Alpine Convention
Working Group Transport

Assessment of external costs induced by noise in mountainous areas

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May, 2018

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Context of the survey

Within the framework of the Alpine Convention1, DGITM (*Mission des Alpes et des Pyrénées*) asked Cerema for technical support in assessing the impacts of external costs in the Alps. The aim was to assess whether the recommendations of the European Eurovignette III Directive (DEEIII) factored in fully all environmental impacts related to traffic in mountainous areas, and more particularly the impact of air and noise pollution. This action was launched in 2016 with a literature review of surveys and reference values in various countries applied to mountainous areas. The first conclusions were:

- The heterogeneity of values used by DEE III and values integrated in the literature review;
- The lack of surveys covering environmental external costs and taking account of the specificity of mountainous areas;

This survey aims at furthering the conclusions of the 2016 literature review by accurately assessing external costs induced by noise on two French transalpine routes. The results presented hereafter were generated by modelling exercises of the exposure of populations, done in compliance with calculation methods recommended by Directive 1999/62/EC. Routes or route portions included in international transit routes and presenting non-mountainous characteristics, i.e. “flat areas”, were also included in this survey and used as reference situations.

1 - Impact and cost of noise

Along with air pollution, noise in the environment is one of two sources of disturbance integrated in the computing of external costs generated by transport activities. Induced externalities are generally classified under three categories [1]:

- ***Impacts on human health:*** if recorded noise levels in the neighbourhood of transport infrastructure do not (or rarely) generate hearing pathologies, they are still, in a proven way [2], associated with so-called “extra-auditory” effects. More particularly, they generate discomfort; sleep disruption; cognitive effects (learning difficulties); and long-term cardiovascular pathologies. International Health Studies conducted to date allow us to correlate part of these effects with a chronic exposure to morbidity indicators, several healthy life years lost, a certain level of cost…
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- ***Ecological impacts:*** these can be effects on living organisms (fauna), or the deterioration of the ambient noise in certain places, natural areas, leisure grounds and tourist areas… These effects are generally not integrated in the calculation of external costs under acoustic impacts because they are difficult to predict and to quantify.
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- ***Impact on the built environment:*** noise can generate planning constraints by restricting the use of land. It can also lead to the depreciation of land. Based on the Hedonic Pricing Method (willingness to pay), the “Boiteux 2” report [3] suggested depreciating rental prices according to noise exposure categories. In France, this method was used as a reference to monetize the impacts of transport infrastructure projects. One of the limits identified in this method is the absence of an explicit integration of the impacts of noise on human health, even though the proposed values did integrate, to some extent, the effects of discomfort (extra-auditory effect).

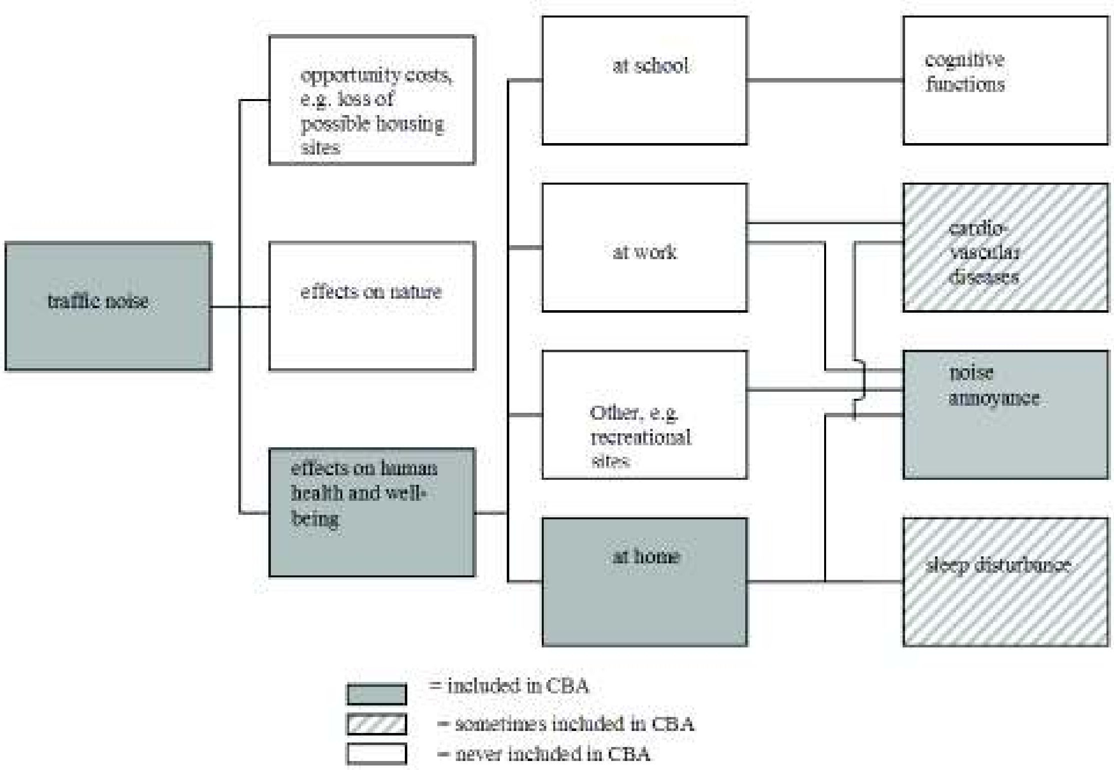


Illustration 1: Conceptual model for calculating external costs induced by traffic noise [1]- CBA=Cost-Benefit Analysis

Cost-Benefit Analysis methods used for assessing noise are currently based mainly on sanitary dose-response values and include the best-documented extra-auditory effects (discomfort) and, increasingly include effects such as sleep disruption, or impact on the cardio-vascular system.

Therefore, the evaluation method and the calculation reference values proposed by the Eurovignette Directive (see below) are based on the quantification of noise effects on exposed populations. The Directive does not specify the nature of effects that should be taken into account. The wording “exposed population” suggests that sanitary effects should be taken into account; however it does not explicitly exclude other externalities.

2 - European "Eurovignette" Directive 1999/62/EC

Directive 1999/62/EC, so-called the "Eurovignette" Directive of the European Parliament and the Council, of 17 June 1999 on the charging of heavy goods vehicles for the use of certain infrastructures, was amended several times. The next pages of this document will refer to the consolidated version of this text, dated April 1st, 2016, which is the latest version available at the time this report is being drafted.

A proposed amendment for Directive 1999/62/EC was filed on May 31st, 2017. It suggests significant modifications regarding the assessment of external costs related to air pollution and noise. These proposals are also discussed in our analysis.

2.1 - Principles for calculating the cost of noise pollution due to traffic

One of the difficulties encountered when estimating the cost of noise disturbances generated by heavy goods vehicles (HGVs) lies in the fact that effects are not linear. Therefore, adding a HGV in mixed traffic situations generates an increase of impacts (logarithmic increase of sound levels), which depends on initial traffic and its composition.

The Eurovignette Directive specifies the calculation modalities applicable to traffic noise generated by HGVs. Two methodologies can be used:

- **Method n°1: detailed calculation**

The detailed method may be used when a Member State wishes to apply fees because of external costs higher than reference values (see Illustration 2).
In this case, the cost of noise pollution generated by HGVs on a type *j* road is calculated as follows:

$$NCV\left(daily\right)=\frac{e\sum_{k_k} NC_{jk}\times POP_k}{WADT}$$

where:

- NC_{jk} represents the cost of disturbance per person exposed on a type *j* road with a *k* noise level. It is clarified that: "the cost per person exposed to a *k* noise level must be estimated by the Member State, or, where applicable, by an independent Authority, taking account of the latest innovations in the field of assessment".

- *e* is an equivalence factor applied between HGVs and light vehicles (LVs).

The proposed modification of Directive 1999/62/EC of May 31st, 2017 clarifies that this factor is "established based on noise emissions corresponding to an average for cars and an average for HGVs". This clarification specifies the assessment conditions for factor *e* versus the text of the Directive.

- POP_k represents the population exposed to *k* daily noise levels per kilometre.

The proposed modification of Directive 1999/62/EC dated May 31st, 2017 clarifies that this variable is estimated according to strategic noise maps developed pursuant to the "Environmental Noise" Directive

2002/49/EC. This particular method was used in this survey.

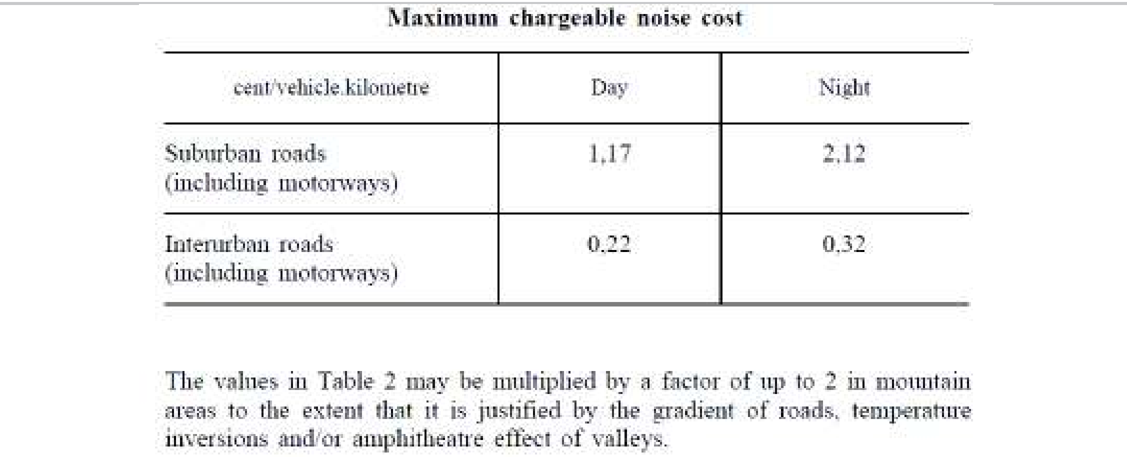
WADT is the weighted average daily traffic (expressed as private cars equivalent). It is calculated as follows:

$$WADT = (1 - \%PL) \times TMJA + e \times \%PL \times TMJA \text{ (veh./d)}$$

This cost (NCV) can also be calculated for day-time or night-time traffic by applying differentiated weighting factors to NC_{jk} .

- **Method n° 2: application of appended unitary values (appendix III ter):**

In this case, values establishing a difference between day-time and night-time traffic are specified (expressed as €ct/veh.km), by making a difference between suburban routes and inter-urban routes (Illustration 2). It is specified "**these values can be multiplied by a maximum factor of 2 in mountain areas".** The proposed arguments justifying this increase are discussed in §8.


Maximum chargeable noise cost

cent/vehicle.kilometre	Day	Night
Suburban roads (including motorways)	1,17	2,12
Interurban roads (including motorways)	0,22	0,32

The values in Table 2 may be multiplied by a factor of up to 2 in mountain areas to the extent that it is justified by the gradient of roads, temperature inversions and/or amphitheatre effect of valleys.

Illustration 2: Extract from Eurovignette Directive (1999/62/EC, Version dated April 1st 2016)

The proposed modification of Directive 1999/62/EC dated May 31st, 2017 replaces these unitary values by "baseline values for external costs charges, included the cost of air and noise pollution". These values aggregate the cost of impacts (see Tables 1 and 2 in the appended Directive proposal).
Moreover, external costs are differentiated depending on vehicle classes, EURO standards for HGVs and coaches, and depending on context, whether suburban or interurban. It clarifies that these values "**may be multiplied by a maximum factor of 2 in mountainous areas and around cities, insofar as this is justified by dispersion, road gradient, altitude or temperature inversions"**. The proposed amendment notably erases the "amphitheatre effect" which was identified as a parameter that could justify the increase of values. Adding cities in areas where a surcharge could be applied translates the will to take account of exposure risks related to the presence of higher population densities.

2.2 - Assessment methods for the cost of noise exposure of populations

- ***Reference values applied in France***

In 2013, the assessment methods for externalities proposed in the so-called “Boiteux” reports were revised [4]. Regarding noise, disturbances and other sanitary hazards (myocardial infarction, angina pectoris, hypertension), the values previously proposed by the HEATCO Project (Harmonised European Approaches for Transport Costing and Project Assessment) were integrated by revising and adapting them to the French context. [5]

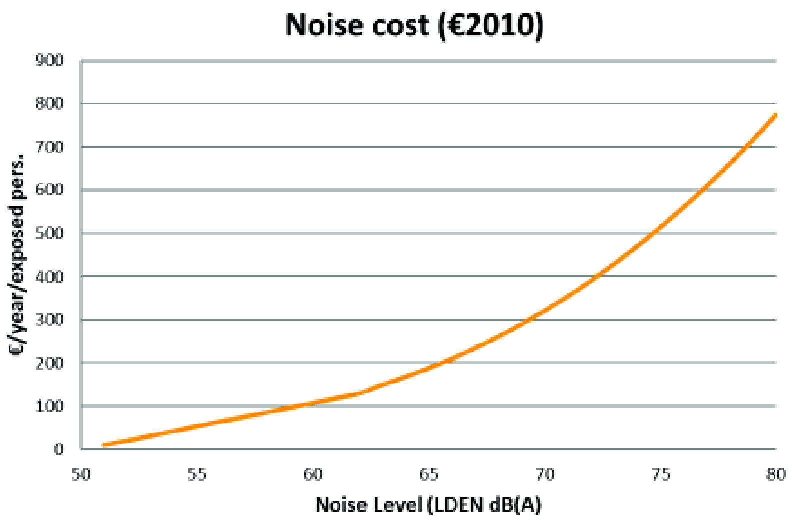


Illustration 3: Reference values expressed in €2010/exposed person/year according to noise exposure levels (cost factor) – detailed values are presented in appended documents – Sources [4] et [5].

These values were selected for estimating external costs in this document.
One should note that no difference was made between vehicle categories (light vehicles/HGVs). Values are established for mixed types of traffic. Only acoustic emissions were calculated based on a difference between light vehicles and HGVs. To the best of our knowledge, no results have been published in scientific literature that would allow discriminating between impacts generated by light vehicles or HGVs that could be applied for estimating external costs.

- ***Noise exposure indicator***

The Eurovignette Directive (V. 04/01/2016) suggests that Strategic Noise Maps produced to implement 2002/49/EC for the assessment and management of environmental noise, should be used to determine which populations are exposed to noise.
As a reminder, this Directive notably requires Members States to establish a mapping of noise levels

around major transport infrastructures (road, rail, air traffic) and around major cities (over 100,000 inhabitants).
LDEN is the noise exposure indicator used at European level. This indicator – annual average daily traffic – includes the “discomfort” aspect and is calculated, based on noise levels assessed during three periods (D: Day, E: Evening, N: Night) and weighted (+5dB in the evening, +10 dB at night) to take account of differences in the level of discomfort expressed for each of these three periods:

$$L_{DEN} = 10 \log\left(\frac{12.10^{\frac{L_{Day}}{10}} + 4.10^{\frac{L_{Evening}+5}{10}} + 8.10^{\frac{L_{Night}+10}{10}}}{24}\right) \text{ (dB(A))}$$

Strategic noise maps are drawn up by modelling (calculating) noise source emissions and noise propagation in an environment described in tri-dimensional features. Benchmarking or metrological properties can potentially be used to ensure that these models are accurate. However, these maps are most often established without using measurements, based solely on the knowledge of both the modelled data reflecting source emissions and the description of the environment. These calculation methods have given rise to EU recommendations.
In France, the Prefect approves European strategic noise maps,which are then published by the competent authorities (major cities, infrastructure managers, local authorities, State departments). These competent authorities are also responsible for developing Environmental Noise Prevention Plans listing actions aimed at reducing the noise exposure of populations, as well as identifying and preserving “Clear Zones”.
Strategic Noise Maps and Environmental Noise Prevention Plans have been reviewed every 5 years since 2007. Year 2017 corresponds to the 3rd review of Strategic Noise Maps (2018 for Environmental Noise Prevention Plans which were originally developed one year later).

- ***Noise levels calculation methods***

Calculations of populations exposed to the noise level required to determine external costs were carried out according to the same principles used to draw up strategic noise maps. For the routes selected in this study, only acoustic contributions of the main infrastructures (motorways) that could be subject to "Eurovignette" taxation were considered. The following methodology was applied:

- **Modelling of acoustic sources:**

Each section of each route is broken down into "acoustically homogeneous" sections, taking into account the supported traffic parameters: traffic volume, regulatory speed, % of heavy goods vehicles. An acoustic emission power is assigned to each source line based on these parameters. Acoustic emissions are calculated in accordance with the applicable French calculation method (NMPB08) [6].

- **3D modelling of the environment:**

A 3D digital model of the propagation environment is used to describe: topography, buildings, acoustic protection, ground conditions (absorbent/reflective) ...

- Calculation of noise levels at 4 meters above ground level and on the facades of residential buildings.

In compliance with regulatory requirements, the method takes into account the effects of weather conditions (so-called favourable or unfavourable propagation situations).

- **Counting the exposed populations**

The noise levels calculated on the facades of residential buildings affected by the modelled acoustic sources are related to the number of inhabitants in each of these buildings.

All databases used in this study come from the Auvergne-Rhône-Alpes Regional Harmonised Observatory (www.orhane.fr).

The various modelling steps described above were carried out using the Mithra-SIG © software developed by the CSTB (Scientific and Technical Centre for Building / *Centre Scientifique et Technique du Bâtiment*) and distributed by GEOMOD.

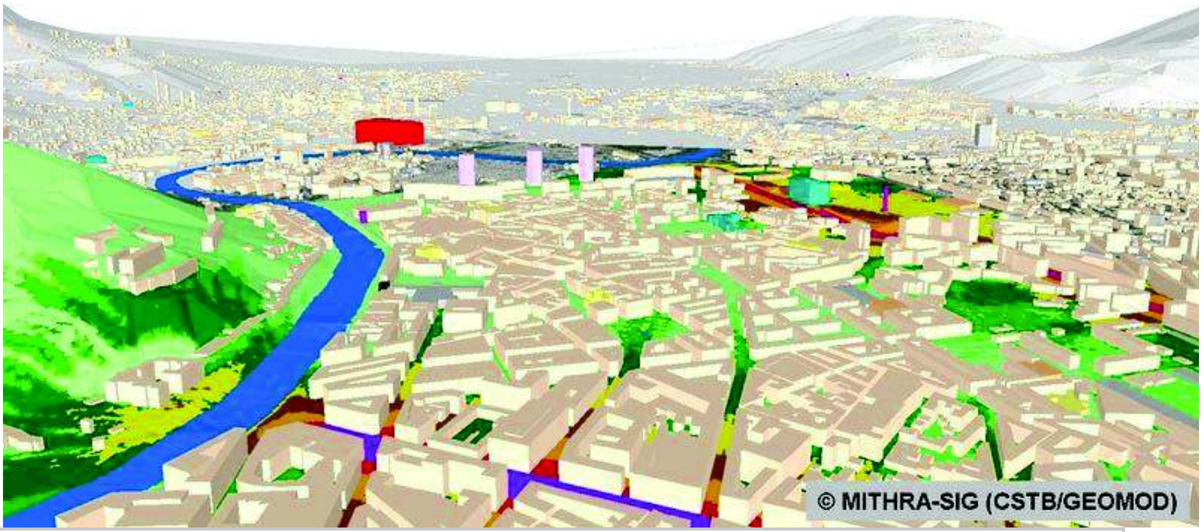


Illustration 4: 3D visualization of an acoustic model made under Mithra-Sig ©

All maps modelled on the three routes studied are shown in Appendix B.

In addition to noise exposure data, the calculation method described in the Eurovignette Directive (see 2.1) requires the setting of an "e" equivalence factor HGV/LV reflecting the more "emissive" nature of HGVs from an acoustic point of view. **The setting of this value is left to the discretion of each Member State.** An estimation proposal, consistent with the exposure calculations, is submitted below.

- ***Equivalence factor "e" for HGVs/LVs***

The "e" equivalence factor for the weighting of the relative weight of noise impacts between HGVs and LVs partly determines the result of the external cost. The Eurovignette Directive does not specify its calculation method. The proposed amendment of May 31st, 2017, however, states that it must be based on the average emission data for both vehicle categories.

Several factors influence the ratio of HGV/LV noise emissions: the (regulatory) speed of both categories of vehicles, the speed or dynamics of traffic (stabilized/pulsed), the slope of the roadway (which exclusively affects HGV emissions), the nature of the pavement surface. Three categories of road coating are used, ranging from low noise (R1) to high noise (R3). The state of deterioration of the coating, generally linked to its age, can also be included in the calculation parameters.

The values presented in Table 1 are based on the emission calculation charts of the French method (NMPB08, [6]). These graphs make it possible to establish the average emission laws of the "engine" and "rolling" components, which relative weight varies with speed. Noteworthy is the fact that they overlap in real life. On the infrastructures studied (motorways) and factoring in regulatory speeds and velocity (assumed as stabilized), the rolling noise component is predominant, with noted differences exceeding 10 dB(A) at emission.

	Acoustic power level Lw/m (1 veh/h)								
	Rolling noise		Engine (steady state)		Rolling noise+ Engine (steady state)				
Speed limit (km/h)	130	90	130	90	130	90	90		
Road cover (less than 2 years)	LV	HGV	LV	HGV	LV	HGV	HGV (slope 6%)	*e*	*e* (slope 6%)
R1	52.8	60.1			53.3	60.6	61.2	5.3	6.1
R2	56.6	63.1	44.1	50.6	56.8	63.4	63.7	4.5	4.8
R3	59.3	64.1			59.4	64.3	64.6	3.1	3.3
Road cover (more than 10 years)	LV	HGV	LV	HGV	LV	HGV	HGV (slope 6%)	*e*	*e* (slope 6%)
R1	56.8	62.5			57.0	62.8	63.2	3.8	4.2
R2	58.6	64.3	44.1	50.6	58.8	64.5	64.8	3.8	4.0
R3	60.9	65.1			61.0	65.3	65.5	2.7	2.8

Table 1: Equivalence factors HGV/LV

These results show that factor e can vary between 2.7 and 6.1 depending on parameters. For all routes subsequently studied, the **value of 4.5** was selected and corresponds to traffic on a "moderately noisy pavement less than 2 years old with moderate slopes, representative of motorway routes analysed." 12

3 - Detailed study of three French routes

In order to identify potential differences in external costs related to the mountainous nature of certain road transport routes, three major corridor sections linking France to neighbouring countries were studied, using the detailed method for calculating external costs (see 2.1 and 2.2). These routes are located in the Rhône-Alpes region and include a structuring highway carrying significant international transit traffic. The acoustic contribution of each structuring motorway axis, which carries most of this transit traffic, is studied below. Noise emissions from other transport routes are not taken into account in the estimation of exposed populations.

The first route links Pont d'Ain (Ain) to Chamonix (Haute-Savoie) via Scientrier. The A40 motorway (E21/E25), known as the " Titans' motorway " runs between Pont-d'Ain and Bellegarde, then the so-called "White Motorway " between Bellegarde and Chamonix. It includes some sections characterized as "mountainous areas". This axis provides road transit between France and Switzerland via the Chamonix Tunnel. It was split into two homogeneous sections, one on each side of the Vuache tunnel, for a total length of 131 km.

The second route is the French portion of the Lyon-Turin axis. It is a mixed plain-and-mountain route, focusing on the A43 motorway (E70), originating east of Lyon (Rhône), crossing the Maurienne valley and leading up to the Fréjus Tunnel (Savoie). The total length of this route under study is about 140 km. It was divided into two main sections separated at the level of the Epine Tunnel (Chambéry).
The third route, which serves as a reference "plain area" in this study, is the A7 motorway (E15) over a stretch of nearly 84 km between Chasse-sur-Rhône (Rhône) and Valence sud (Drôme).
Each **section** of each of the three routes was divided into **subsections** characterized by some homogeneity in terms of traffic, percentage of HGVs, population density and topography.

