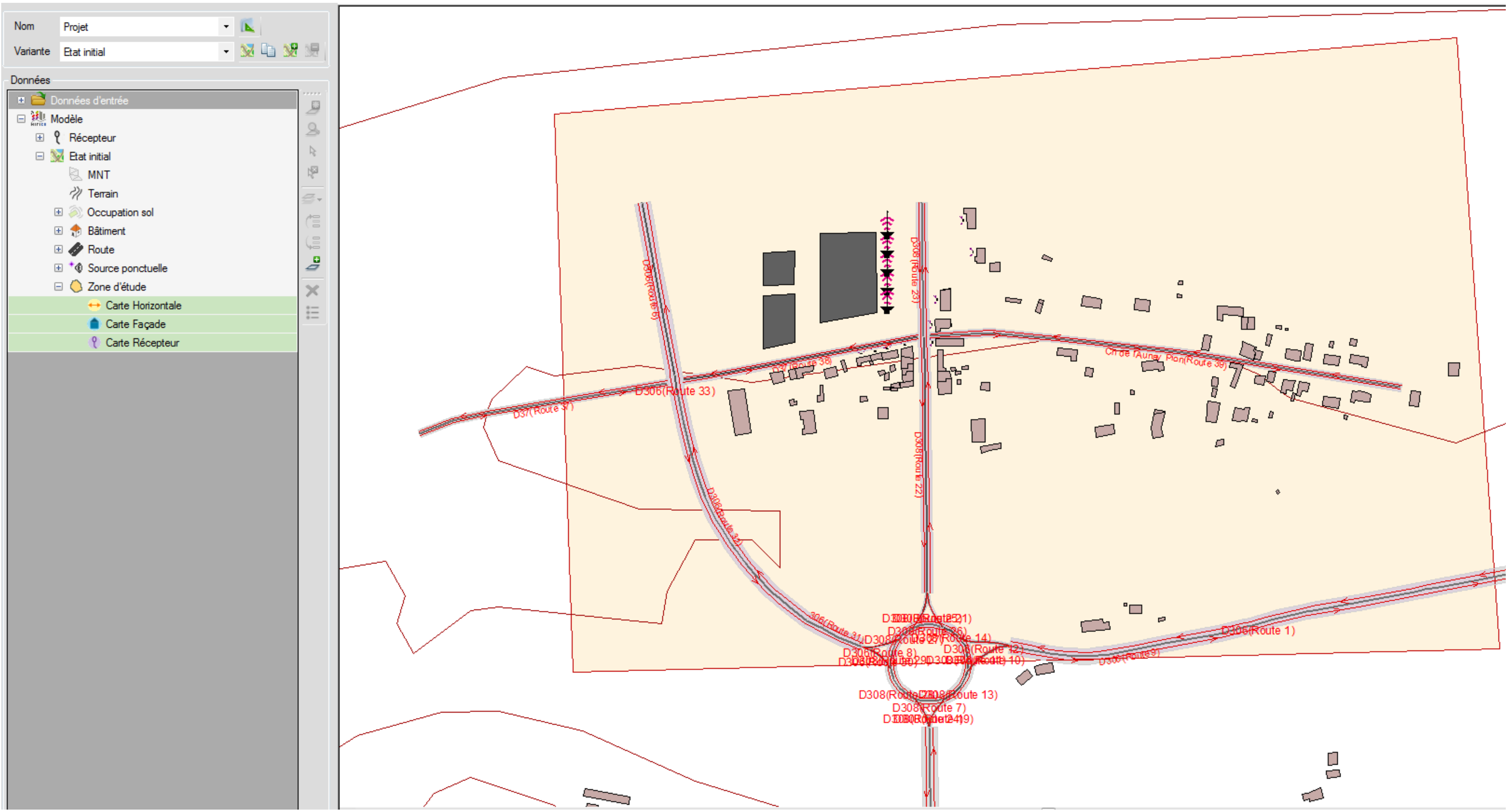
Noise Mapping

Other Elements (Sources, Receivers…)