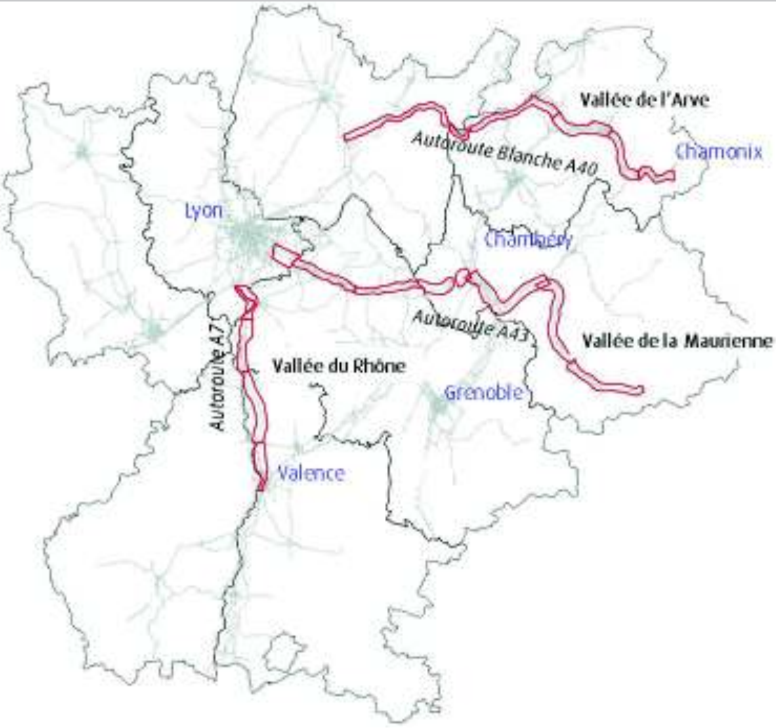


Illustration 5: the three selected routes and their breakdown into homogeneous sub-sections

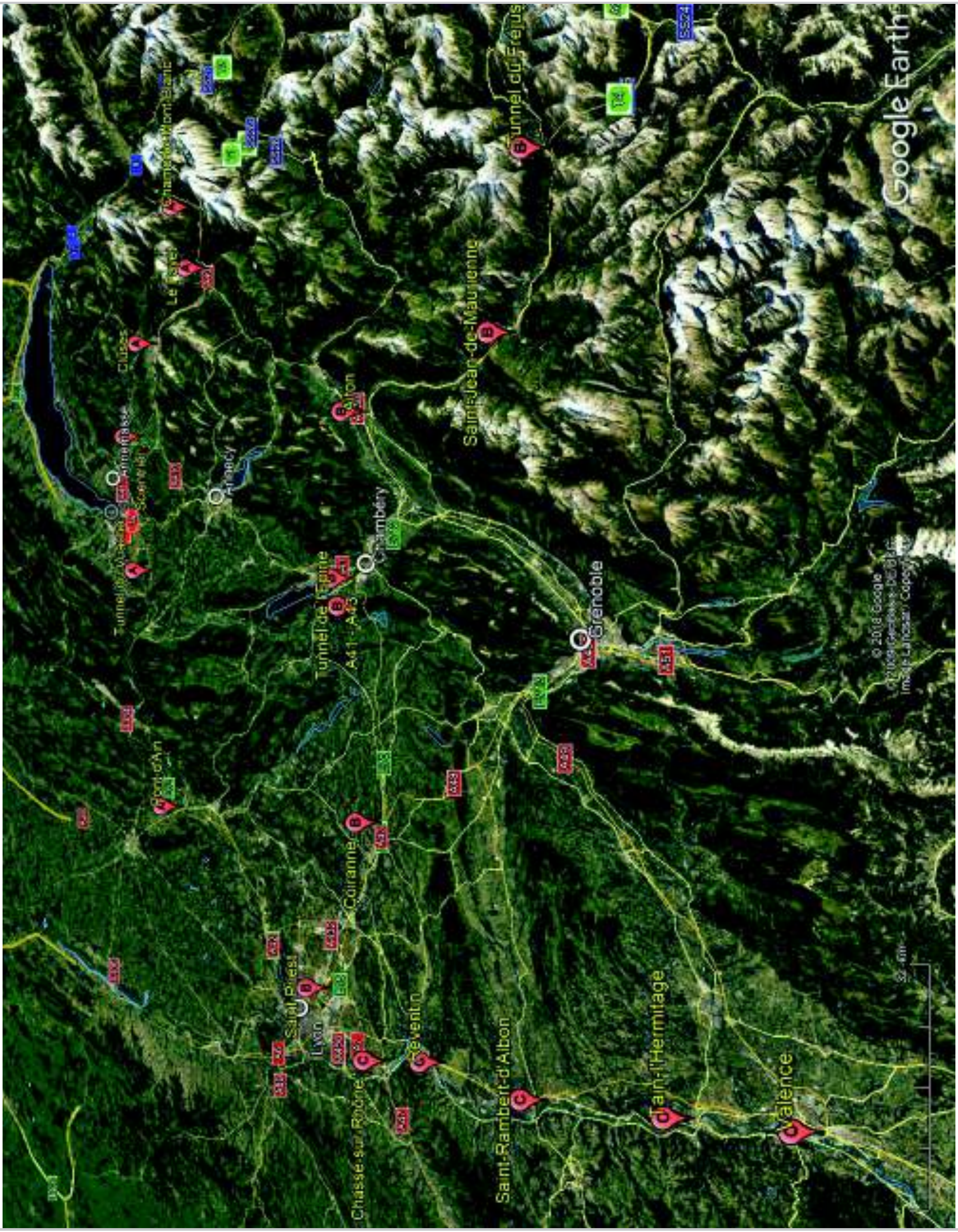


Illustration 6: aerial photograph presenting location plan of the three corridor sections (A7, A40, A43) east of Lyon. Red markers show boundaries of studied subsections (Google Earth).

4 - A40 Route: Pont d’Ain - Chamonix

4.1 - A40, Titans’ motorway – section: Pont d’Ain to Scientrier

This first section of the A40 route was divided into two subsections crossing the departments of Ain (01) and Haute-Savoie (74) and broken down as follows: Pont d’Ain - Tunnel du Vuache – Scientrier.

- ***Traffic characteristics***

Subsections / Section	Terrain Mountain/Plains	AADT (Vh./d)	%HGVs	Length (km)	Maximum Regulatory Speed (HGV/LV) (km/h)
Pont d’Ain/Tunnel du Vuache	Plains/hills	20 307	14.10%	11.8	90//130
Tunnel du Vuache/Scientrier	Plains	29 061	8.64%	38.7	90//130
Pont d'Ain / Scientrier	Plains to hills	27 020	9.60%	50.5	90//130

Table 2: Pont d’Ain – Scientrier – Traffic and topographical characteristics per subsection

This section of the route carries around 27,000 vehicles/day with an average rate of HGVsunder 10%. The regulatory speeds match those associated with the standard French motorway network (130 km/h for light vehicles and 90 km/h for HGVs). The difference in traffic between the two subsections is due to the junction with the A41 at Saint-Julien-en-Genevois, then with the A411 at Annemasse.

• *Topographic profiles*

This first section of the A40 runs through a landscape of plains, hills or medium-high mountains. The motorway is alternately higher or level with built areas or runs along the valleysfloors. The difference in altitude between sources and receivers range from a few dozen meters to barely one hundred. These configurations do not have a marked mountainous character, but each topographical situation can play a role in terms of noise propagation: a dominant source will generally tend to decrease noise levels on buildings located below the source (screen effect due to the presence of a platform); whereas buildings located on hillsides will suffer from diminished noise mitigation and may be more exposed to noise levels (see 8.2).

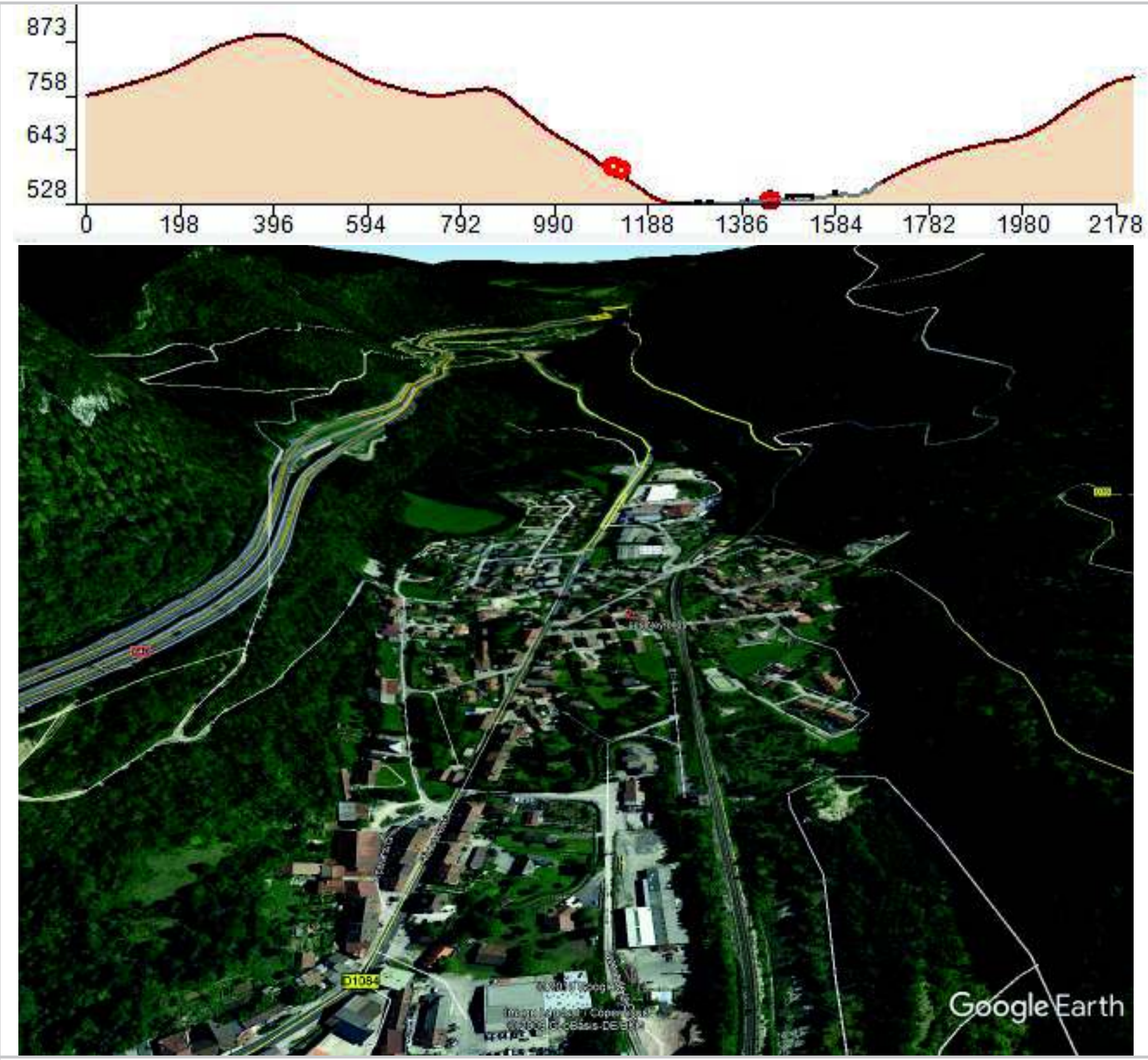


Illustration 7: A40 Pont d'Ain – Tunnel du Vuache. Typical cross-profile of section. Red dots on hillside indicate position of road infrastructure (A40) modelled as acoustic source. Horizontal and vertical scales in meters and aerial photograph (GoogleEarth) of the valley located after the exit of the Vuache Tunnel the Les Neyrolles side.

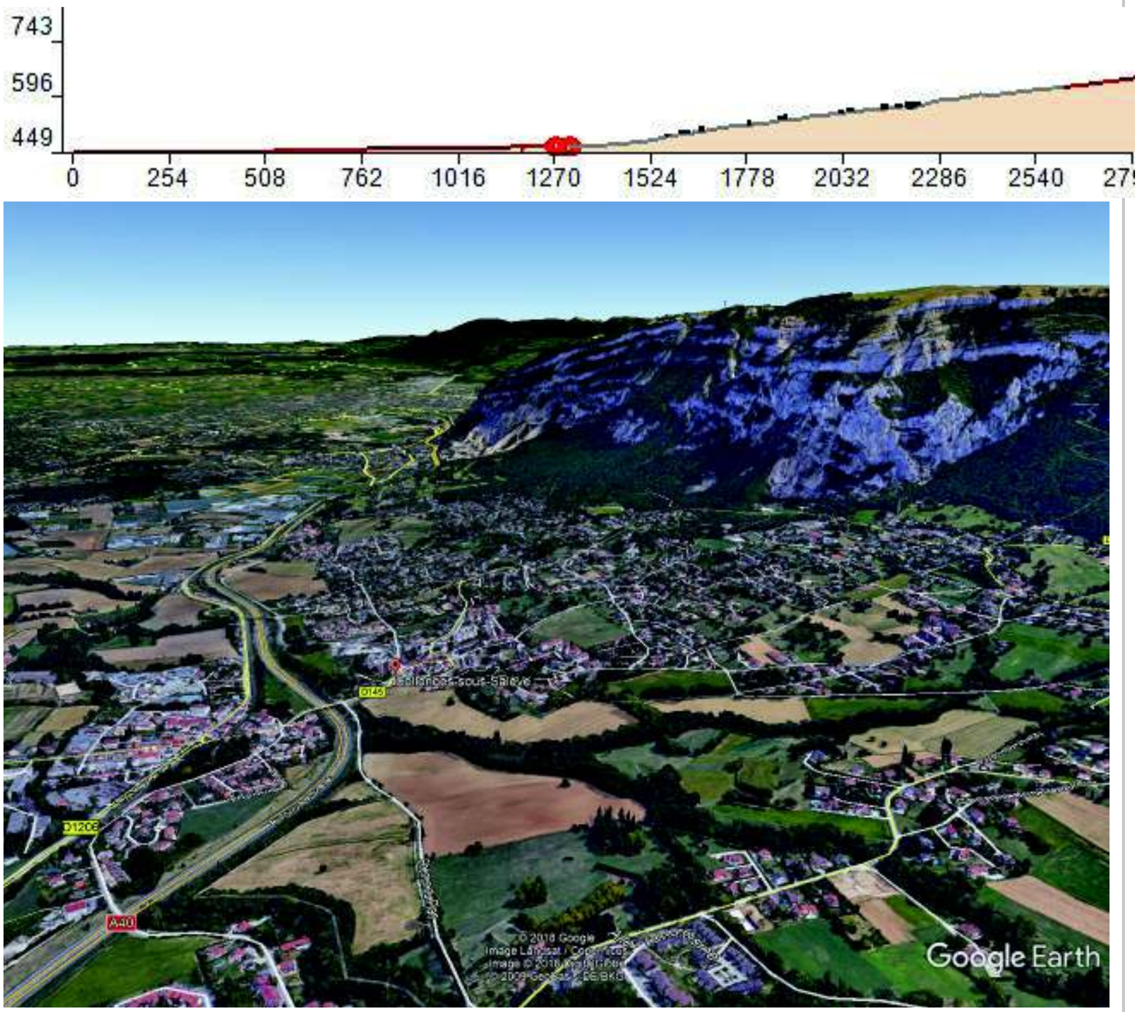


Illustration 8: A40 Tunnel du Vuache – Scientrier. Typical cross-profile of section located next to Collonges-sous-Salève. Red dots indicate position of road infrastructure (A40) modelled as acoustic source. Horizontal and vertical scales in meters and aerial photograph (GoogleEarth) of area close to Collonges-sous-Salève

Along this section, the motorway is occasionally located lower than the built-up areas (Illustration 8). This situation of exposure to noise, or so-called "amphitheatre" exposure, can be construed as unfavourable (for local residents), as the ground effect is restricted by the relative topographical situation of the source and receptors (houses).

However, in this location the motorway is excavated, and the natural terrain protects buildings from noise. (Illustration 9).

Illustration 9: View from the A40 to Collonges-sous-Salève.

- ***Noise related external costs Pont d'Ain to Scientrier***

External costs related to noise generated by HGVs using the A40 were assessed using the methodology described under 2.2. This study only computed populations living in residential buildings and exposed to noise levels above 50 dB(A). The table below shows both the overall annual and per capita external costs (related to the circulation of LVs and HGVs), as well as the specific cost related to HGV traffic (NCV).

Subsections / Section	Terrain Mountain/Plain s	External cost of noise (All Vehicles)	Approx. population density (inhab/km²)	Cost/Pers./yr	NCV (1999/62/EC) ct€/veh.km
Pont d'Ain / Vuache Tunnel	Plains to hills	476 682 €	654	62 €	1.65
Vuache Tunnel / Scientrier	Plain	1 645 267 €	518	82 €	1.39
Pont d'Ain / Scientrier	Plain/Hills	2 121 949 €	460	76 €	1.44

Table 3: Pont d'Ain – Scientrier – External costs for both subsections between Pont d'Ain and Scientrier.

A more detailed analysis, submitted in the following graphs (Figures 10, 11 and 12), identifies the number of people exposed per 1 dB(A) noise level class, as well as the cost associated with each exposure class for both subsections and for the entire section.

The external cost /km on that route is assessed at about 42 k€/km/year.

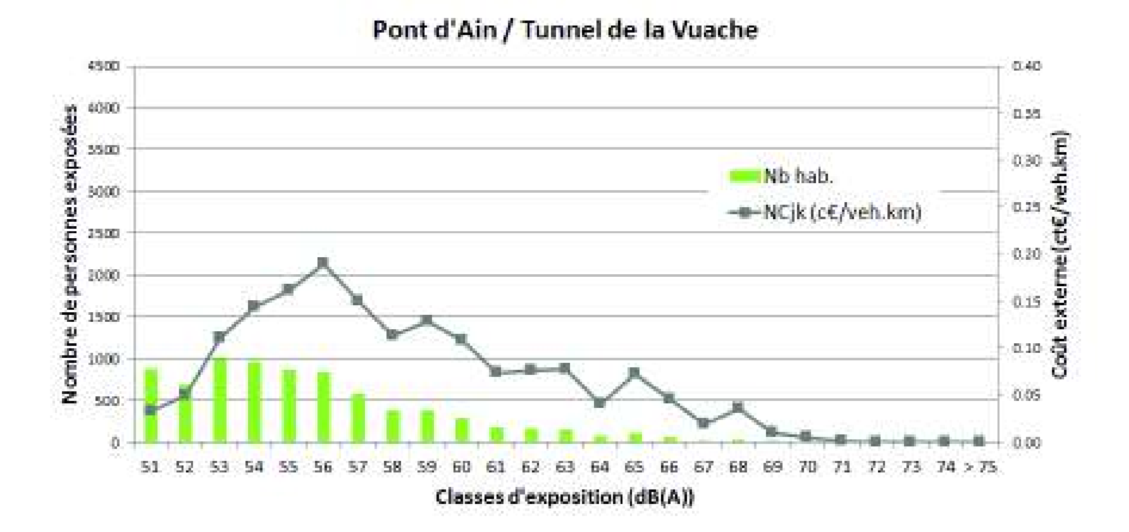


Illustration 10: A40 Pont d'Ain – Vuache Tunnel: Population exposed by noise level class (LDEN (dB(A)) and associated external costs per HGV and per noise level class.

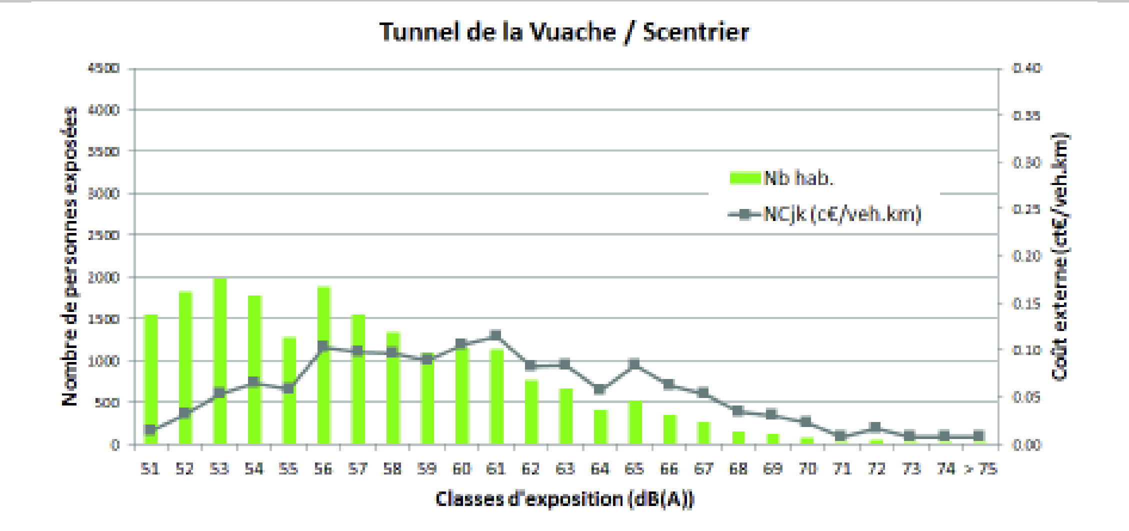


Illustration 11: A40 Vuache Tunnel – Scientrier: population exposed per noise level class (LDEN (dB(A)) and associated external costs per HGV and per noise level class.

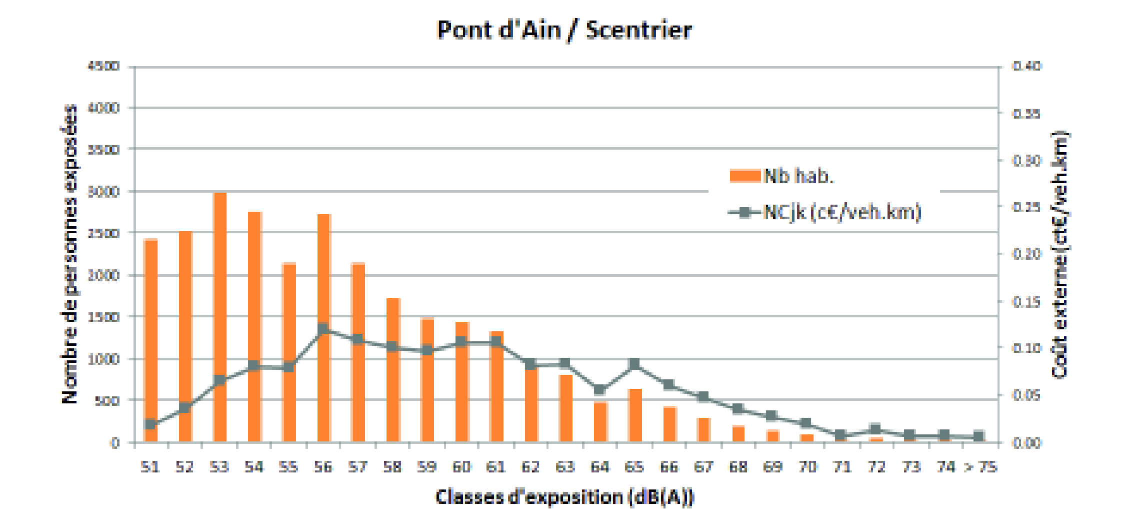


Illustration 12: A40 Pont d'Ain – Scientrier: Population exposed per noise level class (LDEN (dB(A)) and associated external costs per HGV and by noise level class.

It can be noted that, along this section, a large portion of the population is exposed to noise levels below 60 dB(A). Most of the estimated external costs are generated by exposure levels below 68 dB(A) (limit value according to Directive 2002/49/EC), and the overall cost on this section has therefore been reduced (1.44 €ct/HGV. km). This cost remains slightly higher than the maximum chargeable daytime cost proposed in the Eurovignette Directive (1.17 €ct/HGV.km), but lower than the night-time cost (2.12 €ct/HGV. km), given that the LDEN indicator takes a full day into account, by weighting the evening and night-time periods (see 2.2.2).

According to the indicators that were analysed, it is difficult to identify exposure levels on this route that could be qualified as specific to mountainous areas.

4.2 - A40 White Motorway / RN205: Scientrier to Chamonix

This route was broken down into 3 subsections: Scientrier – Cluses – Le Fayet – Chamonix.

Part of the route has motorway characteristics (Scientrier-Le Fayet), and UK type A road n° 205 extends the A40 up to the Mont-Blanc Tunnel.

Located some ten kilometres east from Annemasse, Scientrier marks the entrance into the Arve valley. This valley remains quite wide up to Cluses, then narrows until Saint-Gervais-Le Fayet, before winding tighter all the way up to Chamonix.

Like most French Alpine valleys, built-up areas are mainly located on the floor of the valley in the foothill zone, with the exception of cities located on plateaus at the edge of the mountain level: Les Carroz-d'Arâches, Les Juliars, the Plateau d'Assy... The distance between these sites and main road infrastructures (over 1.5km),plus the plateau topography mitigate noise exposure from valley sources. In the Arve lower valley, cities such as Passy, are located on hillsides, with residential homes less than 1km from the motorway (Illustration 13).

Illustration 13: view from the A40 looking towards Passy

This specific situation, which is more impactful, was identified in the Environmental Noise Prevention

Plan (PPBE 2015) and forced the manager to take action by planning acoustic insulation of certain facades and the construction of acoustic screens (erected between 2016-2019).

Illustration 14: view from the A40 showing acoustic insulation around Scionzier-Cluses

- ***Traffic characteristics***

Subsections / Section	**Terrain Mountain/Plain**	**AADT (Veh./day)**	**%HGV**	**Length (km)**	**Maximum regulatory speed (HGV/LV) (km/h)**
Scientrier / Cluses	Plain	26 396	8,82 %	23,6	90//130
Cluses / Le Fayet	Mountain	17 216	11,23 %	21,1	90//110/130
Le Fayet / Chamonix	Mountain	13 876	15,35 %	35,6	50/70/80/90//50/70/ 90/110
Scientrier / Chamonix	Mixed Plain/Mountain	18 432	11,59 %	80,4	50/70/80/90//50/70/ 90/110/130

Table 4: Scientrier - Chamonix – Traffic and topographic characteristics per subsection

In these sections, there is a significant drop in "all types of vehicles" traffic towards Chamonix. There is however an increase in the relative share of HGV traffic (transit).
Noteworthy also, is the fact that access to the Chamonix tunnel area involves changes in regulatory speed.

- ***Topographic profiles***

The three following illustrations represent the various topographic situations and the passing from the lower to the upper Arve valley where the valley floor increasingly narrows.

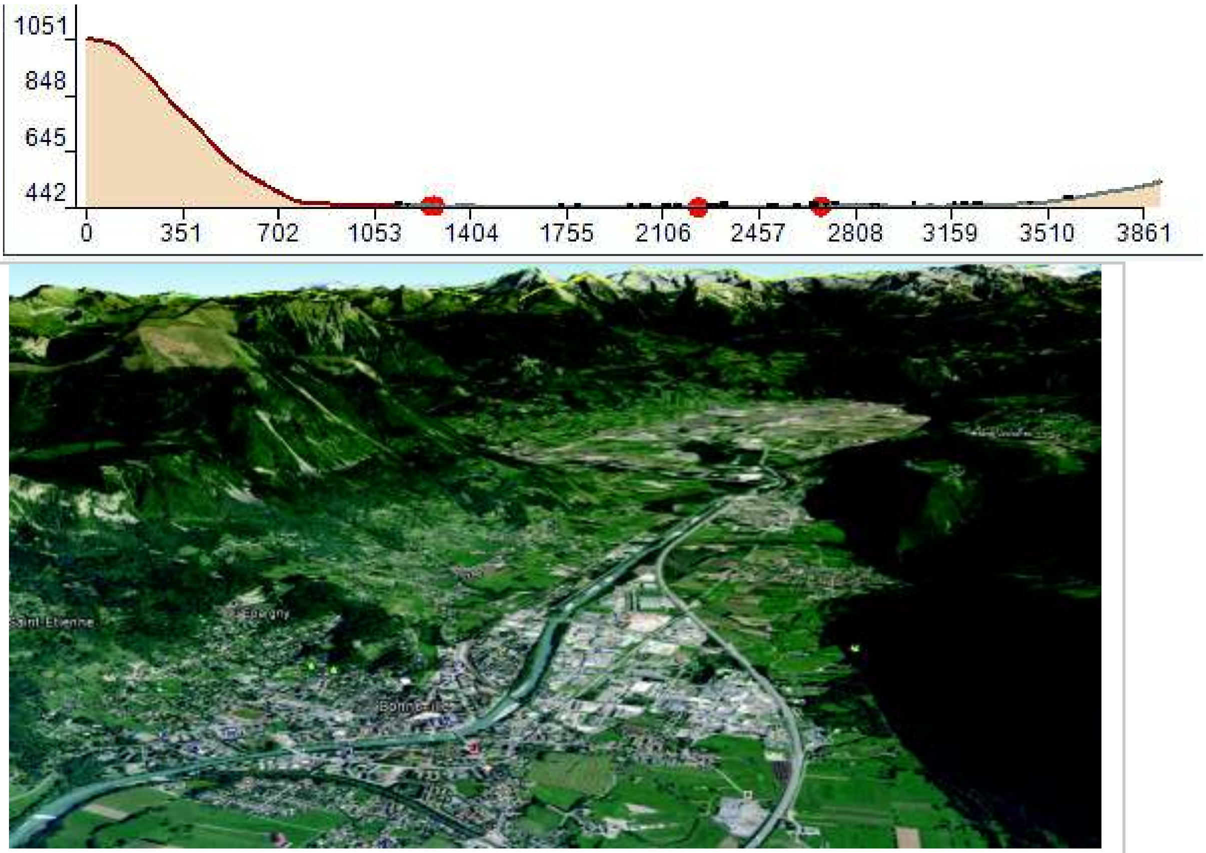


Illustration 15: A40 Scientrier – Cluses - Typical cross-profile of this section. Red dots mark the location of road infrastructure modelled as acoustic sources. Horizontal and vertical scales in meters and aerial view (GoogleEarth) of the area around Bonneville (Arve lower valley).

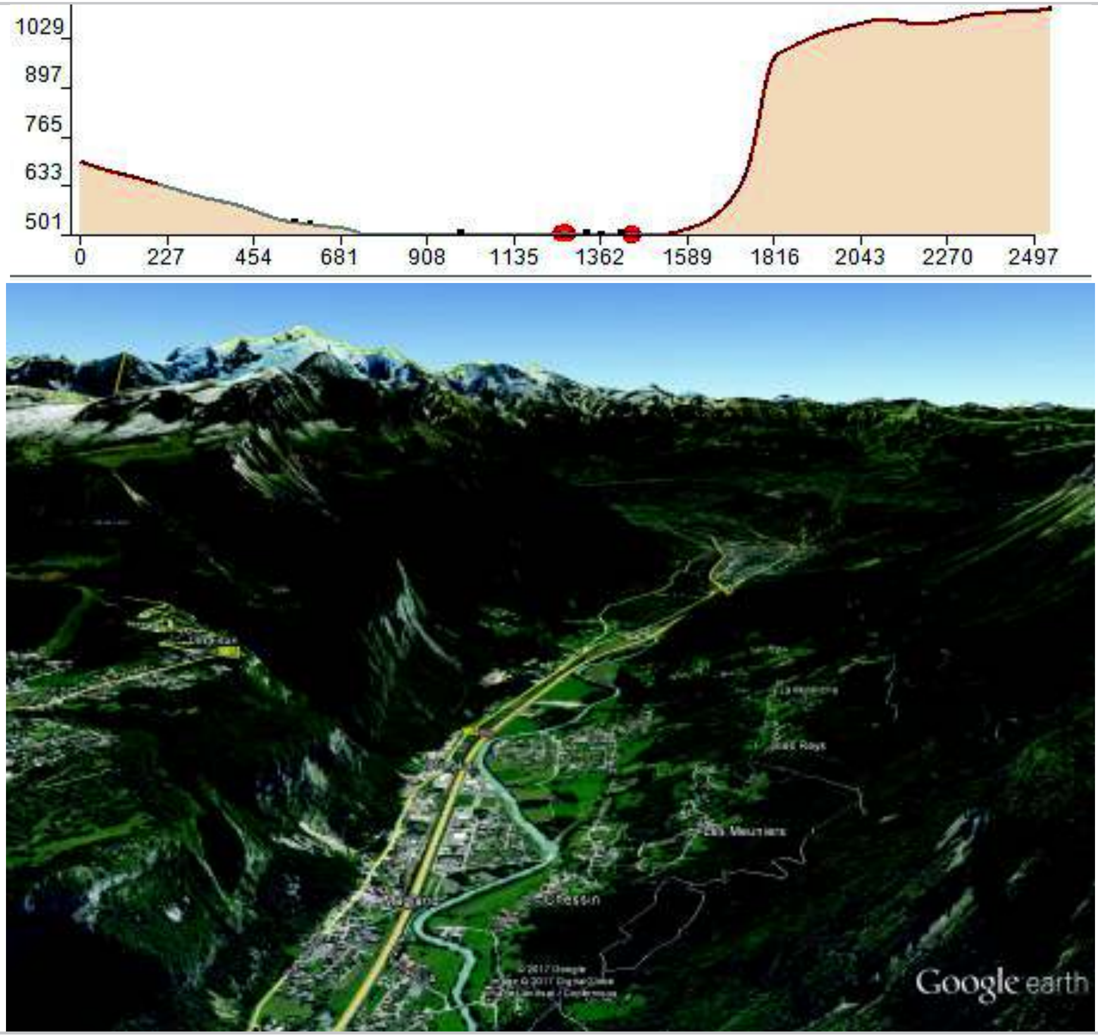
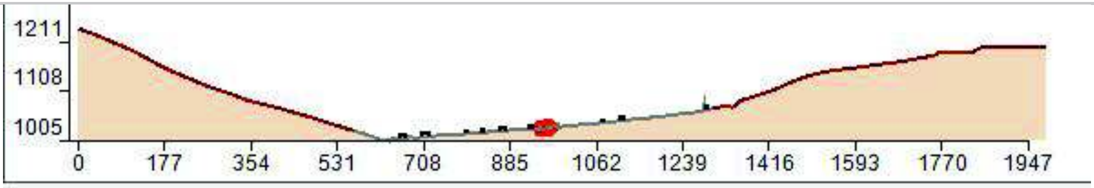


Illustration 16: A40 Cluses - Le Fayet - Typical cross-profile of this section. Red dots mark the location of modelled road infrastructure as acoustic sources. Horizontal and vertical scales in meters and aerial view (GoogleEarth) of the area around Bellegarde.



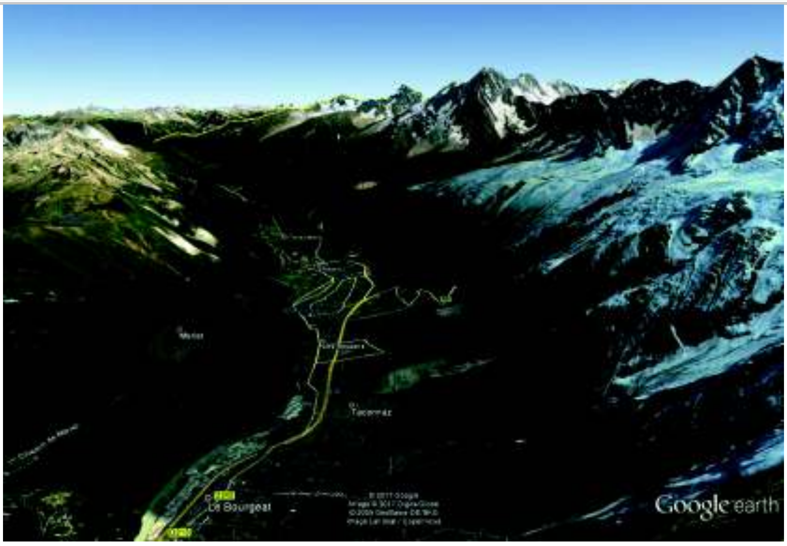


Illustration 17: RN205 Le Fayet - Chamonix - Typical cross-profile of this section. Red dots mark the location of road infrastructure modelled as acoustic sources. Horizontal and vertical scales in meters and aerial view (GoogleEarth) of the area around the Bossons.

- ***Noise related external costs***

Subsections / Section	Terrain Mountain/Plain	External cost of noise (all vehicles)	Approx. population density (inhab/km²)	Cost/Pers./year	NCV (1999/62/CE) ct€/veh.km
A40 Scientrier / Cluses	Plain	2 012 415 €	983	87 €	3.04
A40 Cluses / Le Fayet	Mountain	1 027 053 €	665	73 €	2.50
RN205 Le Fayet / Chamonix	Mountain	360 603 €	149	68 €	0.59
Scientrier / Chamonix	Plain/Mountain	3 400 071 €	530	80 €	2.01

External and NCV costs are quite contrasted across the different subsections. They range from 0.59 €ct/veh.km for the most characteristic portion of a mountainous area (Le Fayet/Chamonix) to 3.04 €ct/veh.km at the entrance of the valley. This difference is mainly due to the higher degree of urbanization in the Bonneville and Cluses sectors, multiplying the number of potentially exposed persons and therefore also external costs. The lowest cost (per vehicle.km) on the last subsection is also due to a higher proportion of HGVs, which is nearly double and thus more spread out. According to these indicators, it is therefore not possible to identify a "mountainous area" specificity on this route (influence of the environment on propagation). Rather,the specificity of this route is related to a lower population density associated with proportionally higher HGV traffic.

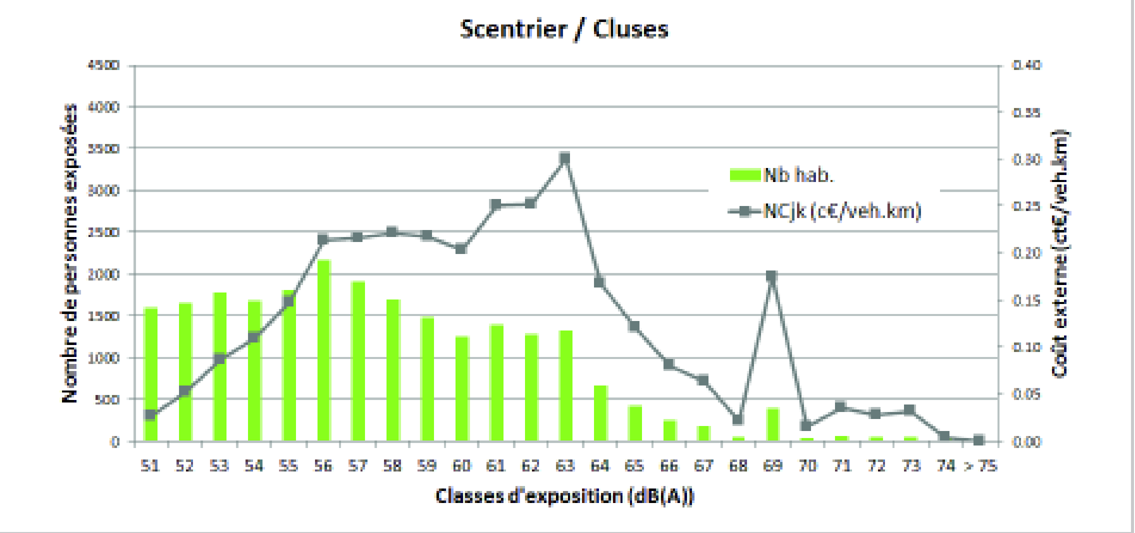


Illustration 18: A40 Scientrier – Cluses: Population exposed per noise level class (LDEN (dB(A)) and associated external costs per HGV and per noise level class.

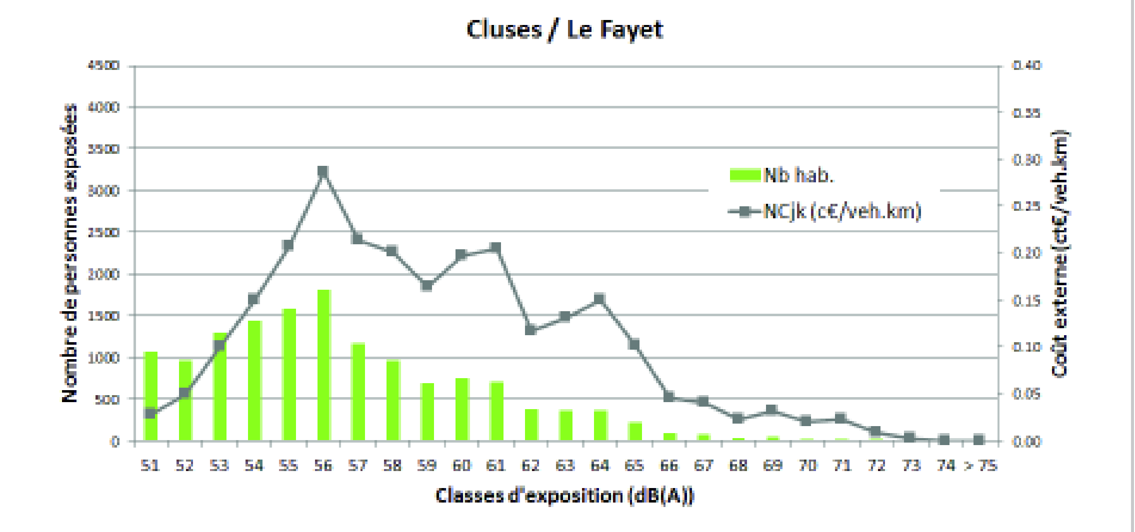


Illustration 19: A40 Cluses – Le Fayet: Population exposed per noise level class (LDEN (dB(A)) and associated external costs per HGV and per noise level class.

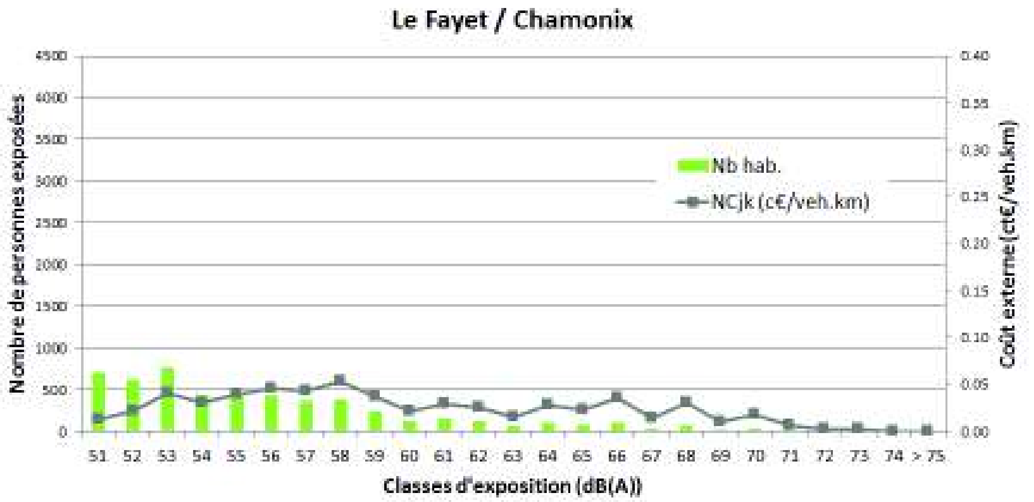


Illustration 20: RN205 Le Fayet – Chamonix: Population exposed per noise level class (LDEN (dB(A)) and associated external costs per HGV and per noise level class.

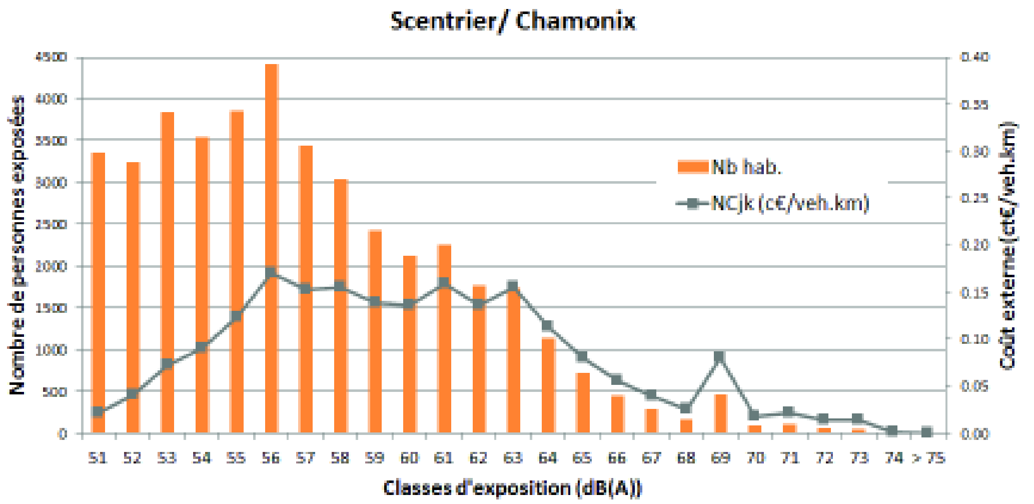


Illustration 21: A40/RN205 Scientrier – Chamonix: Population exposed per noise level class (LDEN (dB(A)) and associated external costs per HGV and per noise level class.

The analysis of exposure results by noise level class shows that external costs are mainly associated with levels below 65 dB(A), i.e. below the exposure limit values of the (68 dB(A)). This observation should be considered in the context of the implementation of noise mitigation policies in France (Noise Black Spot Mitigation Policy, Environmental Noise Prevention Plans). Some buildings have exposure levels above 68 dB(A) and may have been subjected to specific treatment (facade insulation). The Environmental Noise Prevention Plan also includes the protection of 39 buildings exceeding 66 dB(A):

- A40: 22 buildings (Eloise, Archamps, Collonges, Bossey, Gaillard, Scionzier, Cluses);
- RN205: 17 buildings (Passy, Les Houches).

To be noted: the Environmental Noise Prevention Plan for Savoie *département* (74), approved in 2015, includes a description of the vertical protection systems implemented along the A40 (Illustration 22).

Nature	Sens de circulation	Date de réalisation	Commune
Ecran	PK 6.565 au PK 7.045 sens Chamonix-Genève	2004	Sallanches
Ecran	PK 26.025 au PK 25.725 sens Chamonix-Genève	2008	Marnaz
Ecran	PK 16.942 au PK 16.290 sens Genève-Chamonix	2008	Magland
Ecran	PK 16.140 au PK 16.920 sens Chamonix-Genève	2009	Magland
Merlon	PK 32.75 au PK 32.95 sens Genève-Chamonix	2013	Bonneville

Illustration 22: Summary report on vertical protection systems implemented along the A40 from 2004 to 2014. Source: PPBE dpt74 (http://www.haute-savoie.gouv.fr)

The Environmental Noise Prevention Plan also specifies that: "to supplement the 5,747 linear meters of screens erected from *1994 to 2003, ATMB (Highway and tunnel of MtBlanc) installed new acoustic screens, i.e. 2,212 linear meters of protection thus screening 18 private homes and 4 buildings".*

Before being transferred to ATMB, the RN205 road also benefitted from protection works erected at the time by DREAL (Regional Directorate for the environnement, Planning and Housing) and DIRCE (Inter-Departemental Directorates for roads).

Commune	Lieu-dit	Longueur (en ml)
Servoz		550
Les Houches	RD 243	124
Les Houches	RD 243	24
Les Houches	Fond de Taconnaz	78
		120
Les Houches	Taconnaz	54
Les Houches	Taconnaz	141
Les Houches	Route des granges	305
Les Houches	Route des Granges	97
Les Houches	Montquarts	80
Les Houches	Montquarts	92
Les Houches	Montquarts	35
Les Houches	Montquarts	96
Les Houches	Bretelle Montquarts	41
Les Houches	Rives	104
Les Houches	Praz d'en Bas	64
Les Houches	Chemin de la Cliaz	80
Les Houches	Chemin de la Cliaz	168
Les Houches	Taconnaz	124
Les Houches	Vers Creusaz.	60
ChamonixVigie	Pélerins du Bas	130
	Pélerins du Haut	90
	Pélerins du HautClos de	80
	l'Ours	120
Total		2307 ml

Illustration 23: Summary report on vertical protection systems (screens) erected along the RN205 between 2004 and 2014. Source: Environmental Noise Prevention Plan for dpt74 (http://www.haute-savoie.gouv.fr).

Site	Désignation	Longueur (en ml)
Les Houches	Montquarts	500 160
Les Houches	Praz d'en Bas	300
Les Houches	Chemin de la Cliaz	180
Les Houches	Chemin de la Cliaz	150
Chamonix	Creusaz Pélerins du Haut Clos de l'Ours	300 80 100
Total		2400

Illustration 24: Summary report on vertical protection systems (walls) erected along the RN205 between 2004 and 2014. Source: Environmental Noise Prevention Plan for dpt74 (http://www.haute-savoie.gouv.fr).

5 - Route A43: Saint-Priest - Fréjus Tunnel

Via the Fréjus Tunnel,the A43 motorway is the main west-to-east link between Lyon (France) and Modane (Italy).Outbound out of Lyon, it crosses very densely urbanised areas, then less so, passing through more rural areas from Isère to Savoie and the city of Chambéry;upstream from Chambéry, the A43 mergers with the A41,northbound towards Aix-Les-Bains/Annecy; downstream from Chambéry,the A41 becomes southbound towards Grenoble. The A43 then continues on towards the Maurienne valley, which it enters near Aiton. The variety of topographical typologies along this same route thus makes it possible to highlight contrasts in exposures between plains and mountainous areas.

5.1 - Section A43 Savoie Foreland: St-Priest to L'Epine

The first part of the itinerary is characterized by sections of plains and hills. This portion is further divided into two subsections, with a first segment fromSt-Priest to Coiranne, then from Coiranne to L'Epine (tunnel), marking the access to Alpine slopes.

- ***Traffic characteristics***

Subsections / Section	Terrain Mountain/Plain	AADT (Veh./d)	%PL	Length (km)	Maximum regulatory speed (HGV//LV) (km/h)
St-Priest N346/ A43-A48 Coiranne	Plain	73 170	10.54%	26.2	80/90//110/130
A43-A48 Coiranne/ L'Epine	Plain	71 874	13.08%	12.6	90//130
St Priest / L'Epine	Plain	72 750	11.35%	38.8	130/110/90

Table 1: St-Priest – L'Epine – Traffic and topographic characteristics per subsection

Both subsections are relatively homogeneous in terms of traffic volumes, with a slightly higher level of HGV traffic on the Coiranne/L'Epine portion. Except for the peri-urban areas of Lyon and Chambéry, the regulatory speeds in force match those of a standard French motorway network (90/130 km/h).

- ***Topographic profiles***

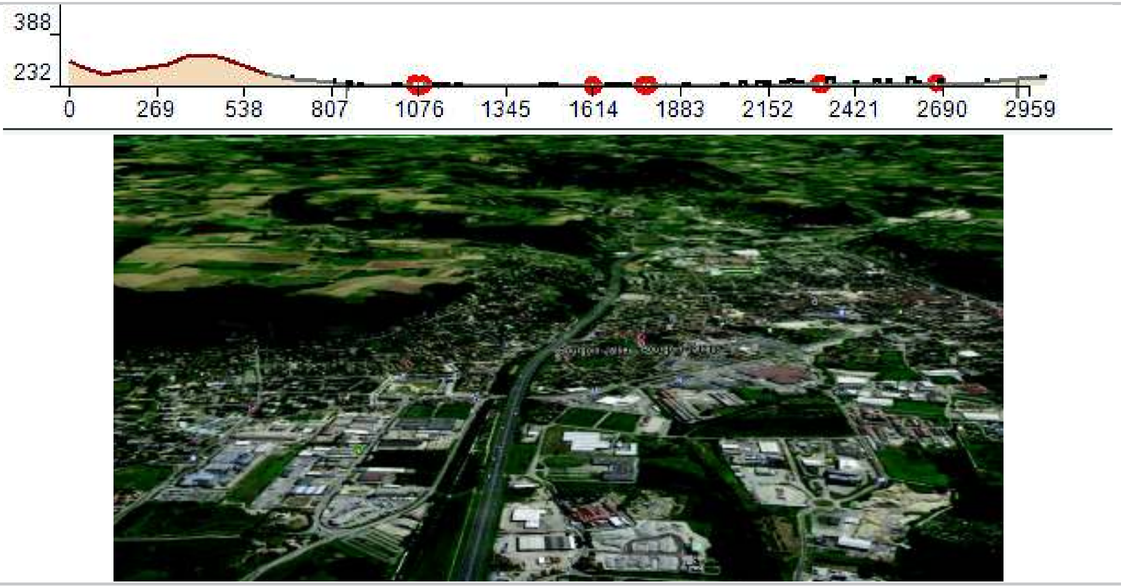


Illustration 25: A43 St-Priest – Coiranne. Typical cross-profile on this subsection. Red dots mark the location of road infrastructure modelled as acoustic sources. Horizontal and vertical scales in meters and aerial photograph (GoogleEarth) of the area near Bourgoin-Jaillieu.