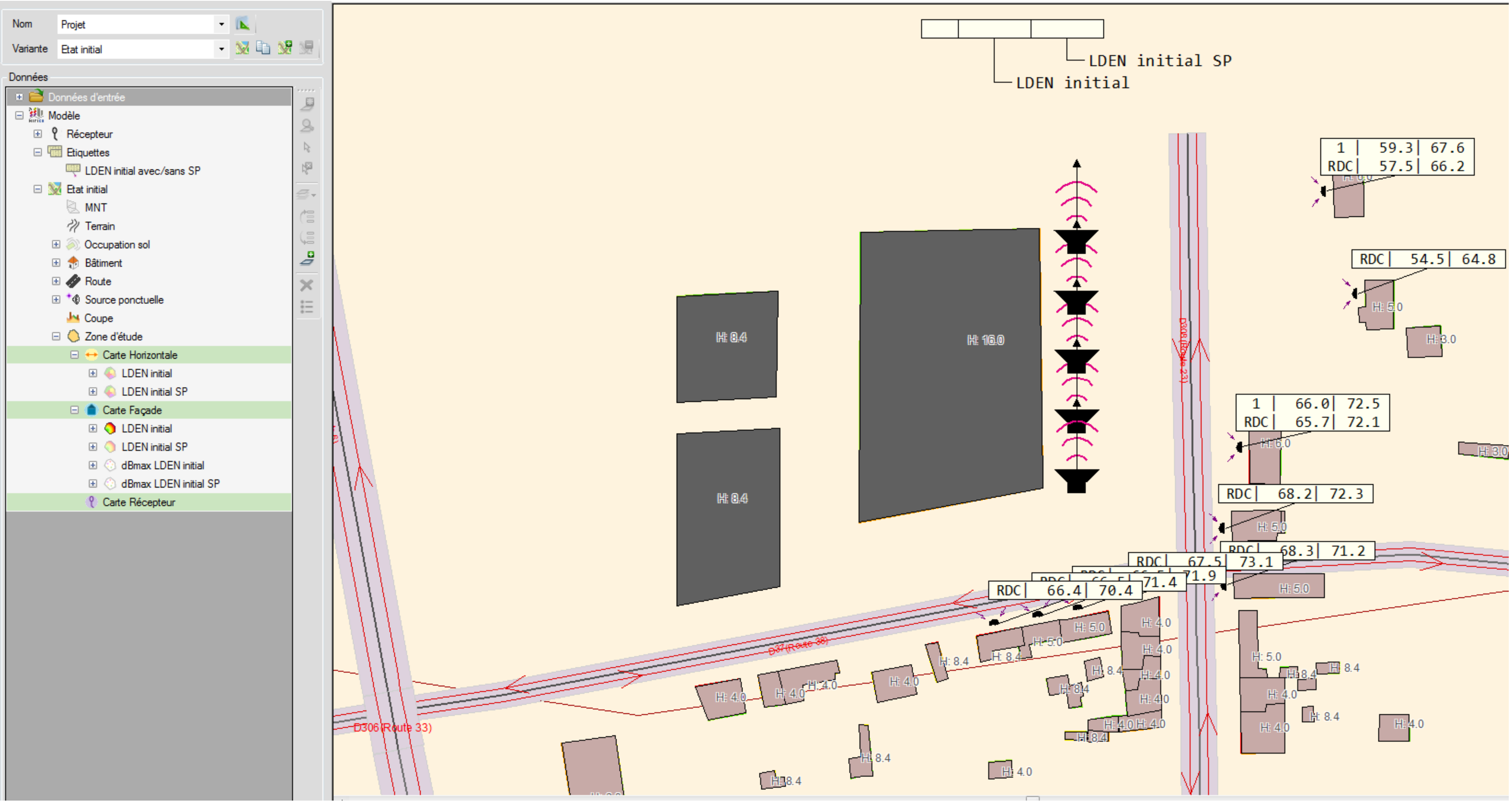
Noise Mapping

Initial state calculation



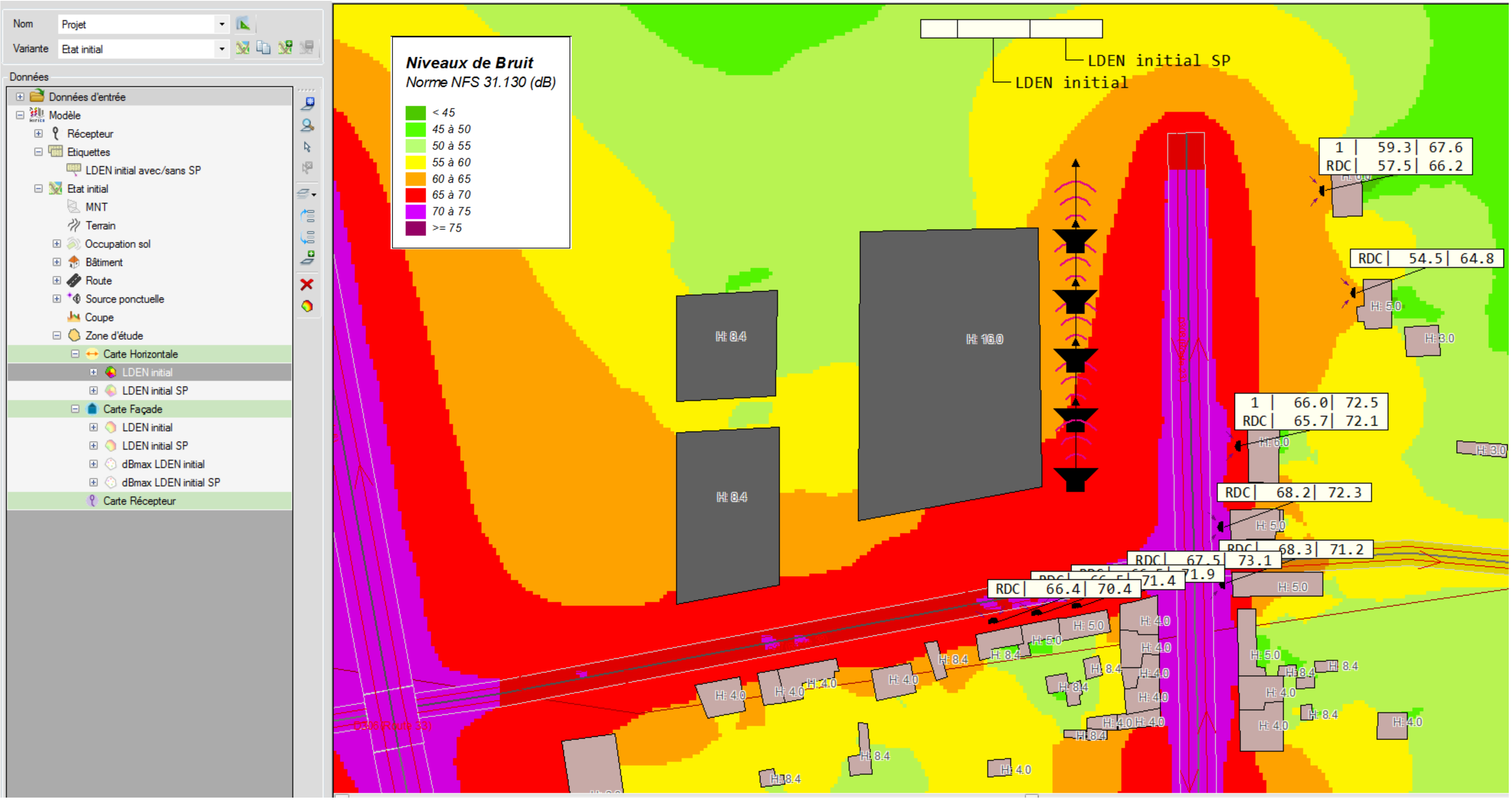
Noise Mapping

Initial state results