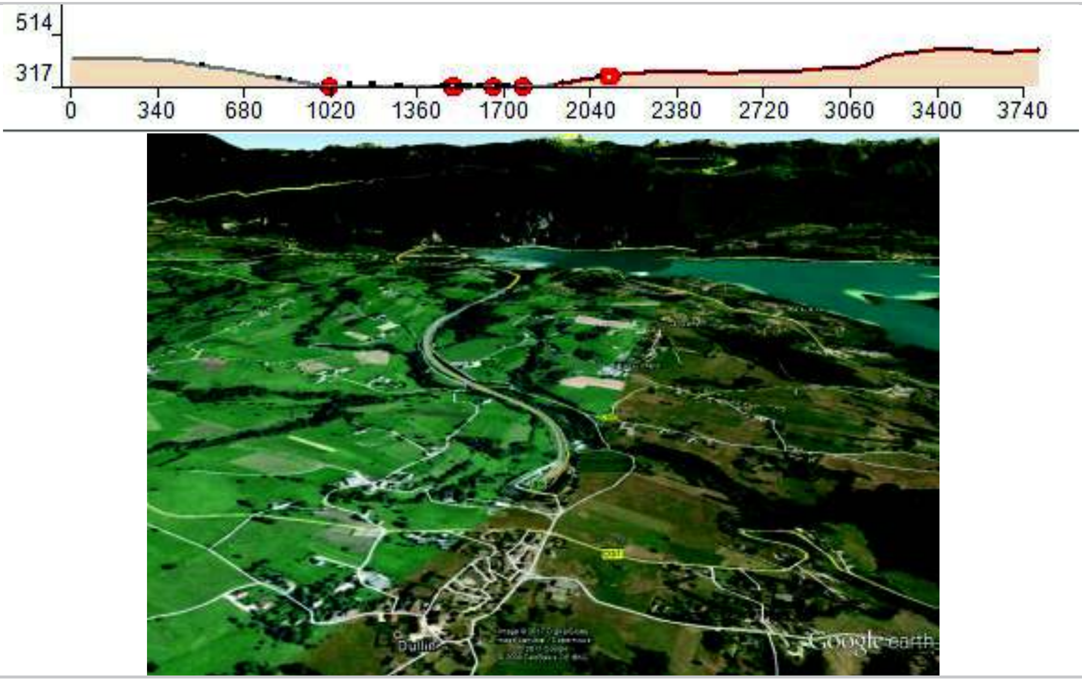


Illustration 26: A43 Coiranne – L'Epine. Typical cross-profile on this subsection. Red dots mark the location of road infrastructure modelled as acoustic sources. Horizontal and vertical scales in meters and aerial photograph (GoogleEarth) of the area near Dullin (Lac d'Aigueblette).

- ***Noise related external costs***

Subsections / Section	Terrain Mountain/Plain	External cost of noise (All vehicle)	Approximate population density (inhab/km²)	Cost/Pers./yr	NCV (1999/62/CE) €ct/veh.km
St Priest N346/ A43-A48 Coiranne	Plain	3 719 216 €	1204	118 €	1.75
A43-A48 Coiranne/ L'Epine	Plain	780 238 €	820	76 €	0.73
St Priest / L'Epine	Plain	4 499 454 €	1080	107 €	1,41

The highest estimated external costs are recorded in the first subsection, where built-up areas near the A43 obviously display a higher density. Throughout the second subsection (Coiranne-L'Epine), built-up areas are more scattered or located farther from the infrastructure, thus limiting populationexposure to noise. The annual external cost per km on this route is estimated at approximately 115.9 k€/km/yr, i.e.the highest cost of all the investigated routes, on par with the external costs estimated on the A7.

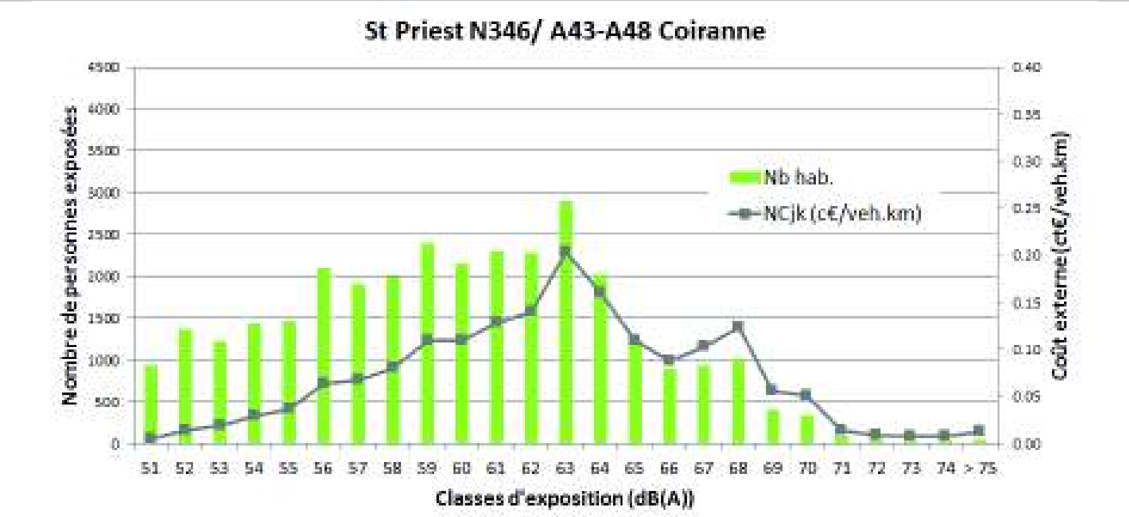


Illustration 27: A43 St-Priest - Coiranne: Population exposed per noise level class (LDEN (dB(A)) and associated external cost per HGV and per noise level class.

External costs on the St-Priest – Coiranne section are mainly associated with exposure levels below 65 dB(A). However, modelling also recorded populations exposed to noise levels reaching around 68 dB(A), which is the threshold value for road noise, according to the European Noise Directive.

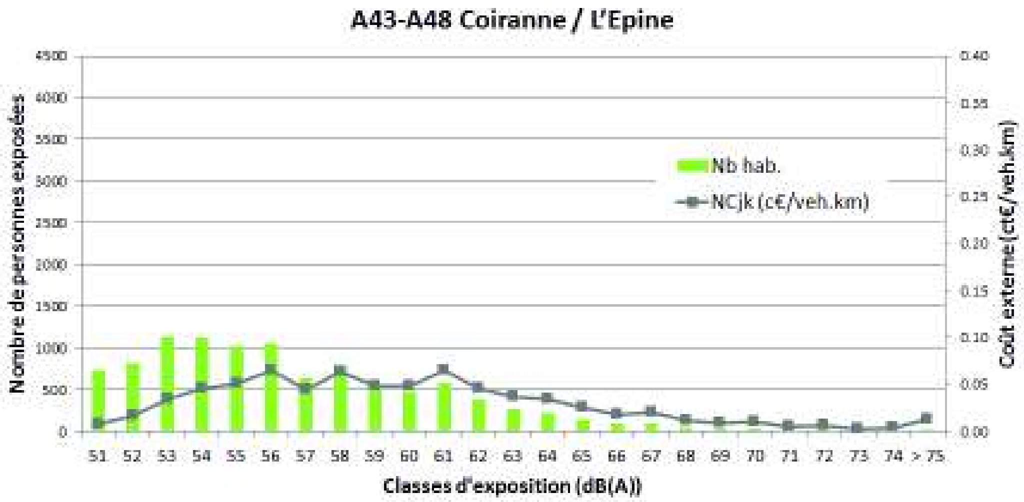


Illustration 28: A43 Coiranne - L'Epine: Population exposed per noise level class (LDEN (dB(A)) and associated external cost per HGV and per noise level class.

The relative distance from urban areas and the protection offered by natural terrain explain why, on the portion between Coiranne and Epine, a majority of people are exposed to levels below 60 dB(A).

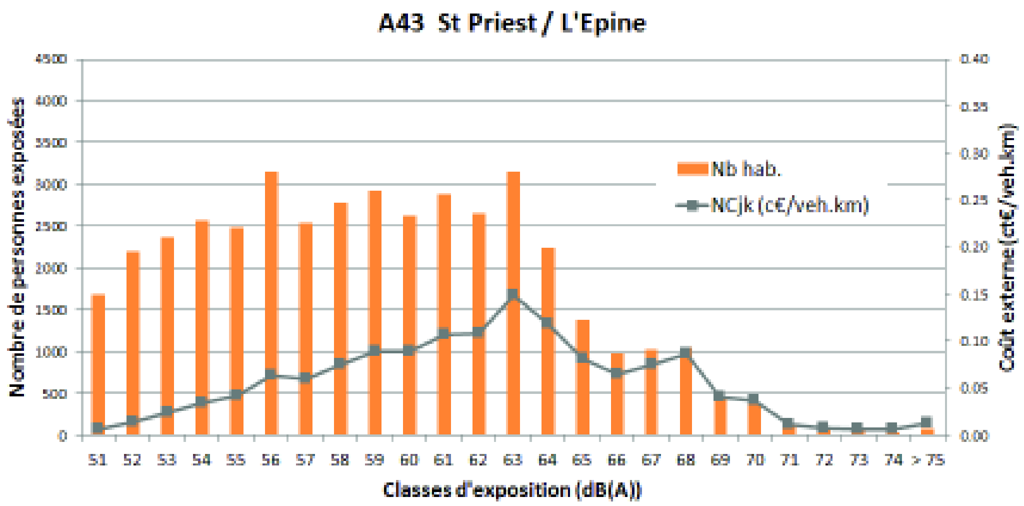


Illustration 29: A43 St Priest - L'Epine: Population exposed per noise level class (LDEN (dB(A)) and associated external cost per HGV and per noise level class.

It should be noted that once again, populations exposed to exposure levels above 68 dB(A) may have been subject to protective measures (particularly facade insulation), as part of the Environmental Noise Prevention Plans implemented(see publications at: http://www.isere.gouv.fr) or of other noise abatement policies (mitigation of black spots). The method for calculating external costs does not take into account the benefit of these treatments of the building envelope since acoustic levels used to calculate the NCV are assessed on the facades of buildings.

5.2 - Section A43: Chambéry - Maurienne Valley

This part of the route marks the access to Alpine slopes. The A43 winds along the valley floors, passing north of Chambéry, before entering the Combe de Savoie and the Maurienne Valley bound towards Italy. For the purposes of the study, the itinerary was broken down into four subsections as follows: L'Epine (tunnel)- the A41-A43 interchange - Aiton - St-Jean de Maurienne - the Fréjus Tunnel.

5.2.1 - *Traffic characteristics*

Subsections/Section	Terrain Mountain/Plain	AADT (Veh./d)	% HGVs	Length (km)	Maximum regulatory speed (HGV//LV) (km/h)
Epine / A41-A43	Plain	47 387	12.70%	5,5	90//90
A41-A43 / Aiton	Plain	32 040	12%	32	90//110/130
Aiton / St-Jean-M	Mountain	10 229	22%	37,4	90//130
St-Jean-M / Fréjus	Mountain	7 220	36%	25	90//130
Epine/Frejus	Mixed Plain/Mountain	18 501	16.49%	99,9	130/110/90

The two first sub-sections have the same characteristics as inter-city motorways in this region, with dense traffic as a whole and a moderate percentage of HGVs (around 12%). Ingress into the Maurienne Valley marks a significant change in traffic volumes and composition, with a marked decrease in AADT, and a relativelysignificant increase in HGV traffic,reaching 36% in the last subsection i.e. St-Jean-de-Maurienne - Fréjus Tunnel.

- ***Topographic profiles***

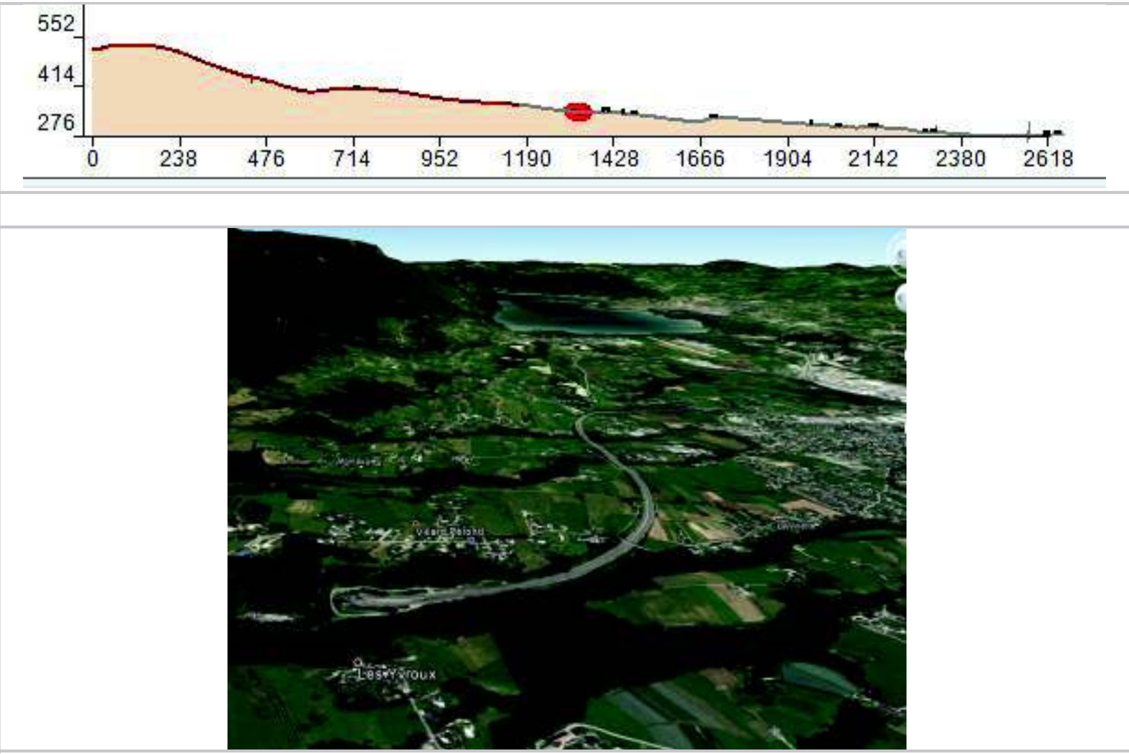


Illustration 30: A43 L'Epine – A41-A43. Aerial photograph (GoogleEarth) of the area close to Chambéry.

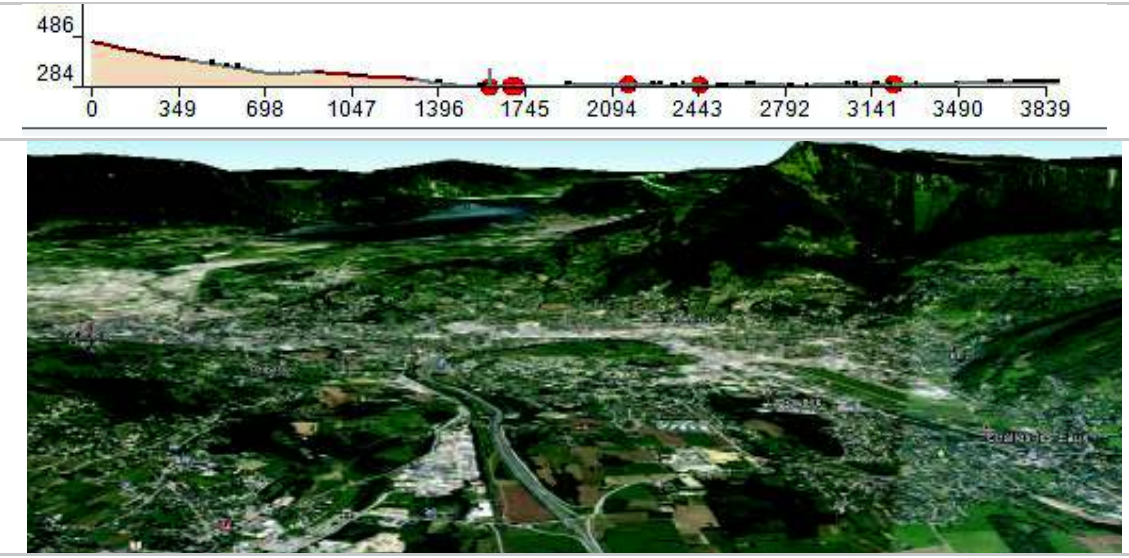


Illustration 31: A43 A41-A43 - Aiton. Typical cross-profile of this section. Red dots mark the location of road infrastructure modelled as acoustic sources. Horizontal and vertical scales (in meters) and aerial view (GoogleEarth) of the area.

The areas in these two first sections are characterized by their heavily built-up flat plainstypology.

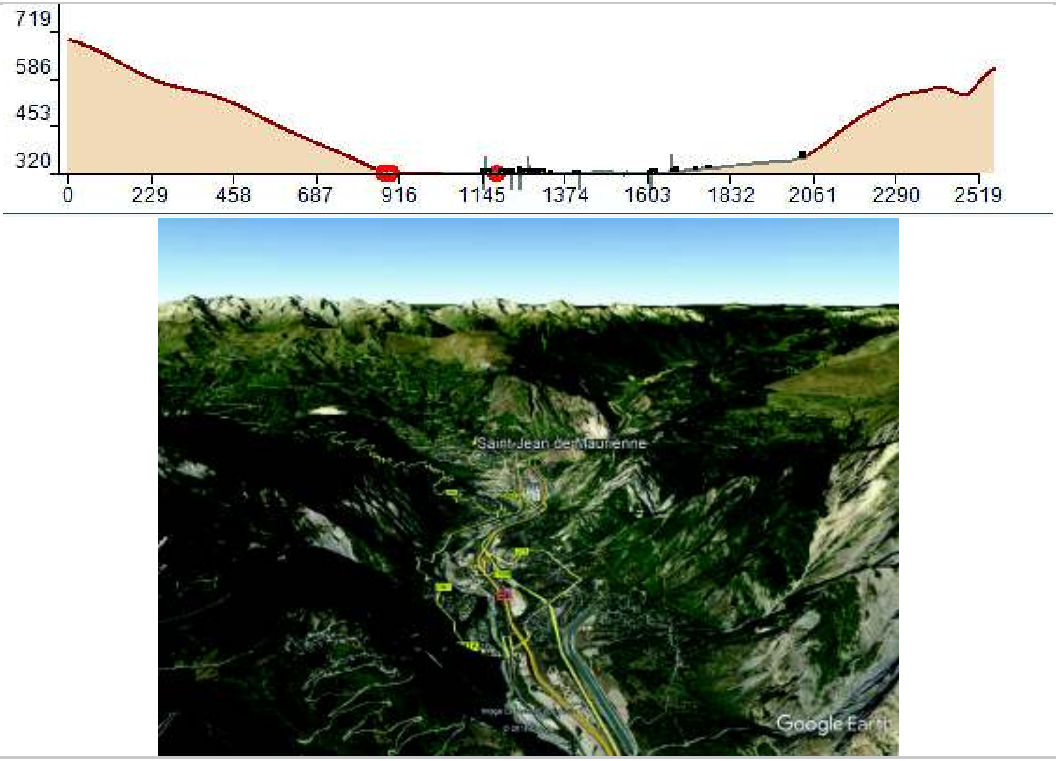


Illustration 32: A43 Aiton – St-Jean de Maurienne. Typical cross-profile on this section. Red dots mark the location of road infrastructure modelled as acoustic sources. Horizontal and vertical scales in meters and aerial photograph (GoogleEarth) close to Saint-Jean-de-Maurienne.

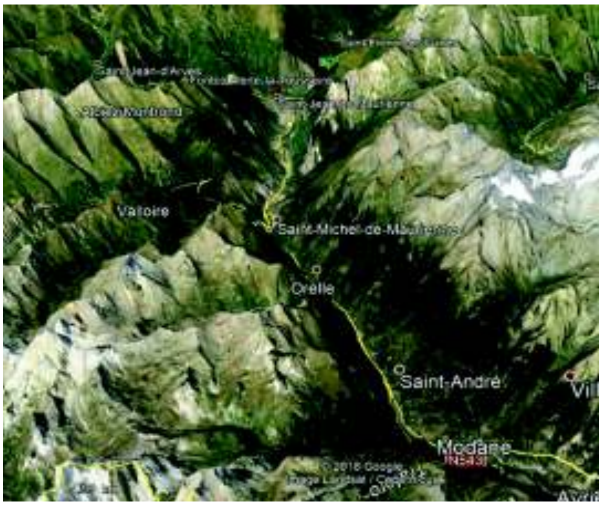


Illustration 33: A43 Aiton – St-Jean de Maurienne. Typical cross-profile on this section. Red dots mark the location of road infrastructure modelled as acoustic sources. Horizontal and vertical scales in meters and aerial photograph (GoogleEarth) of the area around St-Jean-de-Marienne/Modane.

The illustrations above show the classic typology of a V-shaped glacial valley, marked by a strong embankment characteristic of the Maurienne. Urbanization is low and scattered around infrastructures, with the human footprint situatedmostlyon the valley floor.

- ***Noise related external costs***

Section / Route	Terrain Mountain/Plain	External cost of noise (All Vehicles)	Approximate population density (inhab/km²)	Cost/Pers./yr	NCV (1999/62/CE) ct€/veh.km
L'Epine / A41-A43	Plain	592 504 €	1156	93 €	1,95
A41-A43 / Aiton	Plain	2 887 087 €	920	98 €	2,45
Aiton / St-Jean-M	Mountain	269 030 €	129	56 €	0,49
St-Jean-M / Fréjus	Mountain	307 003 €	217	57 €	0,93
L'Epine/Frejus	Mixed	4 055 624 €	461	88 €	1,72

The contrasts in terms of traffic, topography and urbanisation highlighted in the previous paragraphs for these four subsections are also reflected in the estimation of external costs. Around the first two subsections, between L'Epine and Aiton, this more densely populated area indicates noise related external costs within the upper limit rangesuggested by the Directive (between 1.95 et 2.45 €ct/veh.km). At the heart of the Maurienne Valley, the exposed population density is divided by a factor of 5 to 10, but the contribution of HGVs remains significant. This explains the decrease in the NCV indicator: it ranges between 0.49 and 0.93 €ct/veh.km in mountainous sections.

The external cost/km on this route is estimated at approximately 44.5 k€/km/yr.

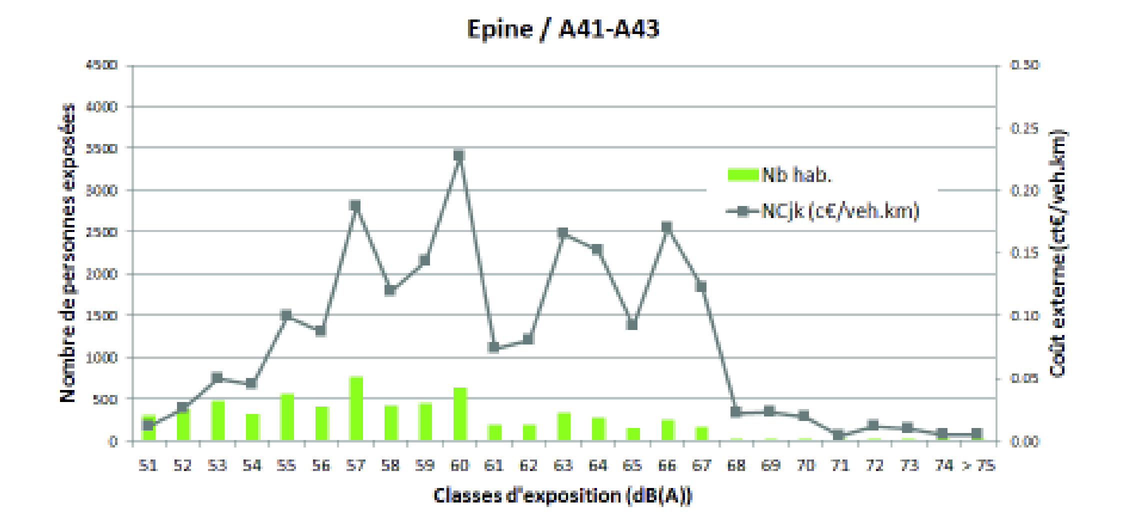


Illustration 34: A43 L'Epine – A41-A43: Population exposed per noise level class (LDEN (dB(A)) and associated external costs per HGV and per noise level class.

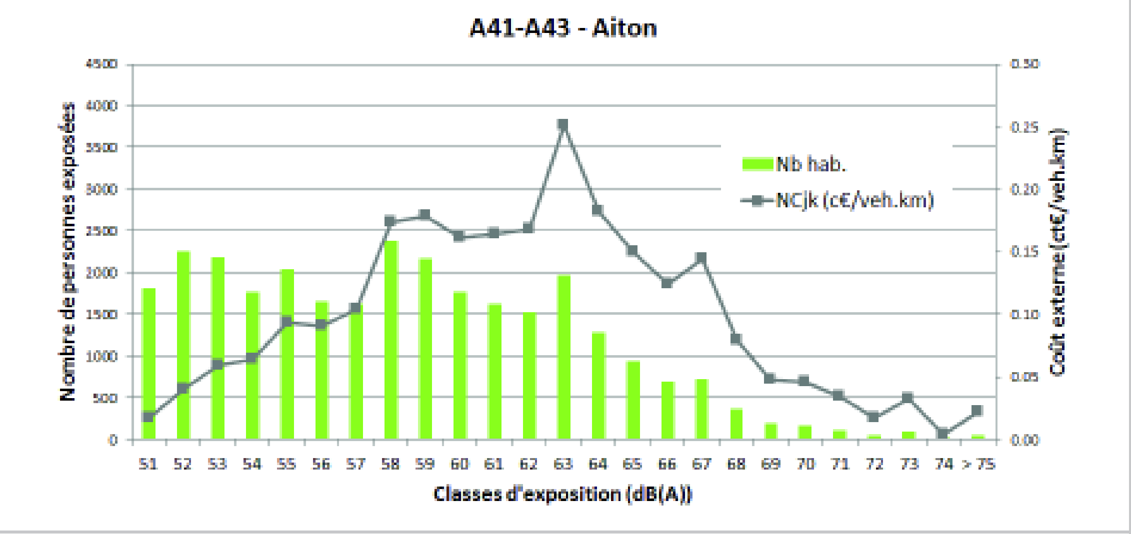


Illustration 35: A43 A41-A43 - Aiton: Population exposed per noise level class (LDEN (dB(A)) and associated external costs per HGV and per noise level class.