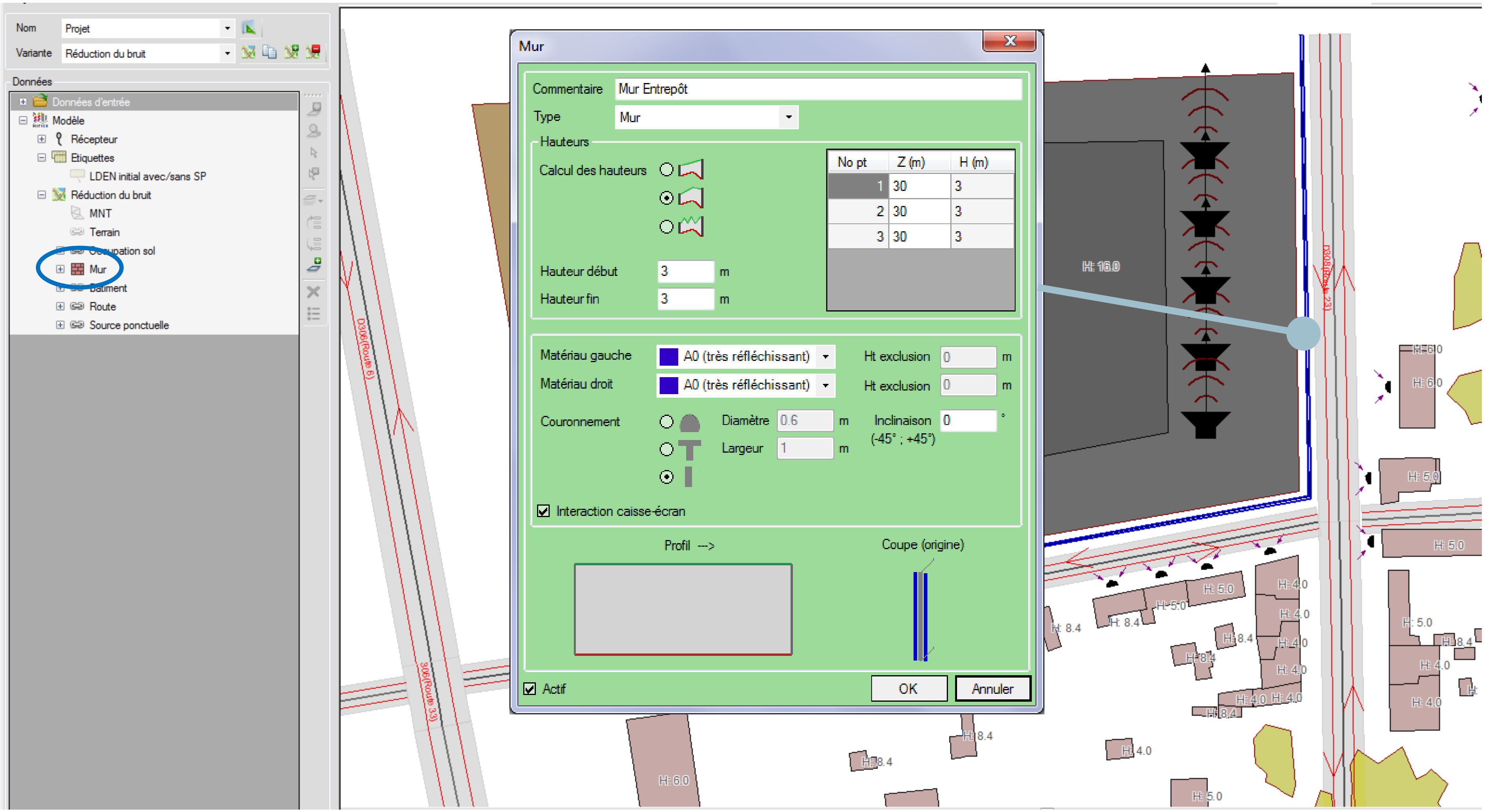
Noise Mapping

Initial state results



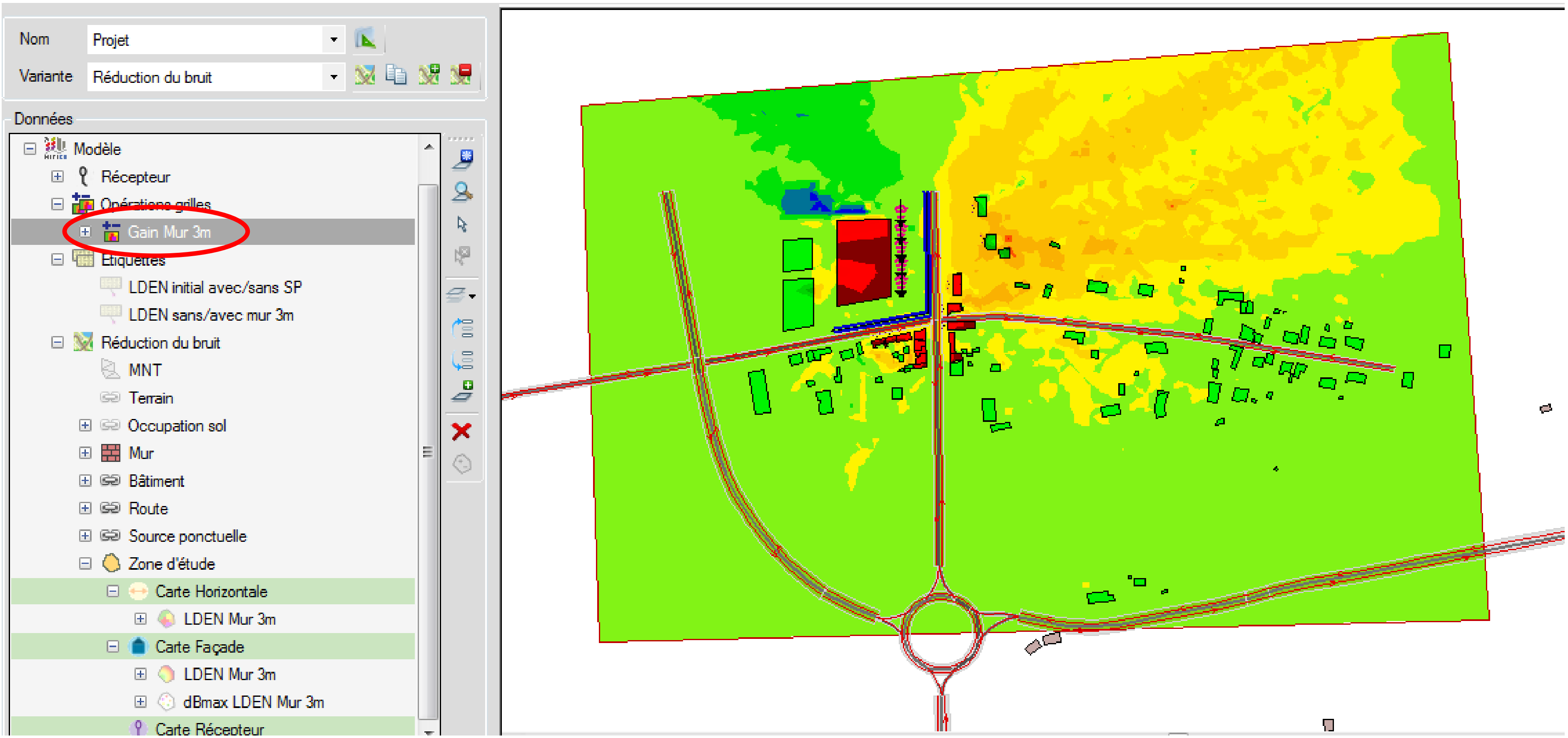
Noise Mapping

Noise abatement scenarios (barriers, traffic, buildings…)



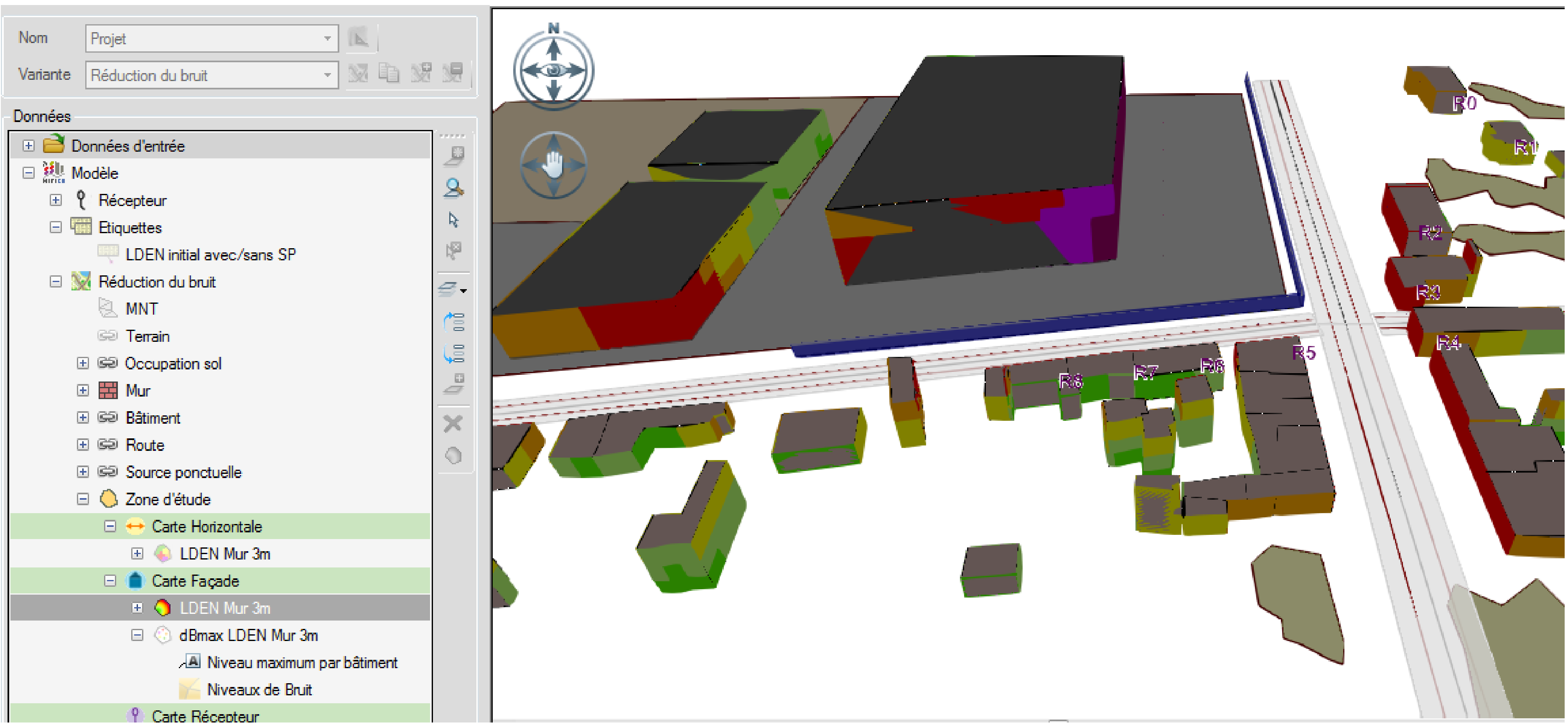
Noise Mapping

Barrier efficiency (also 'Conflict maps'…)