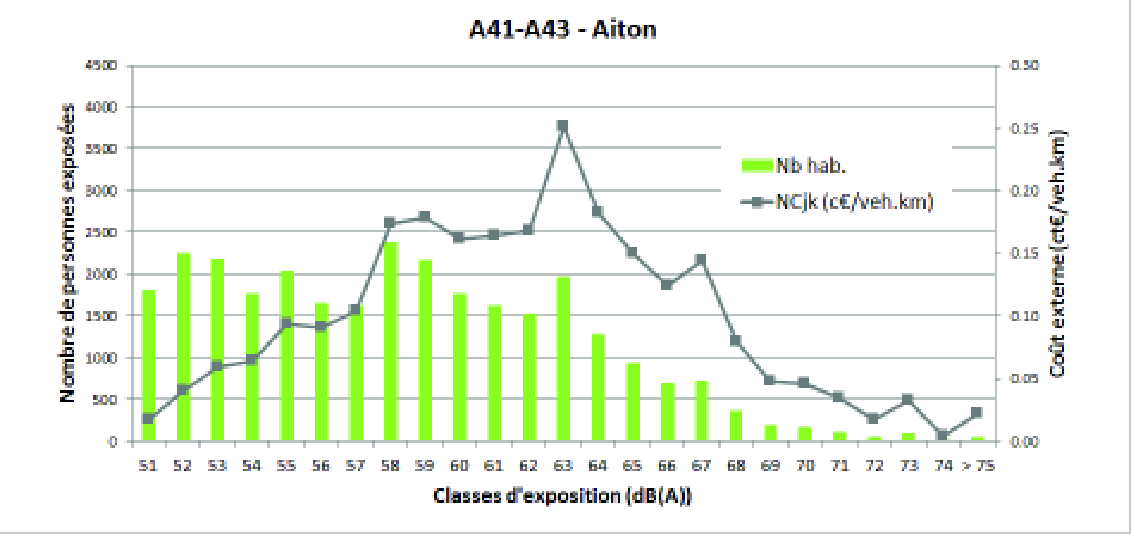


Illustration 36: A43 Aiton – St Jean de Maurienne: Population exposed per noise level class (LDEN (dB(A)) and associated external costs per HGV and per noise level class.

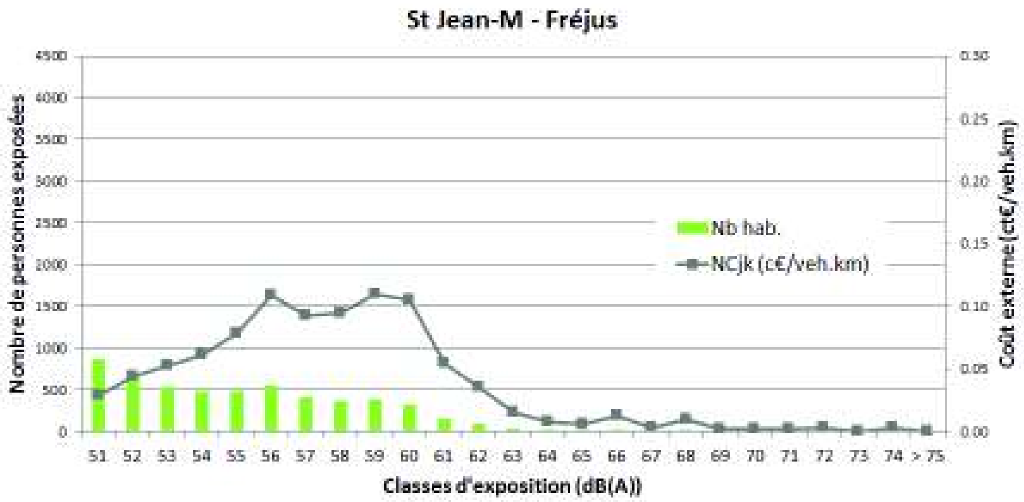


Illustration 37: A43 St-Jean de Maurienne – Fréjus Tunnel: Population exposed per noise level class (LDEN (dB(A)) and associated external costs per HGV and per noise level class.

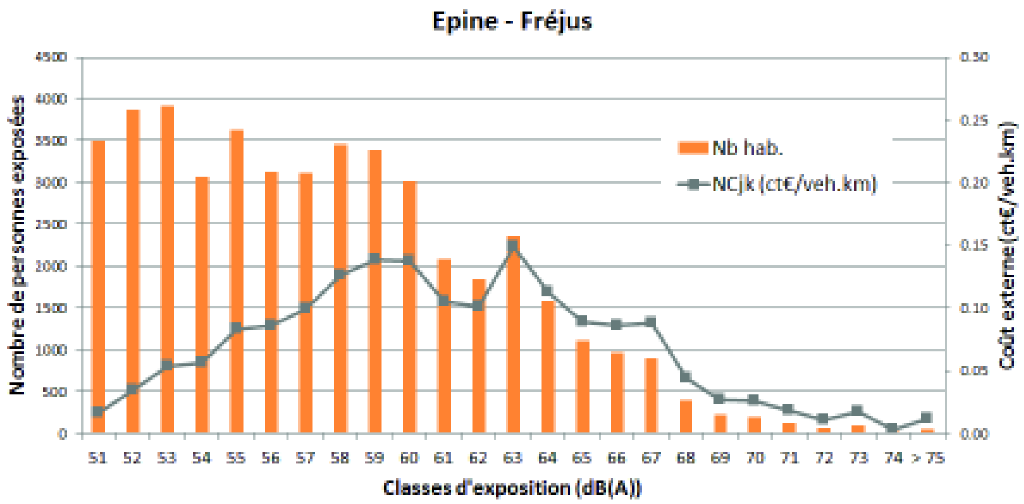


Illustration 38: A43 L'Epine – Fréjus Tunnel: Population exposed per noise level class (LDEN (dB(A)) and associated external costs per HGV and per noise level class.

Analysis by exposure class along the L'Epine-Fréjus Tunnel section shows that population exposure corresponds mainly to levels below 65 dB(A) on building facades and for many, below 60 dB(A). This is particularly the case in the narrowest part of the Maurienne Valley.It should be noted that the motorway was commissioned from Aiton in 1996 and the connection with the Fréjus Tunnel was completed in the early 2000s.The infrastructure thus benefited from the most recent acoustic regulations including the preventive treatment of the most exposed buildings (facade insulation or acoustic screens). Some of the noise related costs have therefore been internalised.
The 2013-2018 Environmental Noise Prevention Plan for Savoie (http://www.savoie.gouv.fr) identified only two remaining Noise Black Points (buildings) in the La Motte Servolex area.

6 - Route A7 the Rhône Valley: Lyon - Valence

The A7 motorway is part of the European routes network (E15 between Lyon and Orange) extending northwards towards Paris via the A6; and southwards linking Lyon to Marseille. The sectionunder study crosses the departments of Isère and Drôme and constitutes a historic corridor connecting the north and south of France. The A7 runs along the Rhône River in a wide valley with limited urban density, with the exception of the cities and conurbations it traverses, i.e. Lyon, Vienne, Valence for the sectionunder study. The A7 motorway is one of the busiest trunk roads in France.

For the purposes of this study, the chosen route has beenlimited to its portion between Lyon and Valence and broken down into four subsections as follows: Chasse-sur-Rhône – Reventin – St Rambert d'Albon – Tain l'Hermitage – Valence Sud.

- ***Traffic characteristics***

Subsections / Route	Terrain Mountain/Plain	AADT (Veh./d)	%HGV	Length (km)	Maximum regulatory speed (HGV//LV) (km/h)
Chasse/Reventin	Plain	109 005	15,41 %	15,6	80/90//110/130
Reventin/St Rambert d'Albon	Plain	70 141	18,26 %	20,6	90//130
St Rambert d'Albon / Tain l'Hermitage	Plain	65 315	17,97 %	29,2	90//130
Tain l'Hermitage/Valence Sud	Plain	62 233	18,11 %	18,4	80/90//110/130
Chasse/Valence Sud	Plain	73 960	17,36 %	83,8	130/110/90

The first section of the itinerary, southbound out of Lyon and its metropolitan area, is the one that carries the most traffic, with nearly 110,000 vehicles per day,of which 15% are heavy goods vehicles (nearly 16,000 HGVs/d). This overall volume decreases as traffic proceedssouth, but the proportion of HGVs increases significantly. Regulatory speeds matchthose of the French motorway network except in the vicinity of major cities or conurbations.

- ***Topographic profiles***

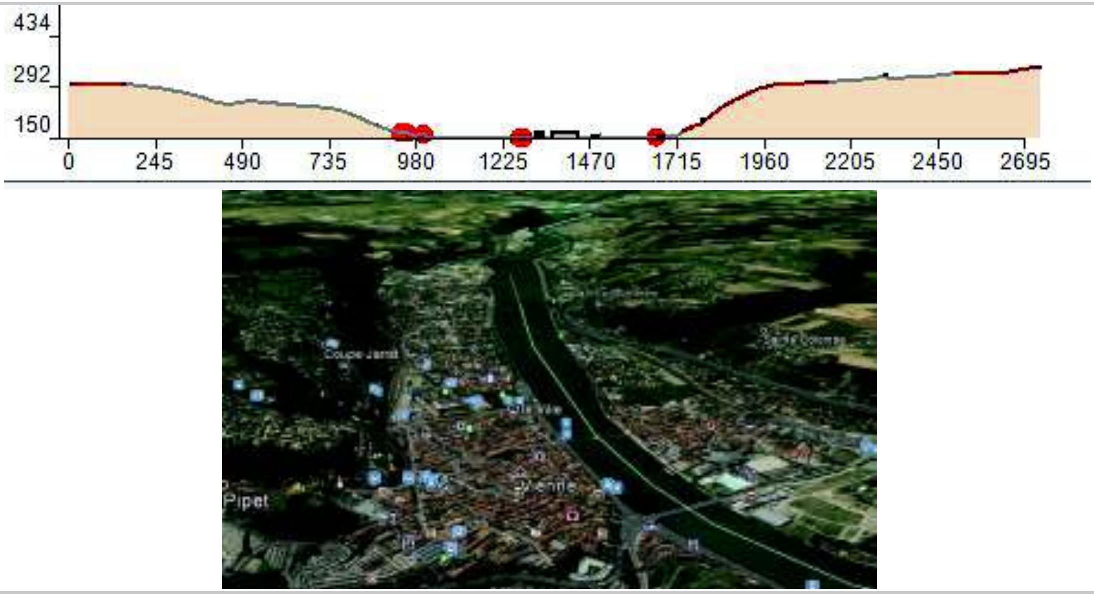


Illustration 39: A7 Chasse – Reventin. Typical cross-profile on this section. Red dots mark the location of road infrastructure modelled as acoustic sources. Horizontal and vertical scales in meters and aerial view (GoogleEarth) of the area close to Vienne.

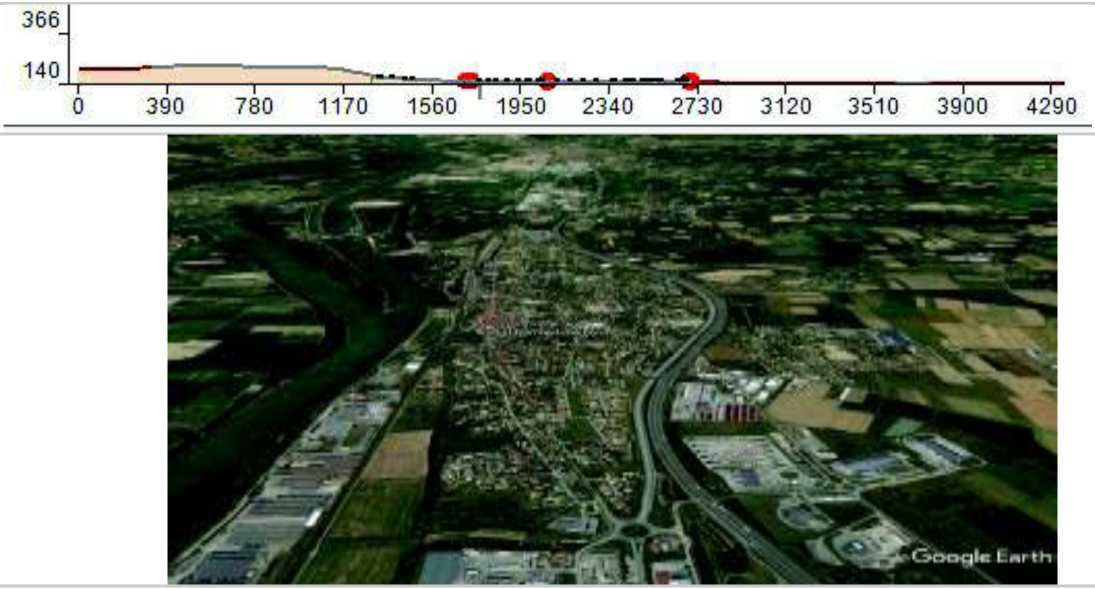
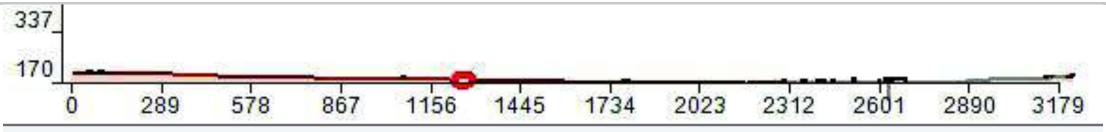


Illustration 40: A7 Reventin – St-Rambert d'Albon. Typical cross-profile on this section. Red dots mark the location of road infrastructure modelled as acoustic sources. Horizontal and vertical scales in meters and aerial view (GoogleEarth) of the area close to St-Rambert d'Albon.



llustration 41: A7 St-Rambert d'Albon – Tain l'Hermitage. Typical cross-profile on this section. Red dots mark the location of road infrastructure modelled as acoustic sources. Horizontal and vertical scales in meters and aerial view (GooglEarth) close to Roussillon.

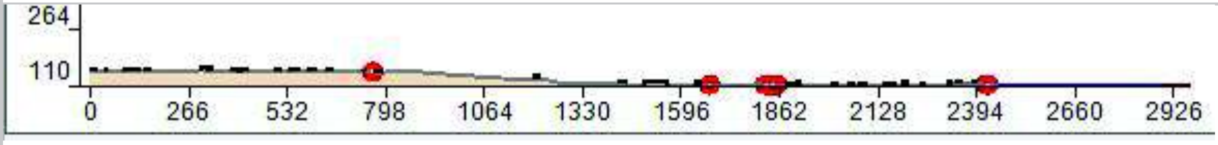


Illustration 42: A7 Tain l'Hermitage – Valence Sud. Typical cross-profile on this section. Red dots mark the location of road infrastructure modelled as acoustic sources. Horizontal and vertical scales in meters and aerial view (GoogleEarth) of the area close to St-Barthélémy de Vals.

Illustration 43: A7 Tain l'Hermitage – Valence Sud. Aerial view (GoogleEarth) of the area close to Valence.

Along thisentire route, the topography is characteristic of plain areas and the first slopesare located several kilometres away from the motorway.

- ***Noise related external costs***

Subsection / Route	Terrain Mountain/Plain	External cost of noise (All Vehicles)	Approximate population density (inhab/km²)	Cost/Pers./yr	NCV (1999/62/CE) €ct/veh.km
Chasse/Reventin	Plain	3 137 845 €	1311	153 €	1,48
Reventin/St Rambert d'Albon	Plain	2 247 634 €	870	125 €	1,17
St Rambert d'Albon / Tain l'Hermitage	Plain	1 466 670 €	311	161 €	0,58
Tain l'Hermitage/Valence Sud	Plain	2 886 984 €	1350	116 €	1,91
Chasse/Valence Sud	Plain	9 739 133 €	862	135 €	1,21

The most important estimated external costs have obviously been identified in subsections crossing the densest urban areas. The calculated NCV values are within the range proposed by the Eurovignette Directive, with the exception of the St Rambert d'Albon/Tain l'Hermitage section (NCV=0.58 €ct/veh.km), which hasthe lowest value due to the particularly low population density exposed to the A7 in this sector.
It should be noted that the external costs over this entire route are the highest of all the routes under study, i.e. approximately 116 k€/km/year. However, the associated NCV values remain "moderate" due to the distribution of costs between a higher number of HGVs.

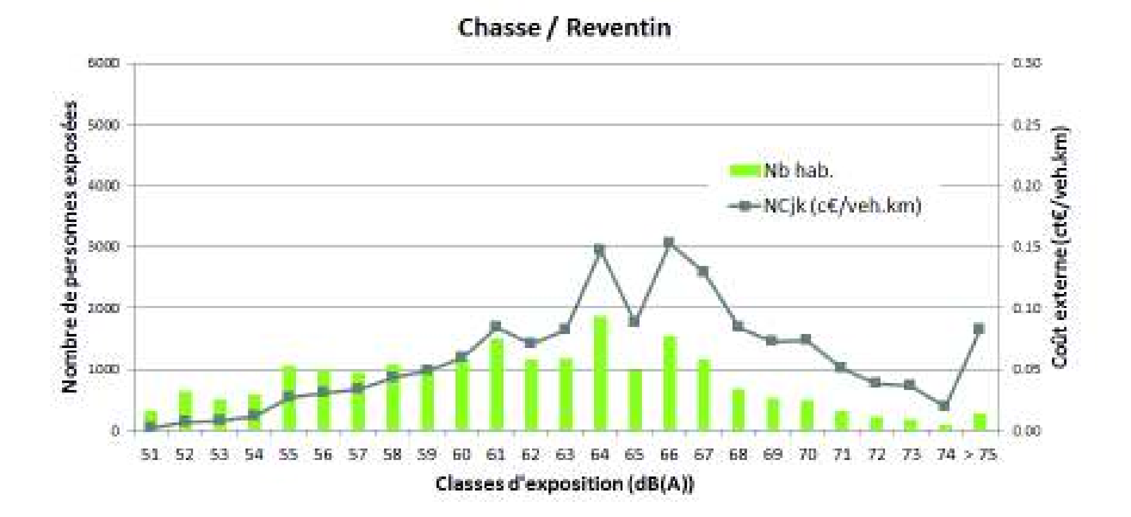


Illustration 44: A7 Chasse – Reventin: Population exposed per noise level class (LDEN (dB(A)) and associated external cost per HGV and per noise level class.

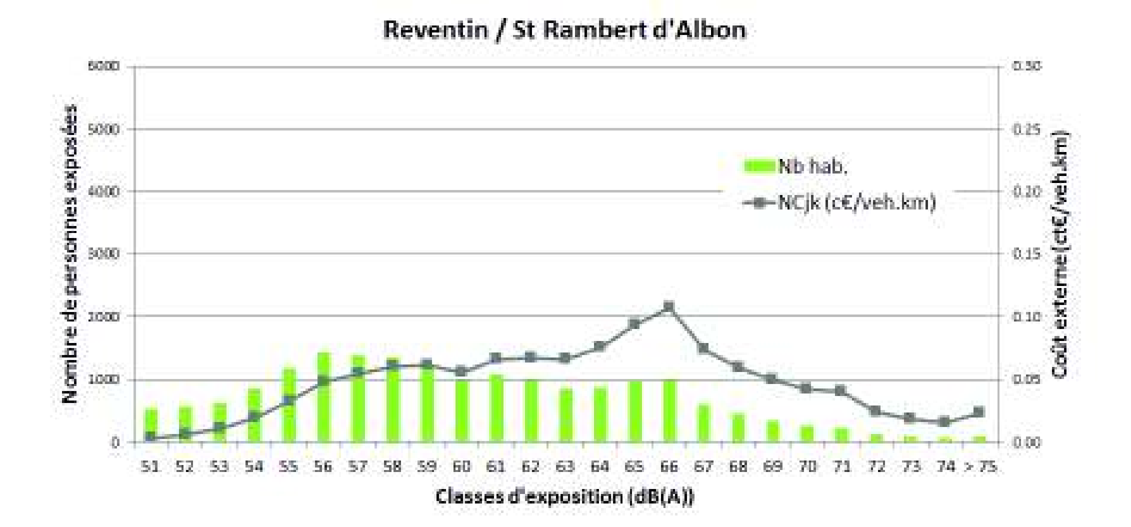


Illustration 45: A7 Reventin – St-Rambert d'Albon: Population exposed per noise level class (LDEN (dB(A)) and associated external cost per HGV and per noise level class.

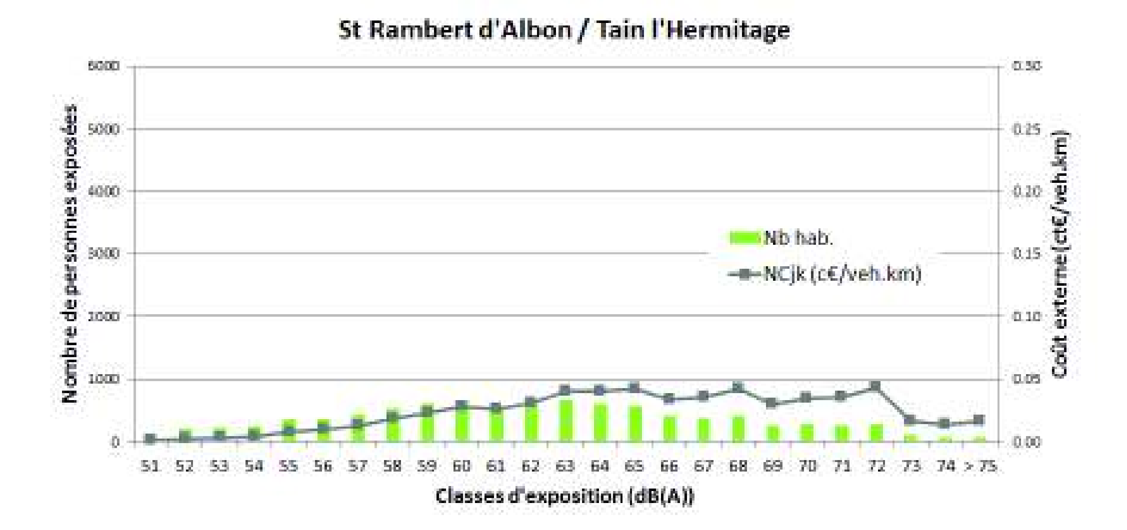


Illustration 46: A7 St-Rambert d'Albon – Tain l'Hermitage: Population exposed per noise level class (LDEN (dB(A)) and associated external cost per HGV and per noise level class.

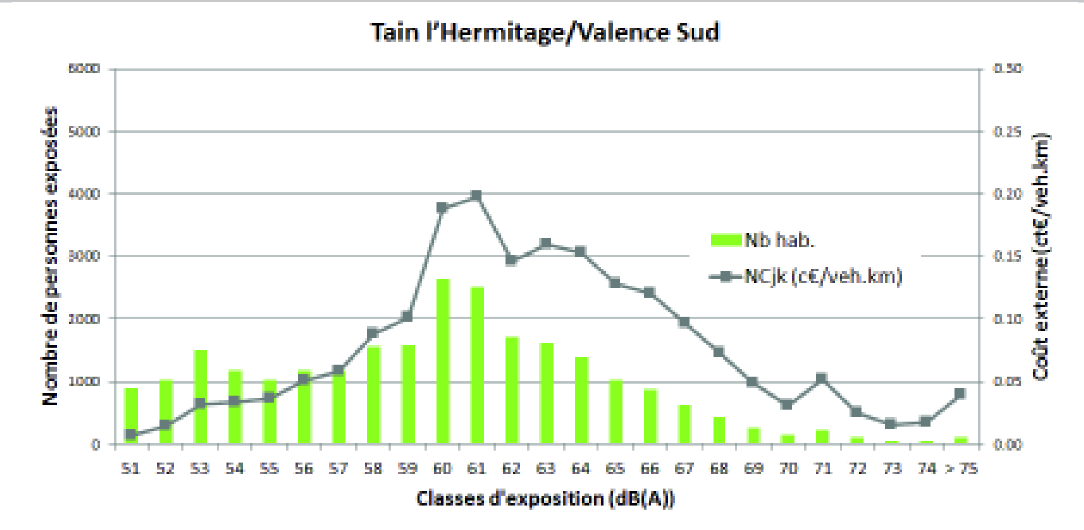


Illustration 47: A7 Tain l'Hermitage – Valence Sud: Population exposed per noise level class (LDEN (dB(A)) and associated external cost per HGV and per noise level class.

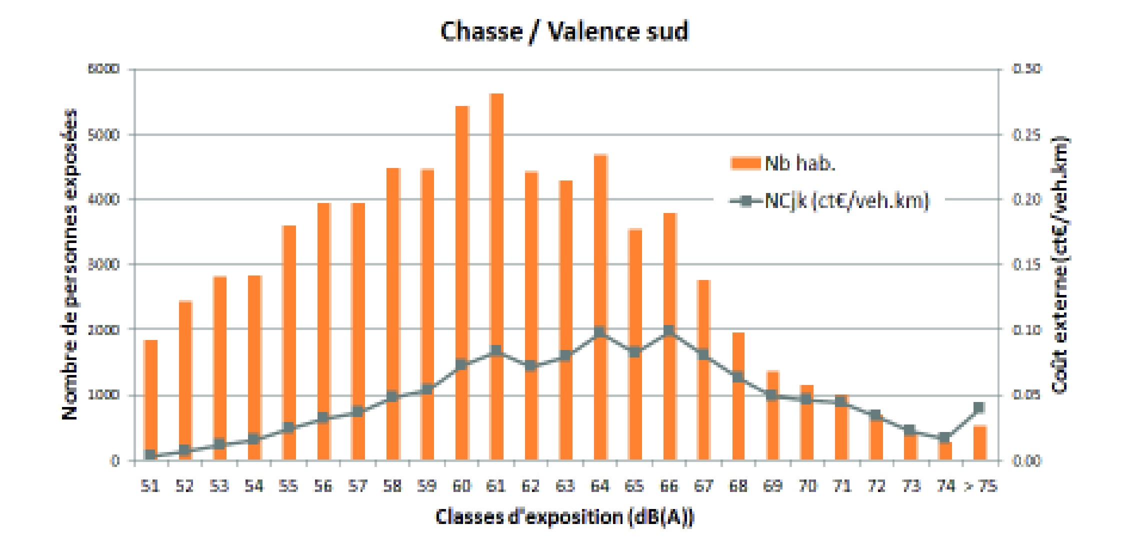


Illustration 48: A7 Chasse-sur-Rhône – Valence Sud: Population exposed per noise level class (LDEN (dB(A)) and associated external cost per HGV and per noise level class.

The external costs are mostly due to population exposures to noise levels below 68 dB(A), but the proportion of the population still exposed to above 68 dB(A) levels remains significant.

As on the other routes, the noise control policies implemented for several decades have made it possible to identify and reduce some of the Noise Black Spots around this trunk road, with the erection of vertical protection or facade insulation.Please note that the assessment of external costs includes the presence of these vertical protections but not the facade insulation works carried out (noise levels calculated on the exterior facade of buildings). us in the department of Isère, the State Environmental Noise Prevention Plan covering the period 2013-2018 (http://www.isere.gouv.fr/)reportsno residual Noise Black Spot around the A7.They have absorbed by facade insulation or by the erection of acoustic screens. The same applies to the Drôme Department (see PPBE 2015-2018, http://www.drome.gouv.fr).

7 - Comparative analysis of external costs per route and conclusions

The following table summarizes all the results for the routes studied, and the breakdown by sub-section. A graphical representation of this table can be found in Illustration 50.

	Subsections	Mountain/Flat	Length (km)	AADT Annual average daily traffic (veh/day)	% HDV (Heavy Duty Vehicles)	Exposed population density (inh,/km²)	Noise cost NCVj (ct€/veh,km)	*NCVj/1000 Pers/km (ct€/veh,/pers)*
E21-E25 European route	Pont d'Ain / Tunnel Vuache	Mix Flat/Mountain	11,8	20 307	14,1%	654	1,65	*2,52*
	Tunnel Vuache / Scientrier	Mix Flat/Mountain	38,7	29 061	8,6%	418	1,39	*2,67*
	Scientrier / Cluses	Mix Flat/Mountain	23,6	26 396	8,8%	983	3,04	*3,09*
	Cluses / Le Fayet	**Mountain**	21,1	17 216	11,2%	665	**2,5**	***3,76***
	Le Fayet / Chamonix	**Mountain**	35,6	13 876	15,3%	149	**0,59**	***3,92***
E70 European route	St Priest N346/ A43-A48 Coiranne	Flat	26,2	73 170	10,5%	1 204	1,75	*1,45*
	A43-A48 Coiranne/ L'Epine	Flat	12,6	71 874	13,1%	820	0,73	*0,89*
	L'Epine / A41-A43	Flat	5,5	47 387	12,7%	1 156	1,95	*1,68*
	A41-A43 / Aiton	Mix Flat/Mountain	32	32 040	12,0%	920	2,45	*2,66*
	Aiton / St-Jean-M	**Mountain**	37,4	10 229	22,0%	129	**0,49**	***3,8***
	St-Jean-M / Fréjus	**Mountain**	25	7 220	36,0%	217	**0,93**	***4,28***
E15 European route	Chasse/Reventin	Flat	15,6	109 005	15,4%	1 311	1,48	*1,13*
	Reventin/St Rambert d'Albon	Flat	20,6	70 141	18,3%	870	1,17	*1,34*
	St Rambert d'Albon / Tain l'Hermitage	Flat	29,2	65 315	18,0%	311	0,58	*1,87*
	Tain l'Hermitage/Valence Sud	Flat	18,4	62 233	18,1%	1 350	1,98	*1,41*
						Average (std. dev.)	**1.51 (0,78)**	***2.43 (1,13)***
						Average « Flat »	**1,26**	***1,39***
						Average « Mix Flat/Mountain »	**2,13**	***2,74***
						Average « Mountain »	**1,13**	***3,92***
						Ratio « Mountain/Flat »		***2.83***

Illustration 49: Summary results for the 3 routes and associated sub-sections. NCV and NCV/1000hab./km averages as well as standard deviations are also presented for all sub-sections and by showing the difference between flat areas and mountainous areas.

The table above make the following possible:
- highlighting the actual stated disturbances taking account of the exposed population in the three valleys under study (last column of table 49).
- assessing, regardless of the population, a mountain/plain ratio (last column of table 49).

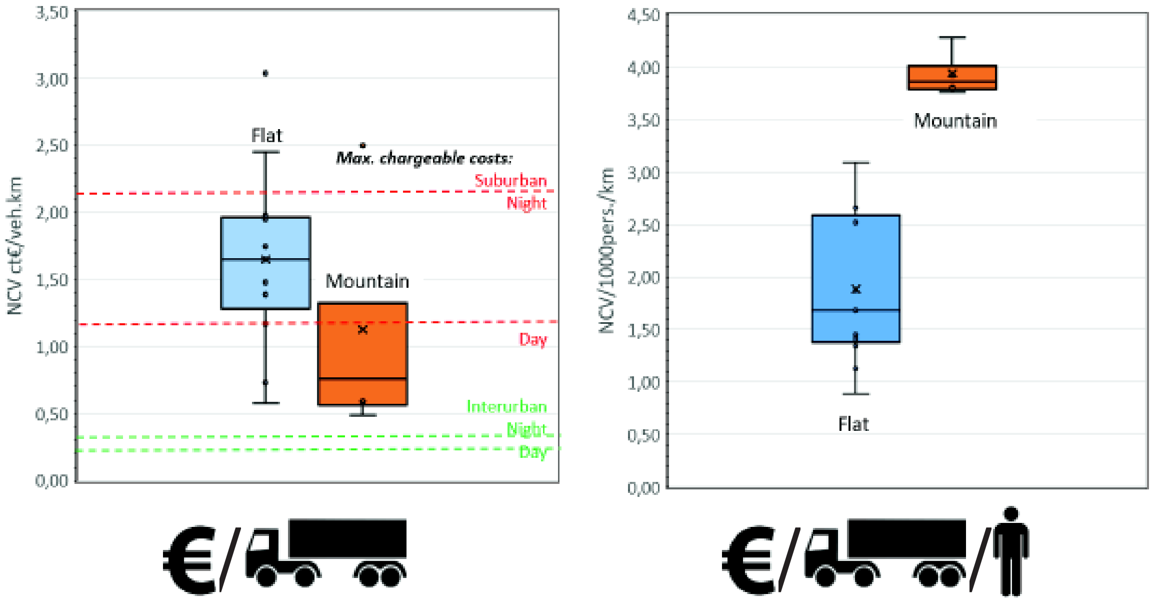


Illustration 50: distribution of results for flat subsections (blue) and mountain subsections (orange). On the left NCVj per HGV, on the right NCV/1000pers./km. Red dotted lines, respectively green, are the suburban, respectively urban, night and day limits of chargeable costs (Eurovignette Directive).

a) Indicator inclusive of population

External costs assessed on the seven flat plain sections vary, according to the NCVj indicator, between 0.58 and 1.98 €ct/veh.km with an average value of1.26 €ct/veh.km. Please note the significant standard deviation: it represents almost 50% of the stated average value.

The estimates calculated for the four mountain sections range from 0.49 to 2.5 €ct/veh.km with an average of1.13 €ct/veh.km. The maximum value is obtained on the Cluses/Le Fayet section, where the highest density of exposed populations is found (665 hab./km²).

b) Indicator exclusive of population

The external costs assessed for the seven plain sections vary according to indicatorNCVj/1,000pers-km,ranging from 0.89 to 1.87 €ct/veh-km/pers with an average value of1.39 €ct/veh-km/pers. We noted a moderate standard deviation.

External costs assessed for the four mountain sections vary according to indicator NCVj/1000pers-km, ranging from 3.76 to 4.28 with an average value of 3.92 NCVj/1000pers-km. We noted a small standard deviation.

The mountain/plain ratio is estimated at**2.8**

c) Benchmarking against the Eurovignette Directive

Appendix III of the Directive authorizes surcharges on the whole European network, for noise disturbances generated by HGVs, based on two criteria:

- the suburban or interurban nature of the section;
- day or night traffic.

It also authorizes applying a factor 2 to theses disturbances in mountainous areas.

Since mountain sections can be considered as suburban axes, the authorized costs of 1.1€ct/veh-km apply for day time, and 2€ct/veh-km for night time.

The results of this study, i.e. 1.39€ct/veh-km, an average for day and night in plains, show the same reference bracket as quoted by the Directive.

However, the mountain/plain ratio estimated in this study is in the order of**2,8**(independently of the population density factor).

d) Comments

Precautionary measures must be taken when interpreting costs calculated with the method we described. Noise levels associated with exposed populations are calculated off facades of residential buildings (external).

The quality of building envelopes, and notably their acoustic insulation, was not factored into the calculation of exposure. However, environmental noise abatement works, supported by public policies and conducted by State agencies and infrastructure managers give rise in part to the reinforcement of the acoustic insulation of buildings.

These actions do not modify external noise levels and therefore external costs as they are calculated, but they limit the exposure of people in their homes. Taking account of the numerous Noise Black Spot Mitigation Operations that have been conducted over the past few years, the calculated external costs are therefore partially overestimated.

Reversely, the cost of such works (acoustic insulation, noise screens etc.) and of their maintenance should be included in the calculation of external costs insofar as they are mainly induced by noise disturbances generated by HGV traffic.

8 - Specificities of the issue of noise in mountainous areas: understanding the Eurovignette case

Among the factors identified as specific to mountainous areas and which could have a negative impact on noise relatedexternal costs, the Eurovignette Directive identifies: slopes, topography and meteorology. The contribution of each of these parameters is discussed below.

8.1 - Contribution of slopes

Road noise emissions are traditionally broken down into two components: engine noise (mechanical operation of the vehicle); and rolling noise (tyre-to-pavement contact). The relative weight of each component in the total emission is related to vehicle speed and traffic dynamics or speed. We can differentiate between the following speeds: stabilized, acceleration, and deceleration. Rolling noise is also dependent on the type of pavement and its condition.

At low speed, engine noise outweighs rolling noise. For LVs, rolling noise will outweigh engine noise above approximately 50 km/h in stabilized speed conditions. For HGVs the limit is slightly higher, at around 70 km/h.
Consequently, rolling noise will always be considered to be predominanton the motorways we studied.

Road gradients affect engine noise, but not rolling noise. Without being completely negligible, a slope will therefore have a limited influence on noise emissions. NMPB08 provides an estimation of the over-emission of noise in descent or ascent for HGVs. It varies between 0 dB(A) (downward slope <2%) and 8 dB(A) (upward slopeat 6%). Combined with the rolling noise, the over-emission for HGVs will be at most around 2 dB(A).
With regard to LVs, it is accepted that any excess acoustic emissions are negligible for gradients below 6%.

The slope factor has been incorporated into the modelling of noise map used to quantify population exposure and therefore external costs.

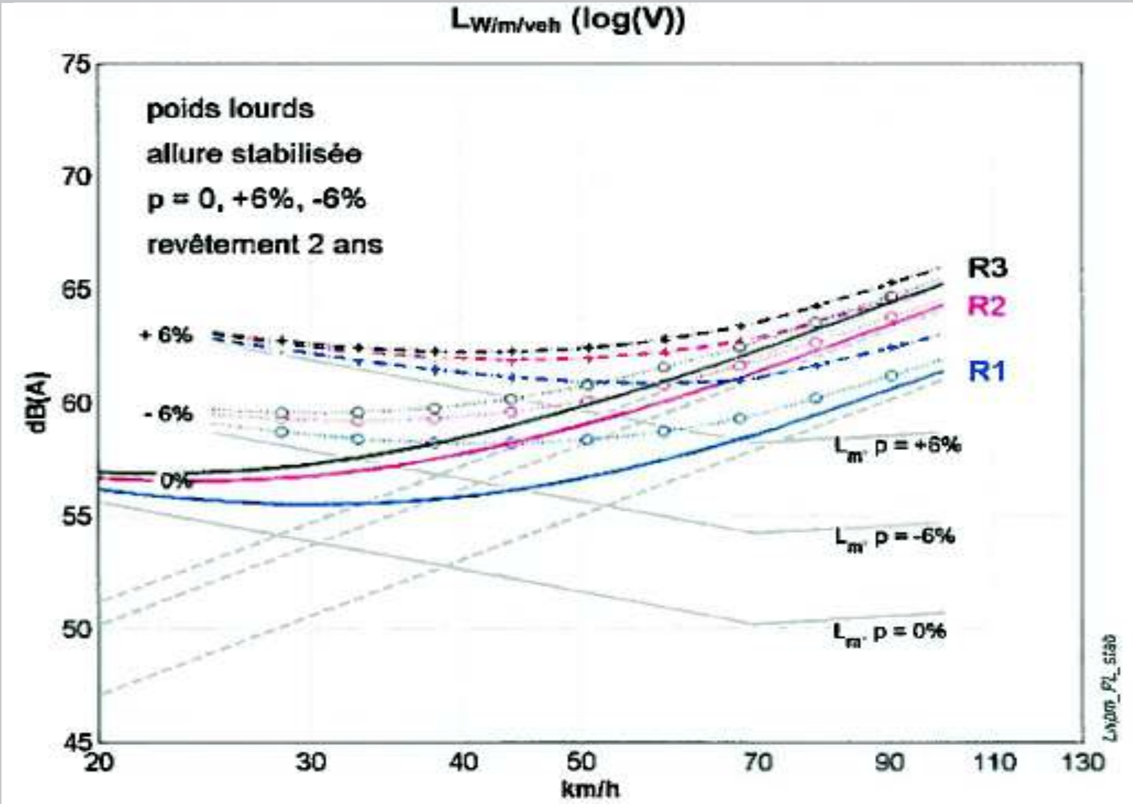


Illustration 51: Emission chart (power level per meter and per vehicle) for HGVs as a function of speed, slope and pavement category (R1, R2, R3), for a recently built pavement (Source: Road noise forecast, Volume 1: Calculation of road traffic noise emissions - Sétra 2009).

8.2 - The amphitheatre effect

The so-called amphitheatre effect is associated in acoustics, with the propagation of sound waves between a source located below a receiver (dominant situation). Such exposure is typical for buildings erected on the slopes of a valley, on the floor of which land transportation infrastructure is found. The relative source-receptor position can minimize the mitigation effect of the sound wave when it reflects during its propagation, on a more or less absorbent ground, or when it encounters other obstacles (natural and artificial). This effect increases with source-receptor distance.
Compared with an exposure in a plain situation, this effect will tend to increase sound levels on dominant receptors located at a few hundred metres;these sound levels are generally moderate due to the distance from the source (natural geometric divergence).
The modelling carried out in this study takes this effect into account through the three-dimensional description of the environment and the absorbent properties of soils.

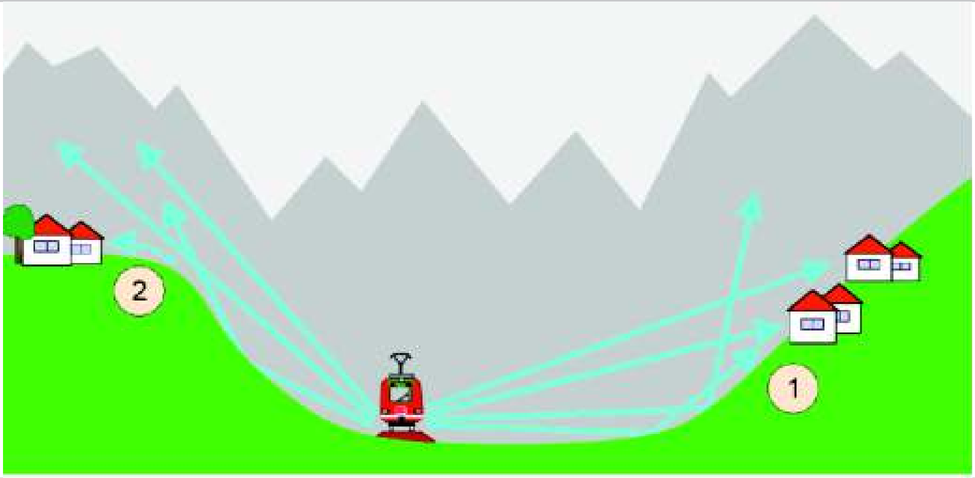


Illustration 52: Illustration of the amphitheatre effect [7]

Along the routes we studied, a number of houses have an amphitheatre-type exposure configuration. However, on the one hand, these houses are relatively few in number compared to "level" exposure situations, and on the other, the buildings involved are generally located farenough to limit noise levels and therefore external costs.

8.3 - The role of reverberation

Mountain zones are easily associated with the phenomenon of acoustic echo or reverberation, resulting from overlapping "echoes" converging towards receivers. The notion of reverberation comes from construction acoustics and is reflected in the persistence of sound over time. This induces an increase in sound level, unlike wider open spaces in which acoustic energy barely returns to the receiver,if at all. Environments of enclosed, semi-open valleys can be where acoustic reflection phenomena similar to the reverberation phenomenon occur, without however going so far as to produce a diffuse, homogeneous field.
Very few scientific studies have been carried out to date to support and quantify the impact of reverberation in mountainous areas.
Between 2009 and 2010, as part of a research and development project carried out for RFF (Réseau Ferré de France, now SNCF-Réseau), the CETE de Lyon (now Cerema Centre-Est) conducted experiments and modelling in order to clarify the tangible influence of reverberation [7]. The site chosen for this study was located in the city of Montvernier, where the Maurienne valley narrows down significantly and becomes very steep-sided (see Illustration 53).

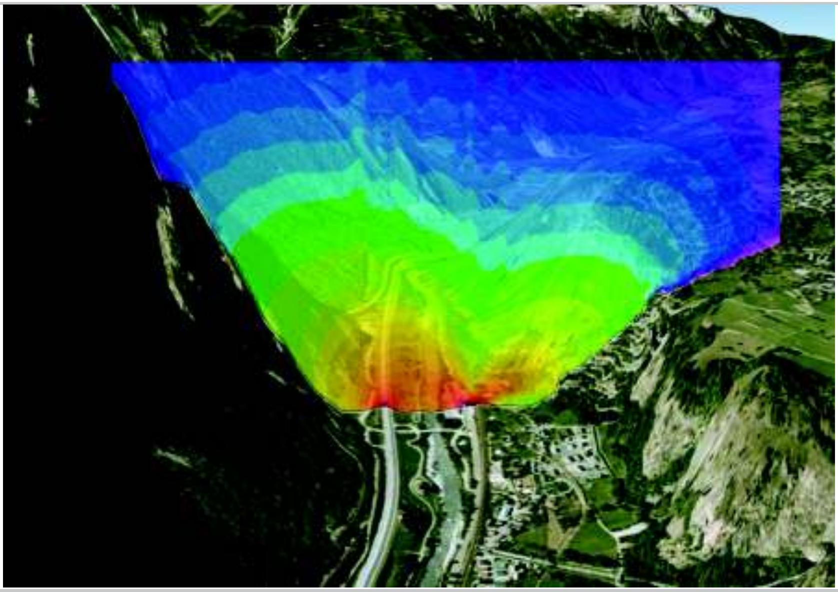


Illustration 53: Modelling of acoustic atmosphere in Montvernier (Savoie), in the heart of the Maurienne valley. The modelling presented here integrates dominant road and rail sources.

Metricsrecorded on the slopes of the Montvernier bends made it possible to isolate the share of acoustic field reverberates by the cliffs. A detailed analysis of these measurementsdisclosed a number of results. It was corroborated by detailed modelling using room acoustics software (Catt-Acoustics) which took into account the phenomena of reflection and diffusion by the walls:

- In narrow valleys with reflective and diffusing walls, the reverberation phenomenon modifies the acoustic atmosphere in certain areas;
- The reverberated field becomes comparable to the quasi-direct field (having undergone only a few reflections: direct, reflection on the ground) when one moves far enough away from the sources, i.e., in this case, on the slopes overhanging the bottom of the valley;
- In the direct vicinity of transport infrastructures, up to a few hundred metres away, the reverberation phenomenon is negligible (direct field predominates);

- The reverberated field consists of sound "rays" that have travelled several hundred metres before reaching receivers. During these "journeys", acoustic energy has significantly decreased;
- However, as we move away from the sources, the direct field decreases (geometric divergence and sound absorption), and the portion of reverberated field can match the direct field.
- In the case of this valley, considered to be very steep-sided, the contribution of the reverberant field remains negligible in built-up areas on the valley floor (close to infrastructures) and therefore of no consequence on population exposure. However, it affects outdoor spaces.
- The effect of reverberation should be taken into account if sensitive buildings (including homes) werelocated on the slopes in a distant but dominant position with respect to the noise sources considered. This was not the case in the Maurienne Valley.

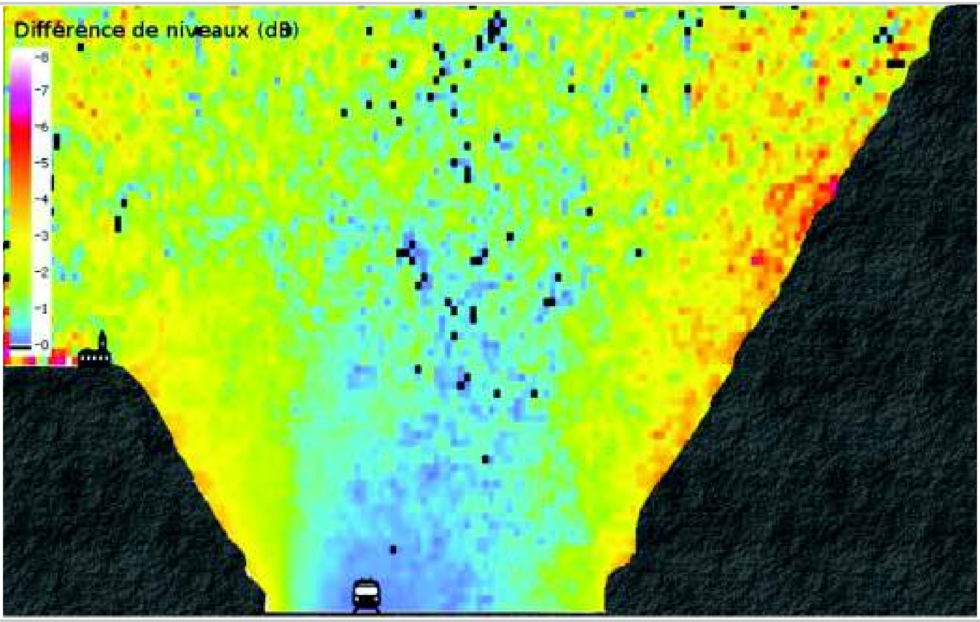


Illustration 54: Highlighting the areas of influence of reverberation in the Maurienne Valley. This influence is more pronounced on the slopes and increases when the distance from the source does.

In a majority of valley situations crossed by major transit routes, built-up areas are located on the valley floor near these routes. Reverberation will therefore only play a secondary role in the population's exposure to noise.

This conclusion does not entail that the phenomenon has no impact in mountain environments; however, the calculation of external costs is based on the quantification of people exposed to levels above 50 dB(A) in their homes.Reverberation will therefore generally have an impact on the unbuilt outdoor environment (natural areas, regional parks, hiking trails, etc.), with the result that noise sources located on the floor of the valley are perceived and background noise levels are increased.This impact is not taken into account by current methods when calculating external costs.

8.4 - The role of meteorology

The propagation of acoustic waves is influenced by the state of the atmosphere and in particular the wind or air temperature fields between the source and the receiver. Apart from the phenomena of reflections on obstacles, in a homogeneous atmosphere, an acoustic wave propagates in a "straight line" between the source and the receiver. In the presence of wind and/or temperature gradients, the variation in propagation parameters (velocity) above the ground will have the effect of bending (refraction phenomenon) acoustic rays upwards or downwards. These phenomena of "acoustic mirages", well documented and integrated into sound level standards and forecasting tools, can lead to differences of several decibels between propagation situations in a homogeneous or heterogeneous atmosphere.