Noise Mapping

Façade Maps



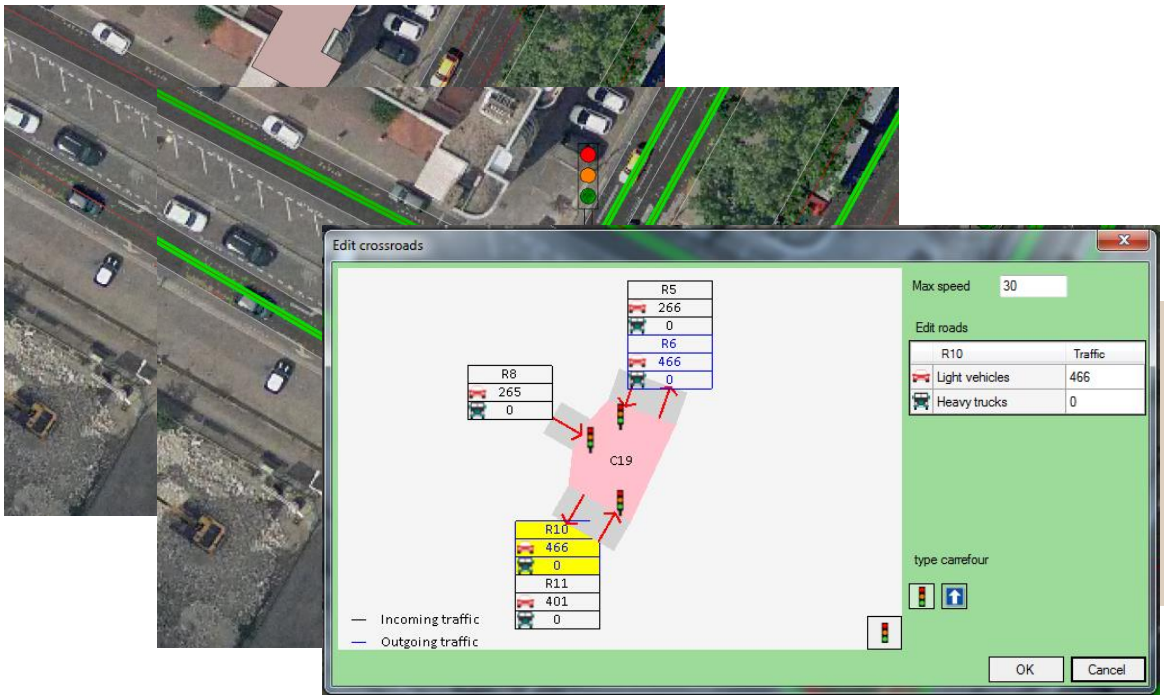
Noise Mapping

Displaying with Google Earth (.kmz)

Noise Mapping

Toward Perceptive Noise Mapping

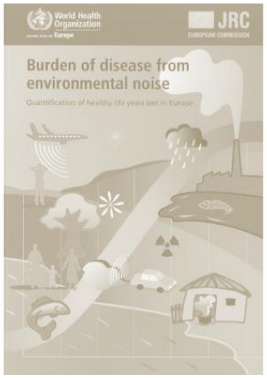
Preparing detailed traffic data under MithraSIG