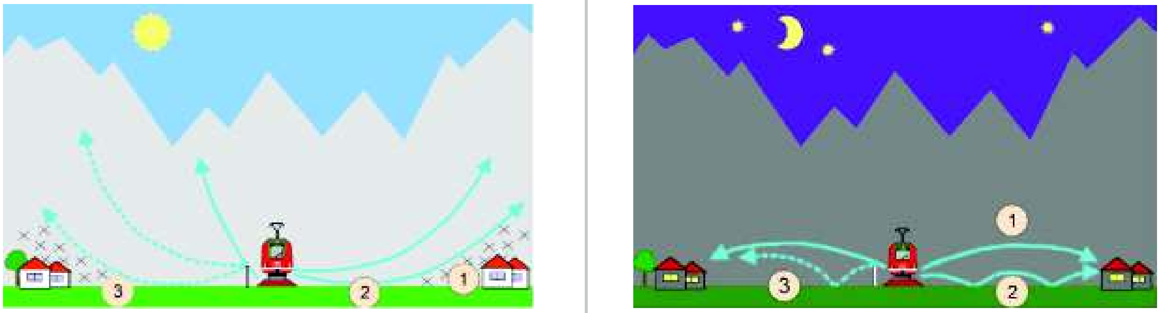


Illustration 55: Influence of meteorology on the trajectory of sound rays: left, upward refraction due to a negative temperature gradient; right, downward refraction due to a positive temperature gradient (temperature inversion) [7]

Weather conditions specific to mountain areas (*foehn*wind effect, corridor winds, temperature inversions) can be conducive to these refraction phenomena of acoustic waves.In the case of upward refraction, the phenomenon generally tends to reduce exposure. On the other hand, downward refraction can result in acoustic waves "down-flowing" onto certain receivers, sometimes even while those are protected by obstacles placed on the propagation path.

The influence of variations in weather conditions is particularly sensitive for receivers located several hundred metres from the source(s), where noise levels are generally already moderate. The consequences on the estimation of external costs therefore remain rather low. The calculation of noise level indicators (LDEN), integrate weather conditions by weighting the periods known as favourable and unfavourable to propagation, thanks to knowledge of the corresponding meteorological occurrences.

9 - Bibliography

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[5] HEATCO, « Developing Harmonised European Approaches for Transport Costing and Project Assessment », FP6‑2002‑SSP‑1/502481, 2006.
[6] Sétra, *Prévision du bruit routier - Tome 1, Calcul des émissions sonores dues au trafic routier*, vol. 1. 2009.
[7] Cete de Lyon, « Etude des impacts acoustiques en Combe de Savoie et vallée de la Maurienne », Réseau Ferré de France, 2010.

10 - Appendix

Appendix A – Reference value in €2010/person exposed /year as a function of the sound exposure level (cost factor) – Sources [4] and [5]

Noise exposure level (dB (A))	Cost in €2010/pers
51	11 €
52	21 €
53	32 €
54	43 €
55	54 €
56	65 €
57	75 €
58	86 €
59	97 €
60	108 €
61	119 €
62	130 €
63	150 €
64	168 €
65	188 €
66	210 €
67	235 €
68	261 €
69	290 €
70	321 €
71	354 €
72	390 €
73	429 €
74	470 €
75	514 €
76	560 €
77	609 €
78	661 €
79	716 €
80	774 €

Appendix B – Modelling maps for the three routes

Acoustic modelling Pont d'Ain to Chamonix

The road noise maps presented below take into account the contributions of all infrastructures carrying more than 5,000 vehicles/day (classified infrastructures). However, the calculation of external costs only includes the acoustic contribution of the motorway.

Noise levels are represented as isophones, per 5 dB(A) classes.Modelling gives the levels on the facades of each building (not visible on the maps). To estimate exposure, the level on the most exposed facade is selected and associated with the population occupying the building.

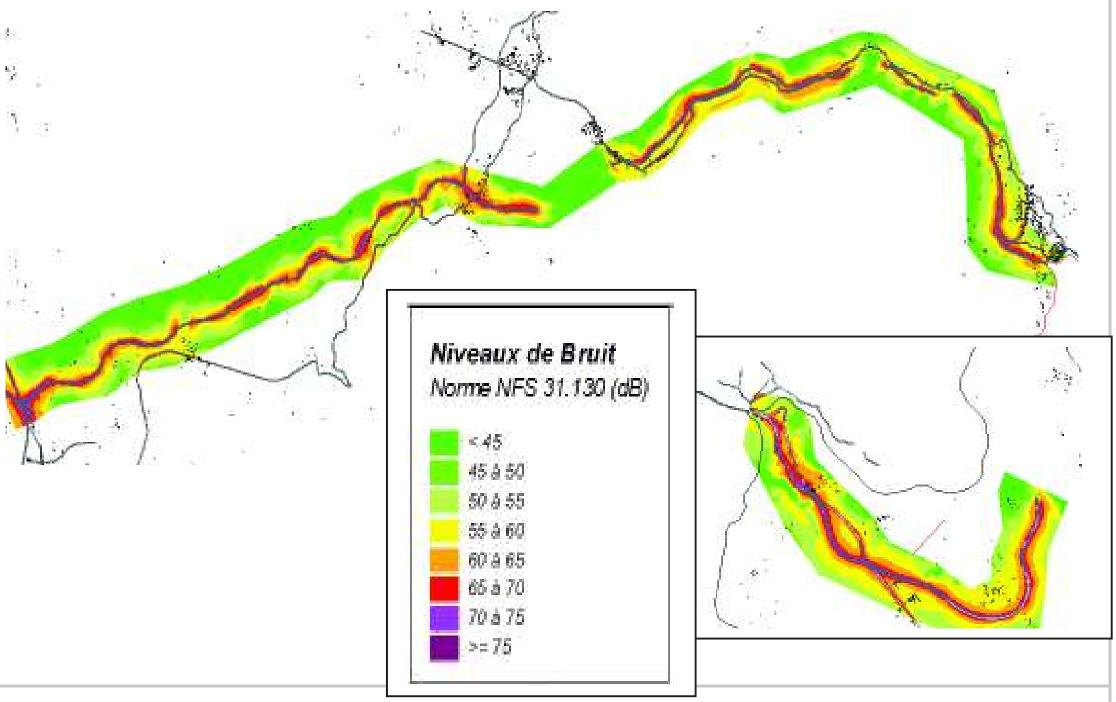

Illustration 56: First sub-section - Pont d'Ain – Vuache Tunnel. Horizontal map of noise levels (LDEN (dB(A)) calculated at 4 meters above ground. For graphic display reasons, the section located after the Vuache Tunne was positioned to the side.l

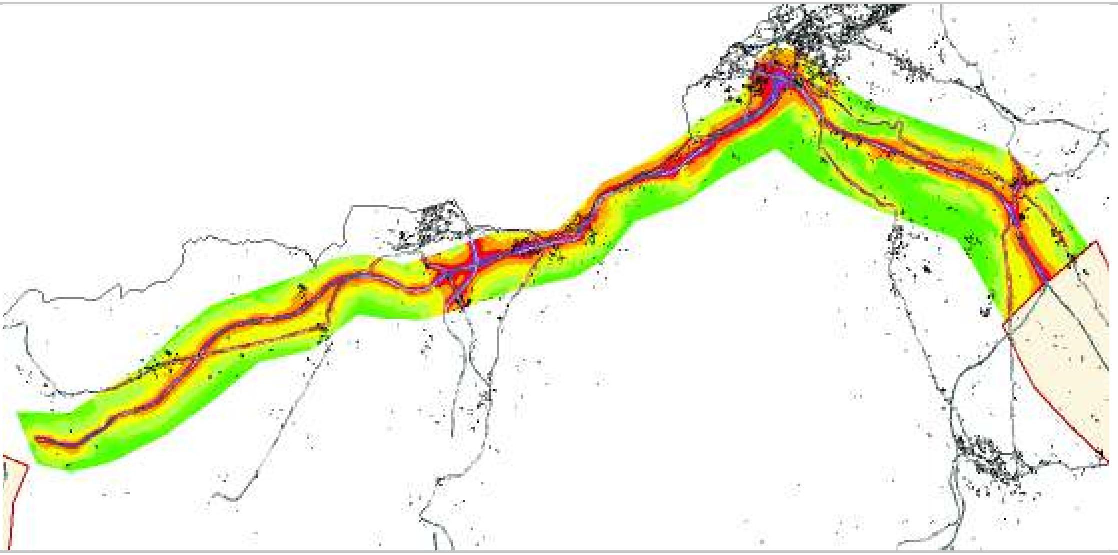

Illustration 57: Second sub-section – Vuache Tunnel – Scientrier. Horizontal mapping of noise levels (LDEN (dB(A)) calculated at 4 meters above ground.

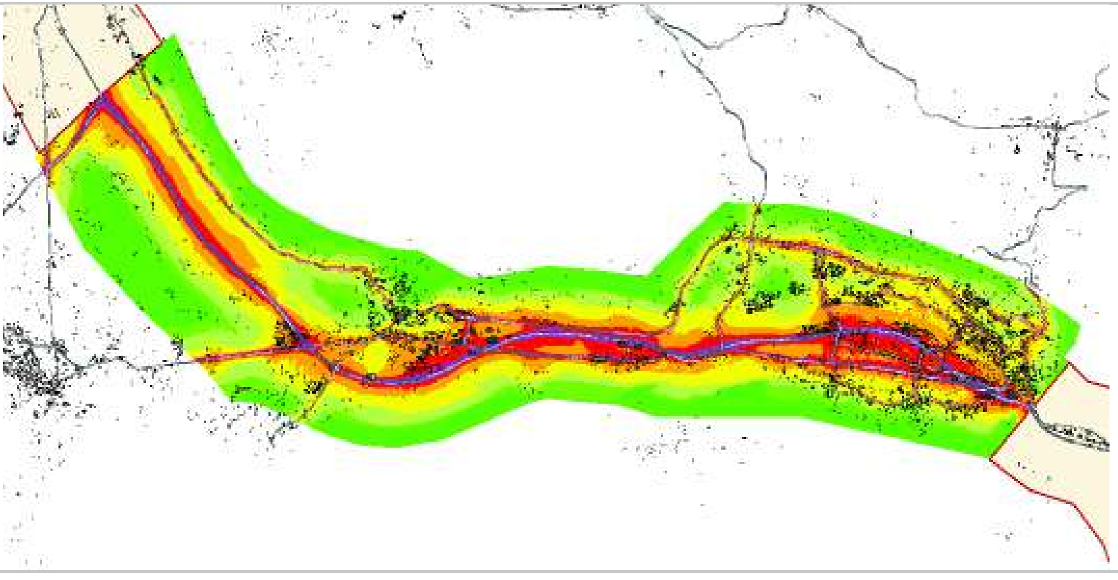

Illustration 58: A40 Scientrier – Cluses. Horizontal mapping of noise levels (LDEN (dB(A)) calculated at 4 meters above ground.

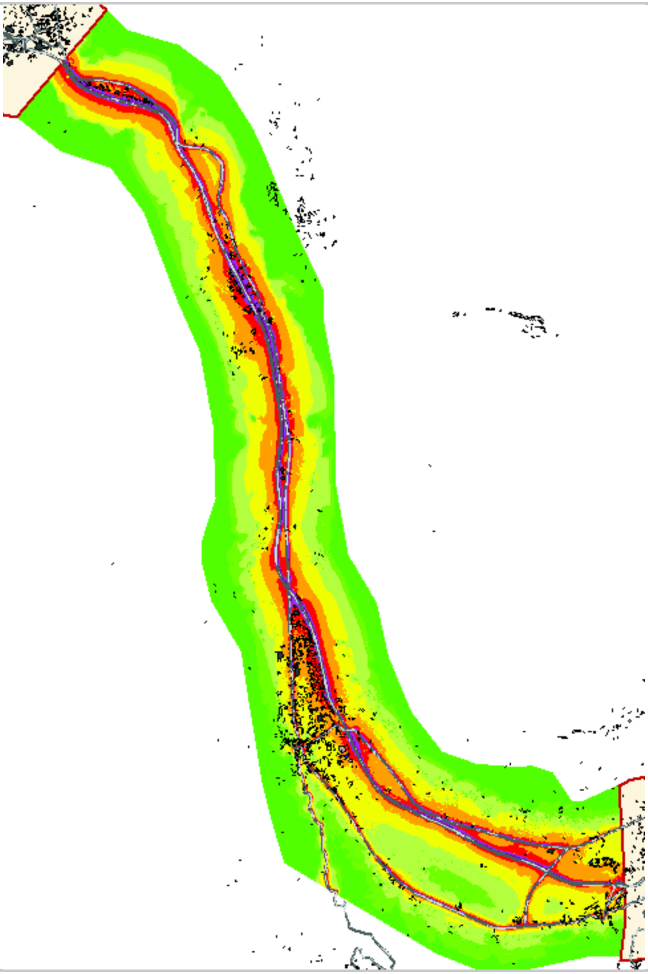

Illustration 59: A40 Cluses – Le Fayet. Horizontal mapping of noise levels (LDEN (dB(A)) calculated at 4 meters above ground.

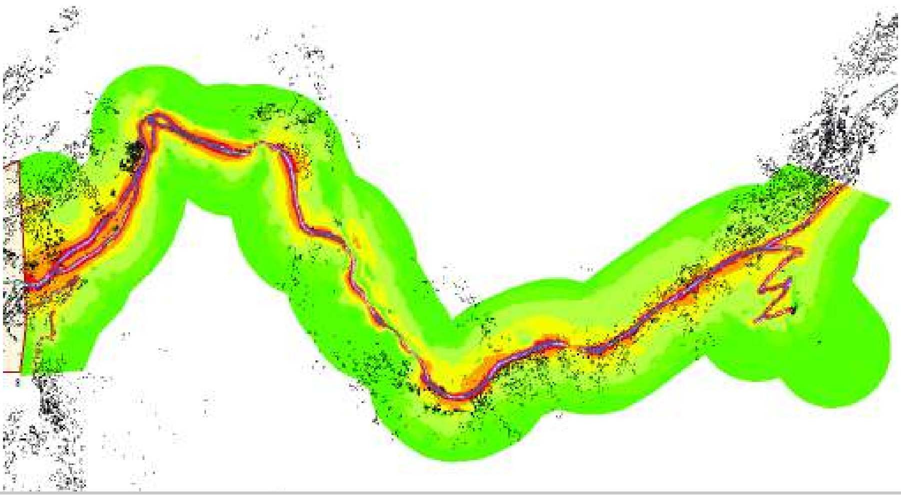

Illustration 60: A40 Le Fayet Chamonix. Horizontal mapping of noise levels (LDEN (dB(A)) calculated at 4 meters above ground.

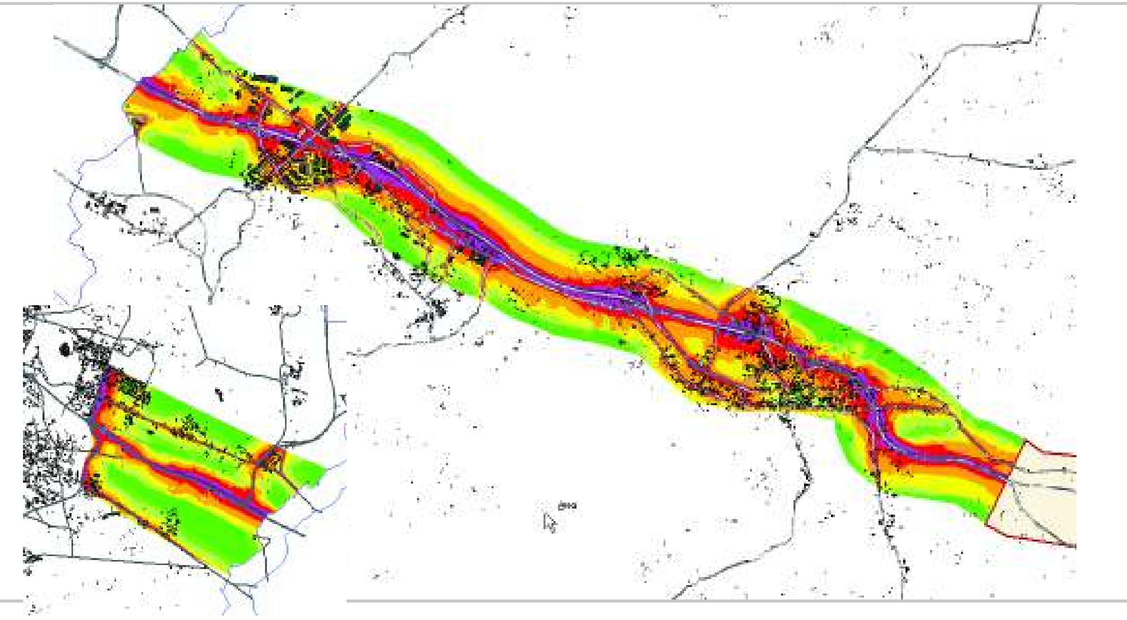

Illustration 61: A43 St Priest – Coiranne. Horizontal mapping of noise levels (LDEN (dB(A)) calculated at 4 meters above ground. For graphic display reasons, the section located at the level of St Priest was positioned below (see box).

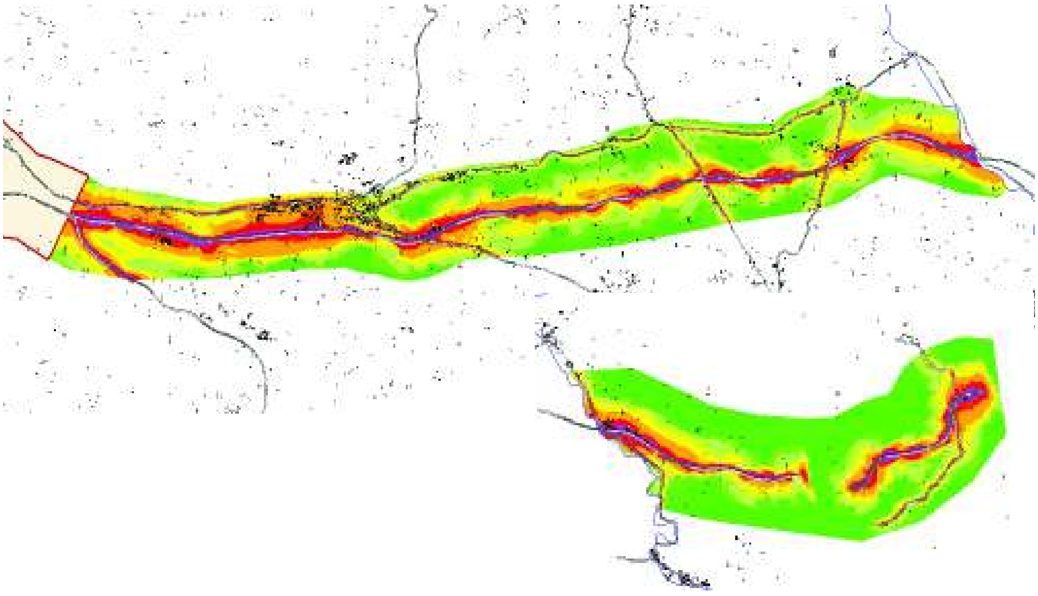

Illustration 62: A43 Coiranne - L'Epine. Horizontal mapping of noise levels (LDEN (dB(A)) calculated at 4 meters above ground. For graphic display reasons, the section located above the L'Epine tunnel was positioned below (see box).

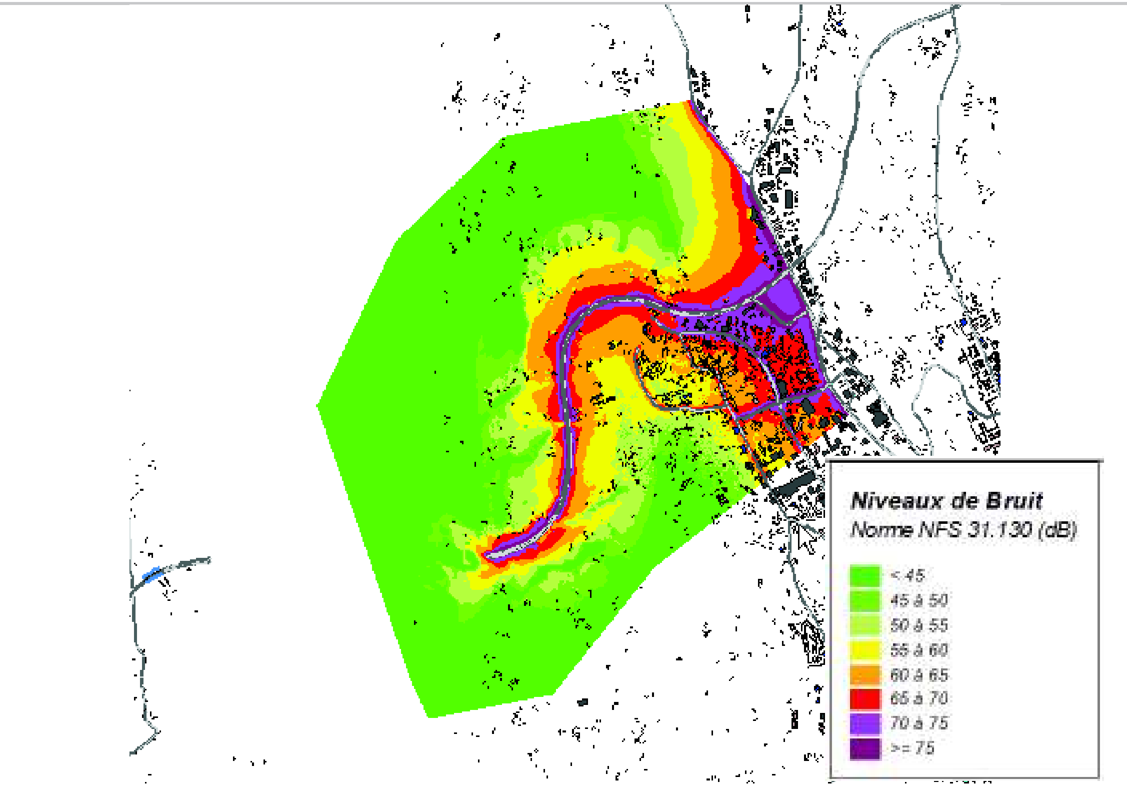

Illustration 63: A43 L'Épine – A41-A43. Horizontal mapping of noise levels (LDEN (dB(A)) calculated at 4 meters above ground.

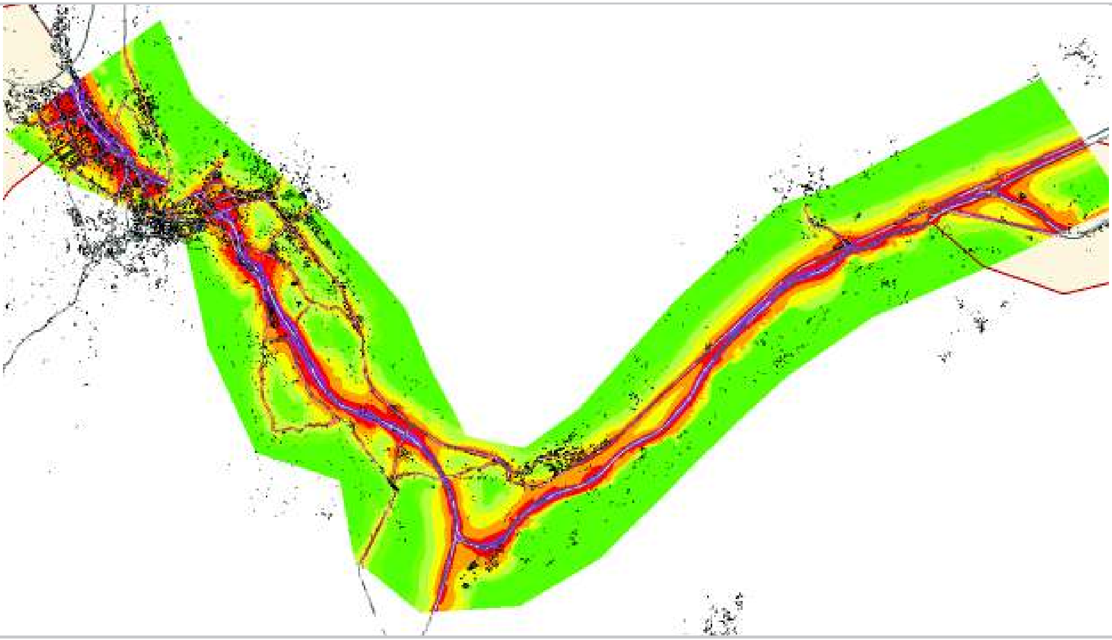

Illustration 64: A43 A41-A43 - Aiton. Horizontal mapping of noise levels (LDEN (dB(A)) calculated at 4 meters above ground.

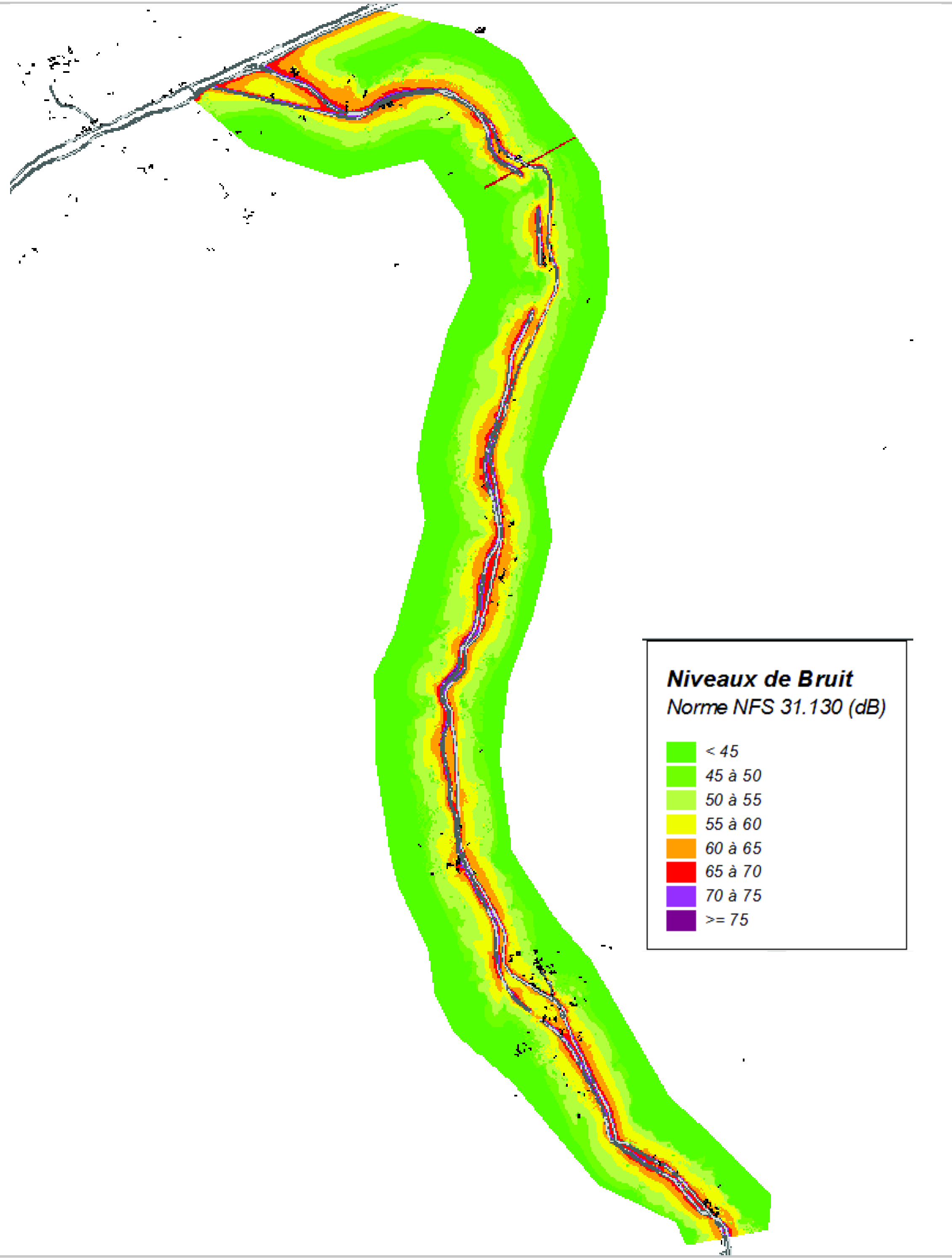

Illustration 65: Aiton – St Jean de Maurienne. Horizontal mapping of noise levels (LDEN (dB(A)) calculated at 4 meters above ground.

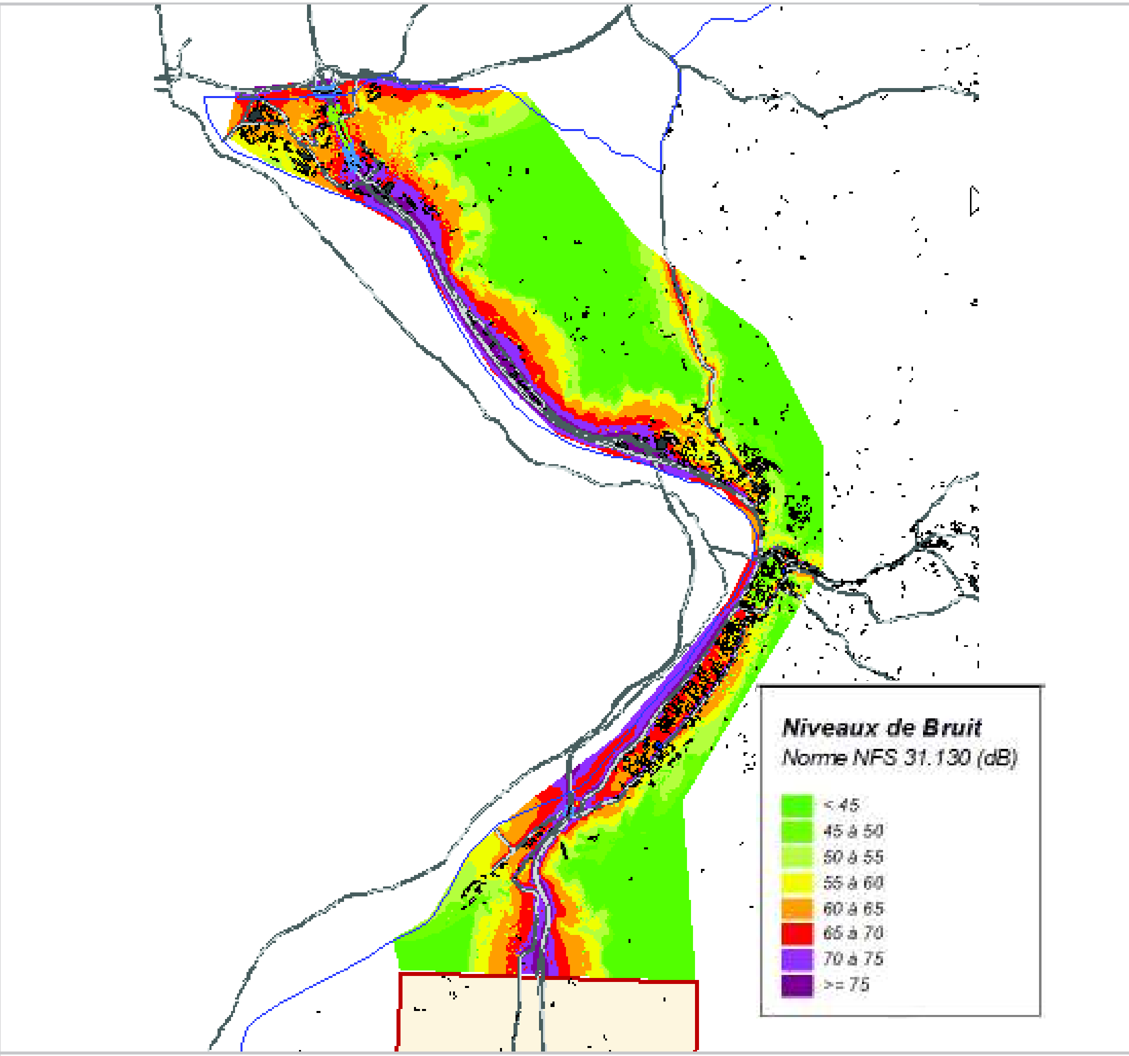

Illustration 66: A7 Chasse – Reventin. Horizontal mapping of noise levels (LDEN (dB(A)) calculated at 4 meters above ground.

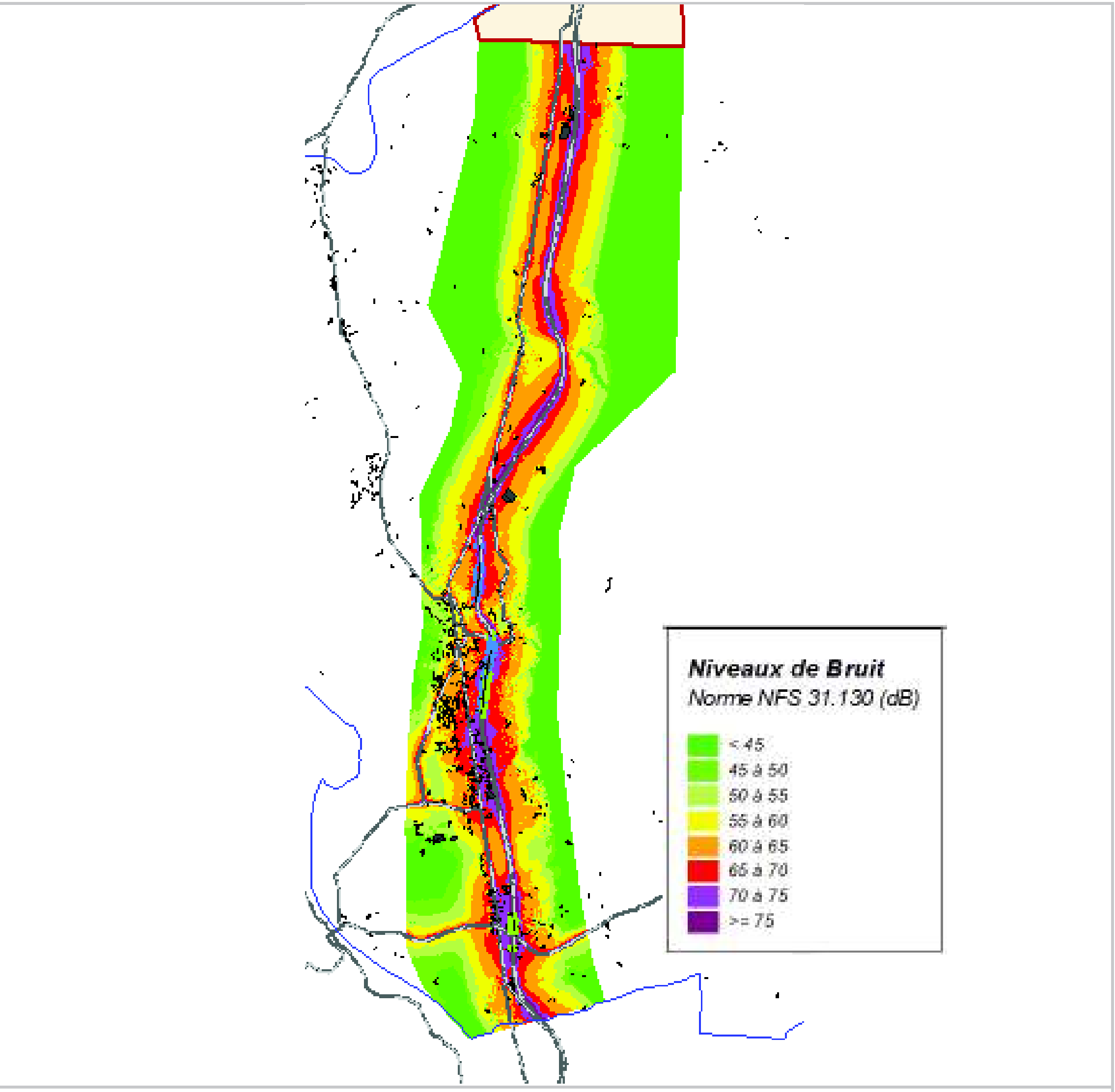

Illustration 67: A7 Reventin – St Rambert d'Albon. Horizontal mapping of noise levels (LDEN (dB(A)) calculated at 4 meters above ground.

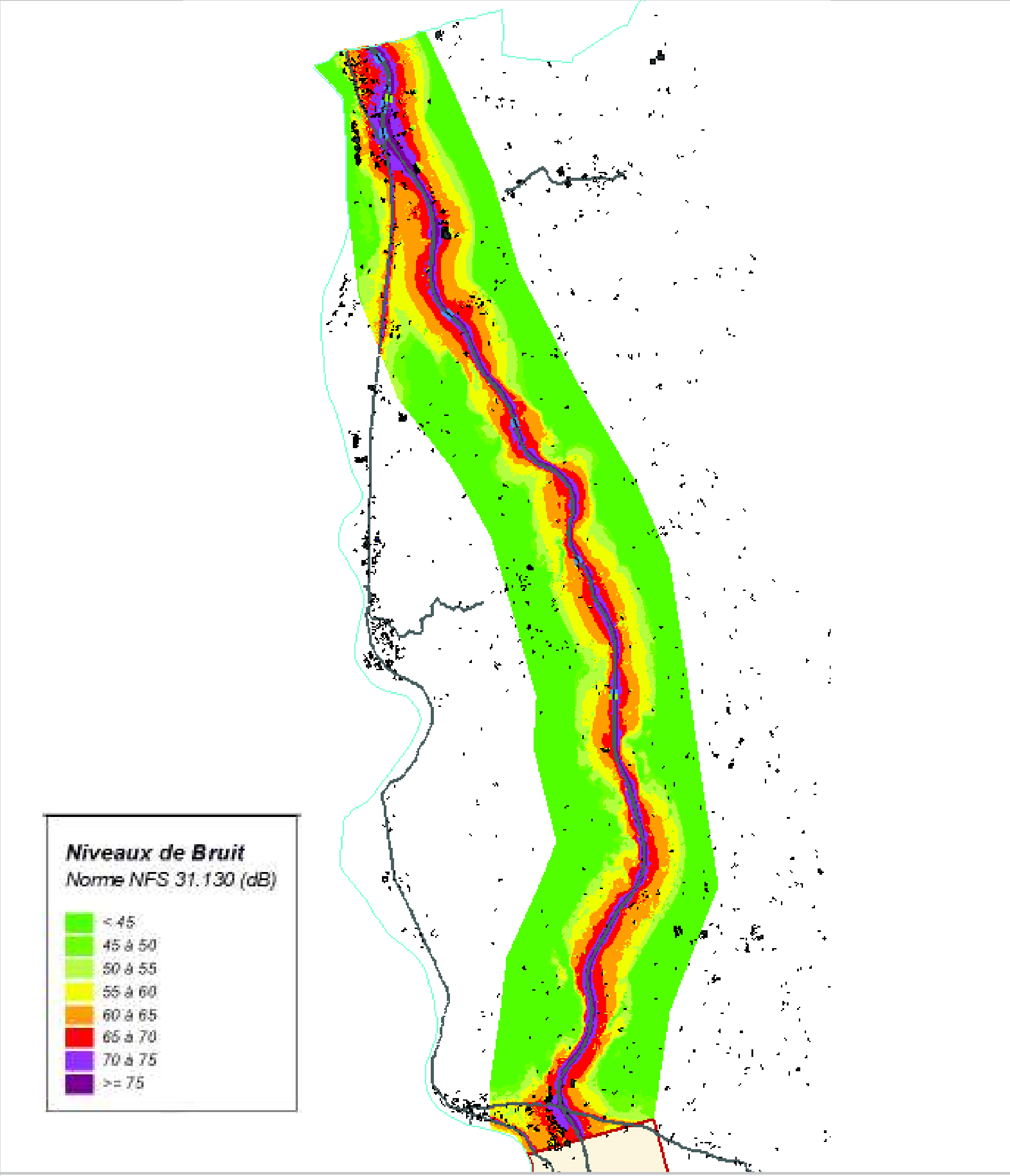

Illustration 68: A7 St Rambert d'Albon – Tain l'Hermitage. Horizontal mapping of noise levels (LDEN (dB(A)) calculated at 4 meters above ground.

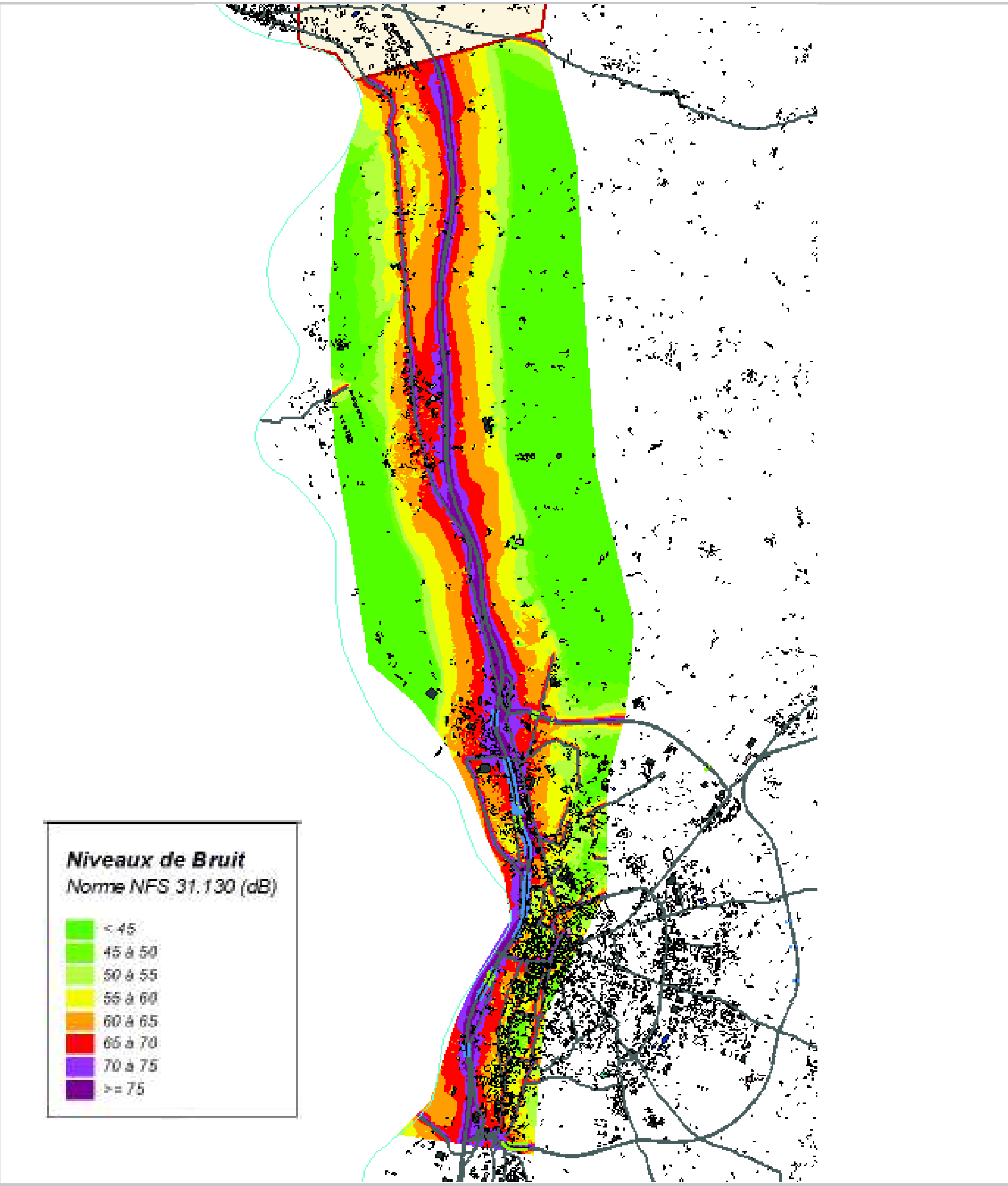

Illustration 69: A7 Tain l'Hermitage – Valence Sud. Horizontal mapping of noise levels (LDEN (dB(A)) calculated at 4 meters above ground.

Appendix C – Additional analysis information per section

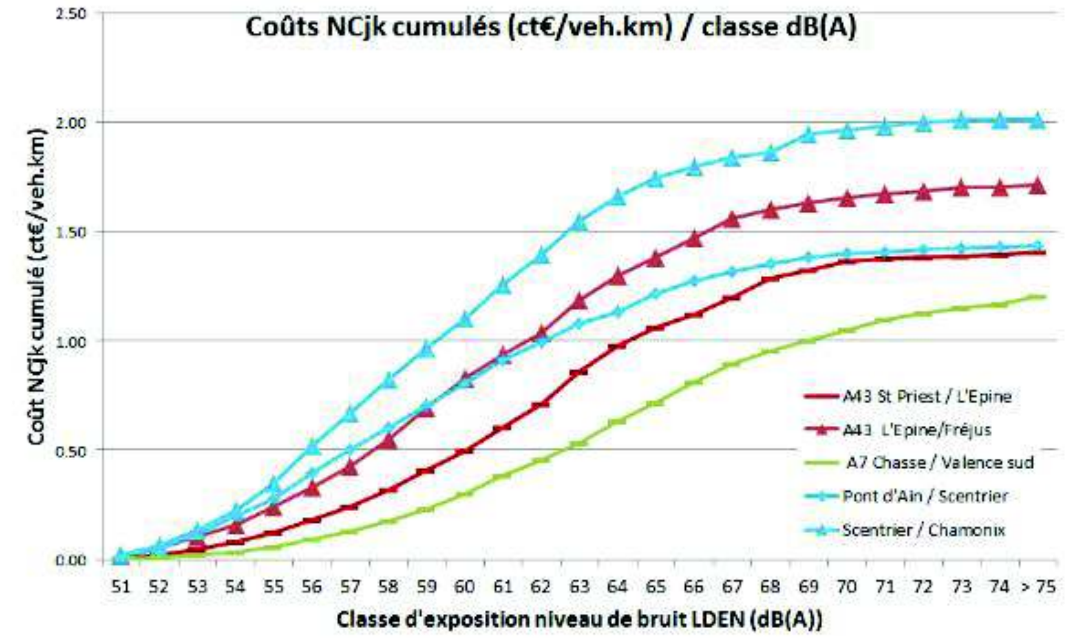

Illustration 70: cumulated NCV by noise level class for the 5 routes analysed.

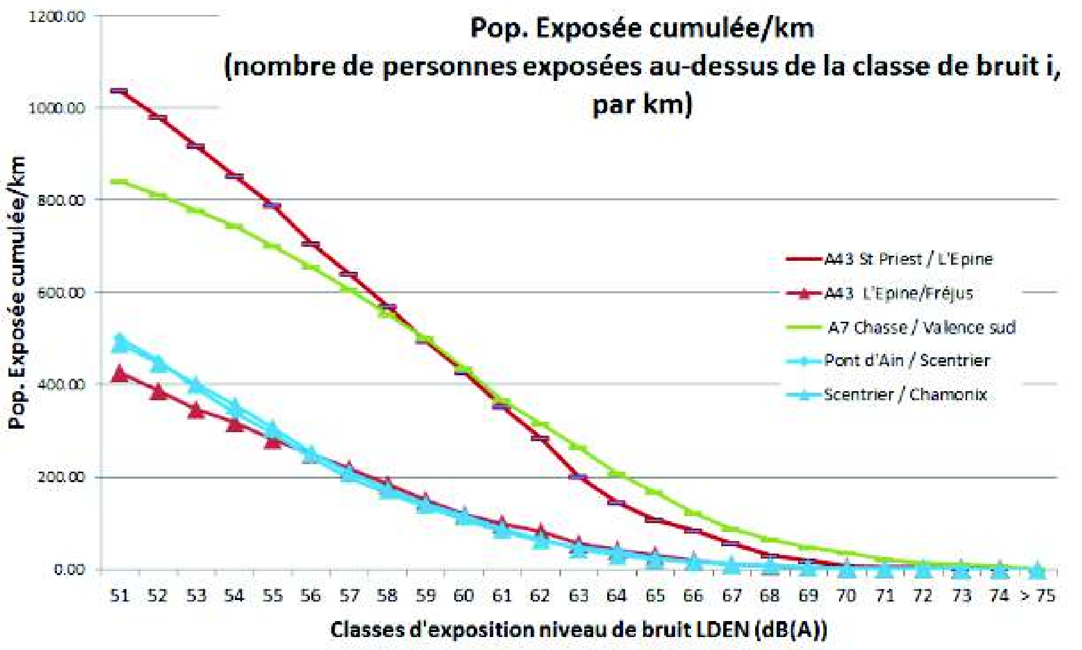

Illustration 71: Population (number of inhabitants) exposed to noise level higher than the one considered for each route.

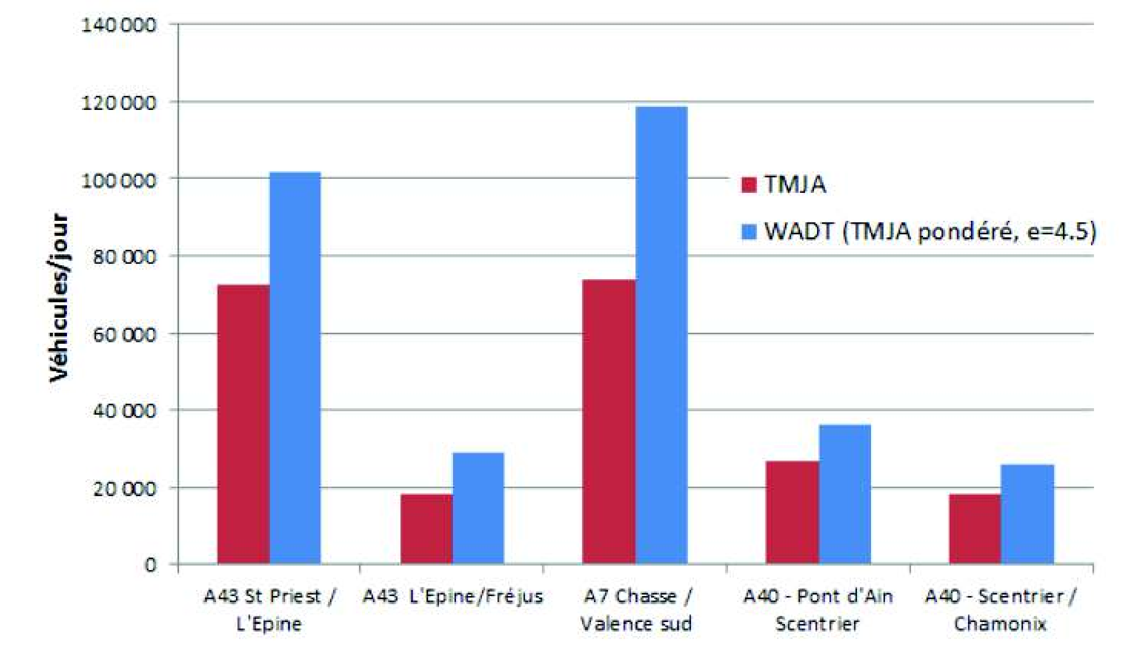

Illustration 72: Summary of AADTs and WADT (with 4.5 equivalent factor) along the routes studied. This graph displays the relative weight of HGV levels for each of the 5 routes.