Exporting toward MithraSON for dynamic traffic simulations

Outline

Context



Models

Noise Mapping

MithraSIG

3D Sound Rendering

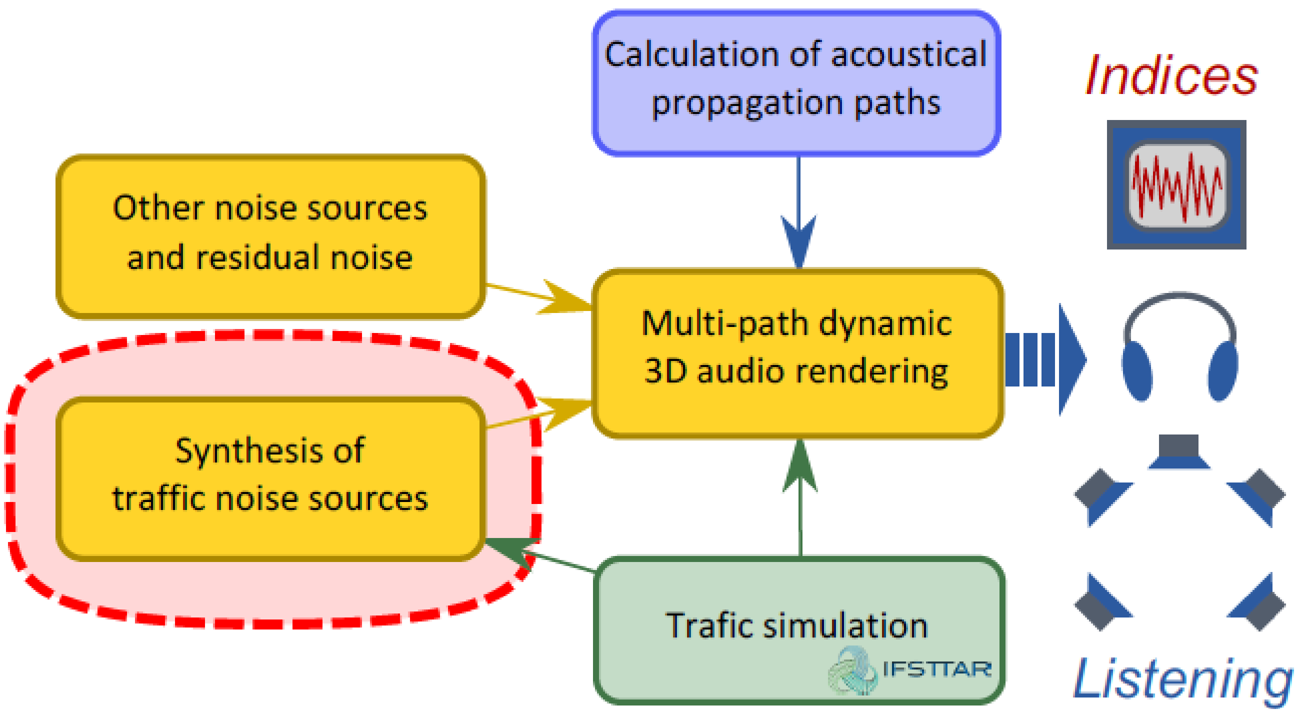
MithraSON

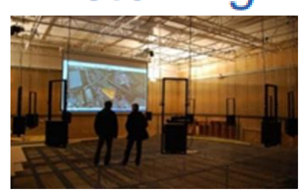
Perspectives

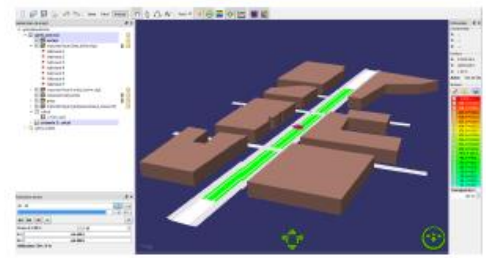
3D Sound Rendering

Principles

General framework





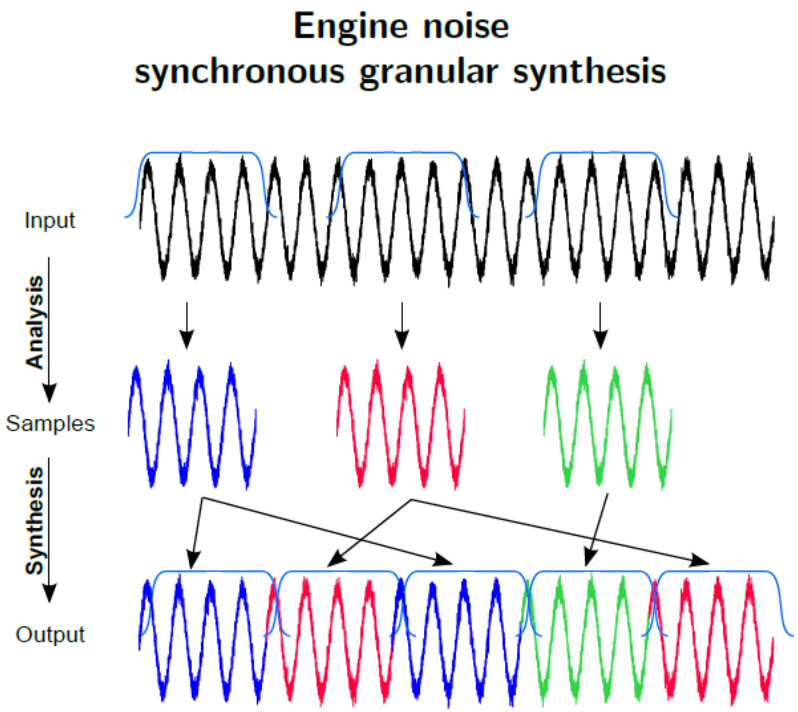


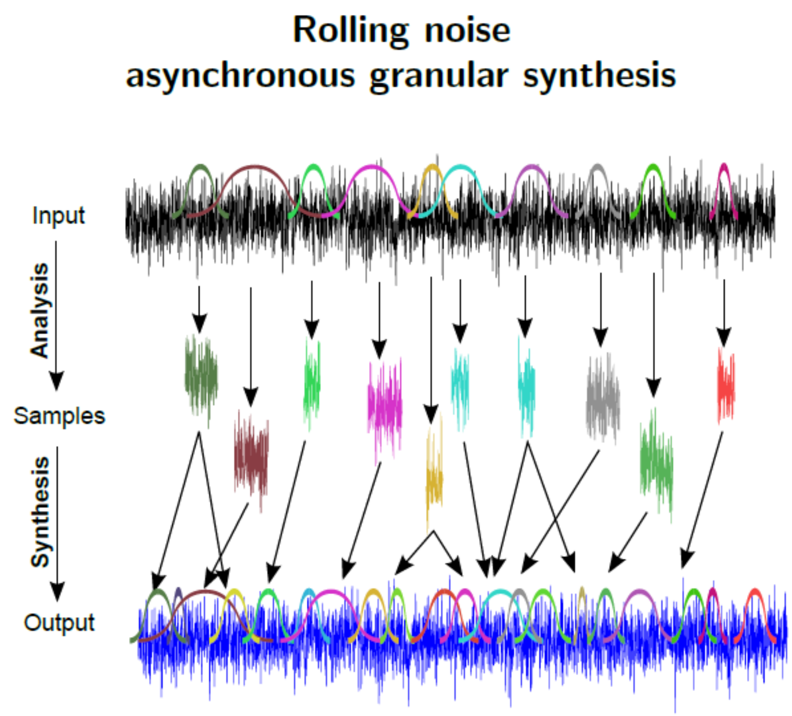
MithraSON

CSTB, http://logiciels.cstb.fr/sante-confort/acoustique-environmentale-et-urbaine/mithrason

3D Sound Rendering

Granular Synthesis





J. Maillard, J. Jagla, N. Martin, *Sample-based engine noise synthesis…, JASA 132(5), 3098-3108 (2012)*

J. Maillard, J. Jagla, *Effect of Load on Engine Noise for the Auralization of Road Traffic, EuroNoise 2015, Maastricht*

3D Sound Rendering

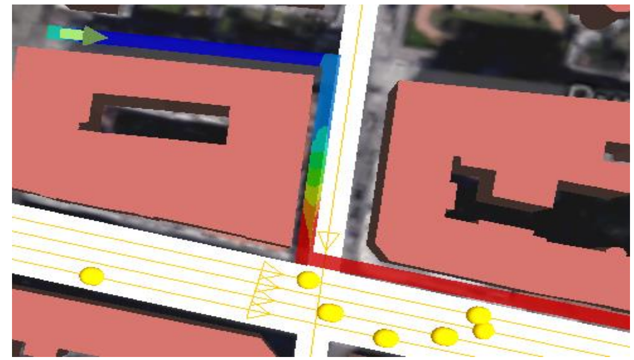
Some demos…

3D Sound Rendering

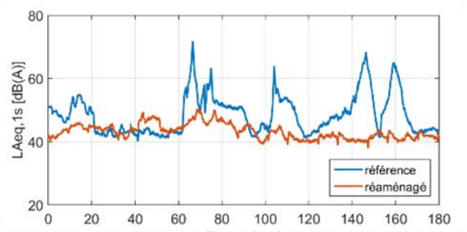
Quick presentation of MithraSON

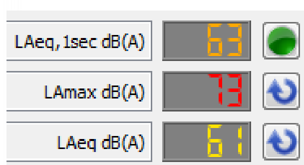
Data (can be imported from MithraSIG)

Paths characterisation

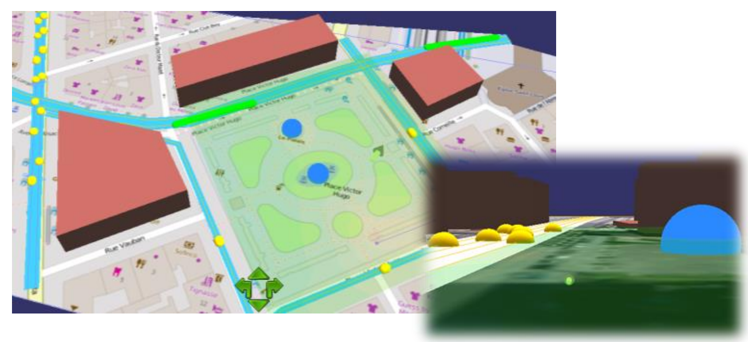


Dynamic Indicators Scenarios comparison



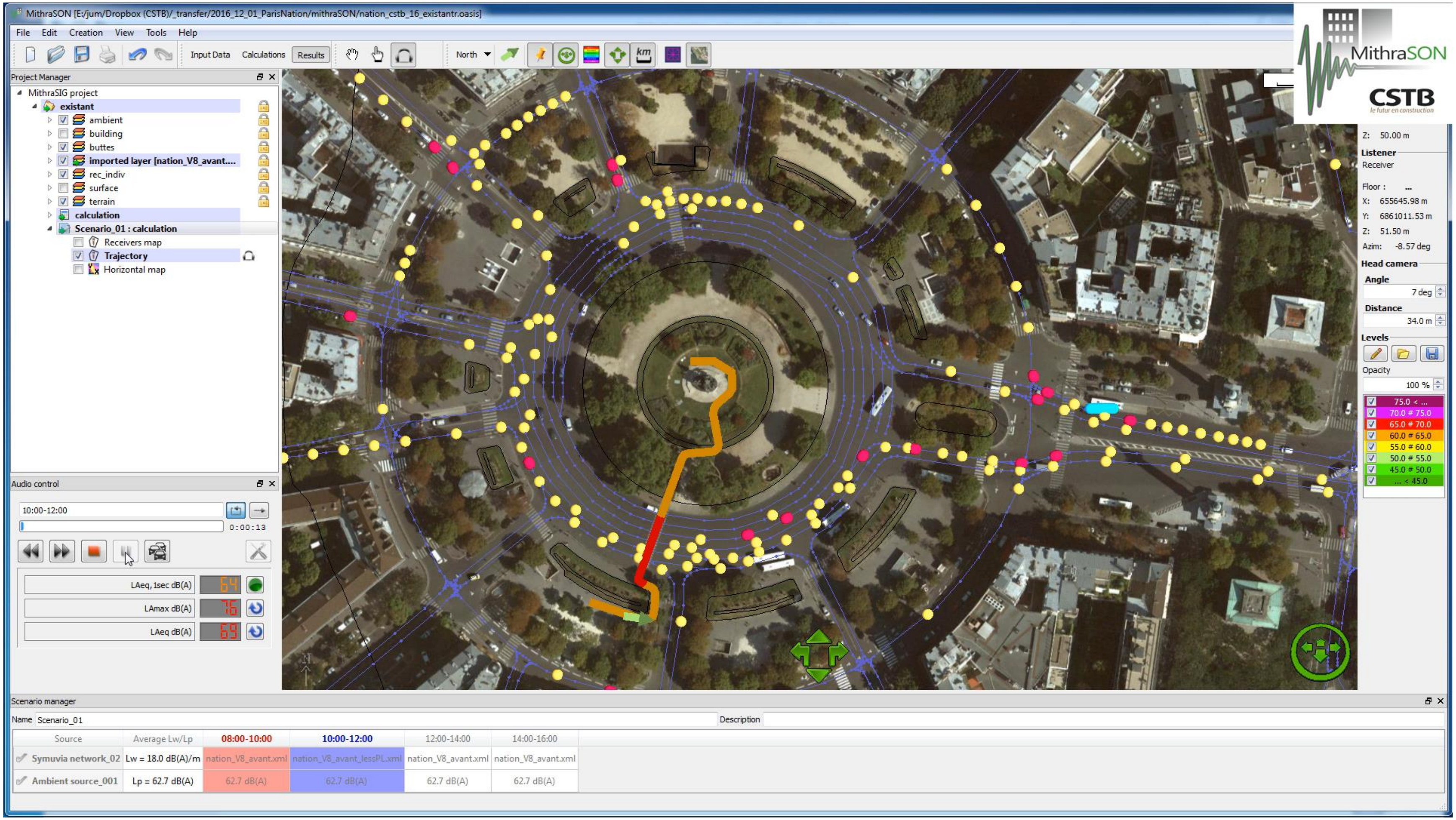


Immersive listening



3D Sound Rendering

Recent project: Place de la Nation, Paris



3D Sound Rendering

Application Example #1: teaching tool

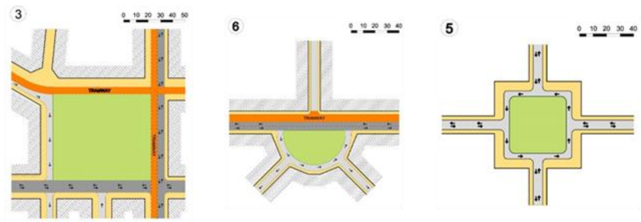
Context

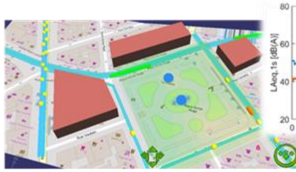
Application Example #2: REMUS Project (low barriers)

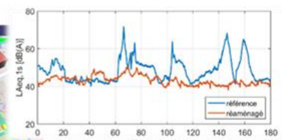
Typologies et scénarios

Simulations
- Indicateurs A/U/R
- Séquences sonores

Guide interactif
Evaluation



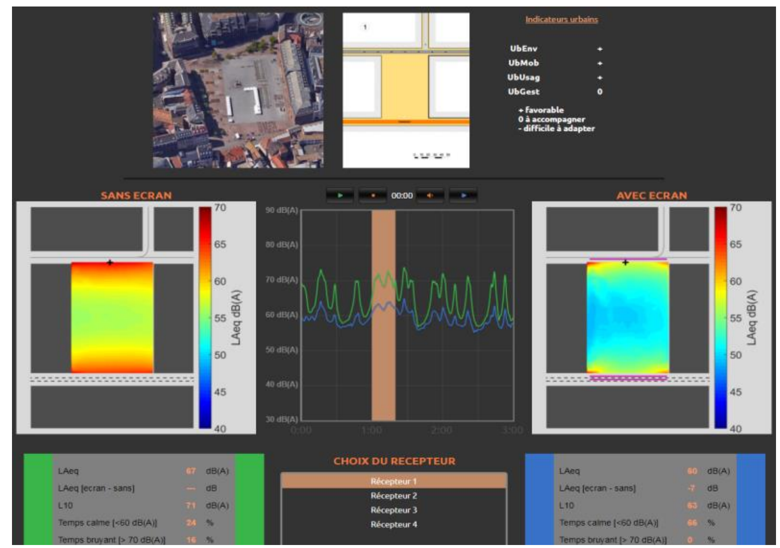




http://ecran-urbain.cstb.fr/

Chrome or Firefox!

Demo…



Defrance J, Maillard J, Laforgue J-D, Bouakil S, Brunet B, *Outil d'aide à la décision pour la réalisation de mobiliers urbains acoustiques (Projet RÉMUS)*, Congrès Français d'Acoustique, Le Havre, 23-27 avril 2018

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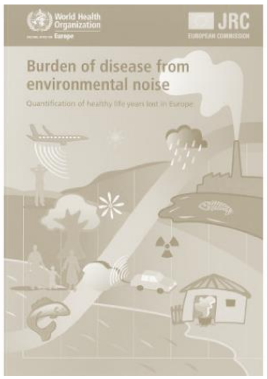

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Perspectives

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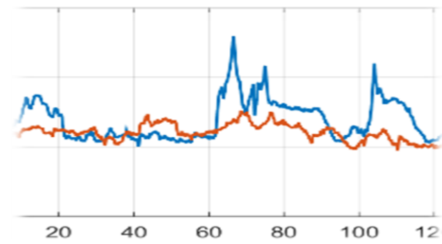
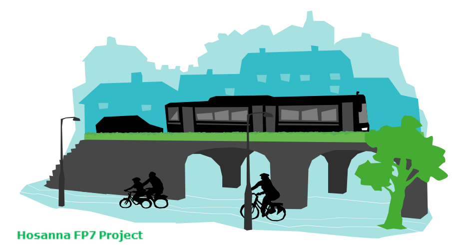
Concluding remarks & Perspectives

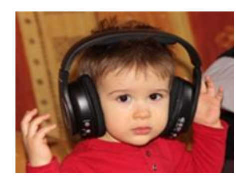
- An engineering model = a compromise
- A good acoustic engineer knows the limits



- Hybrid approaches may be useful (eg. Ray/Num)
- Dynamic indicators should be used



- Urban planning first as a solution
- Also innovative solutions (greening, low height…)
- HS-PS links to be more investigated (through maps)



- Perceptive Noise Mapping as an efficient tool for dialogue

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