iMONITRAF! WP 5

Annoyance

State of art

iMonitraf! case

Summary Review

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CONTENT

1 Annoyance: state of art

Recently, the European council tends to preserve areas with good sound quality and reduce the impact on population with the by European directive 2002/49/EC of 25th June on the assessment, management and reduction of environmental noise.

In the World Health Organization final report, the adverse effect of noise is defined as any change in organism morphology or physiology resulting in damage of some functional capacity, or as in an increase of stress or an increase of the system's feeling due to both the damaging effect of noise and other environmental factor. The noise pollution includes different specific effects as:

- Damaging of hearing property
- Difficulty in speaking and communication
- Sleep disturbance
- Cardiovascular effects
- Effects on working performance, mental and behaviour disturbance
- Difficulty in learning during the school age
- Decrease of real estate value
- Sense of dissatisfaction in the inhabitants, explained as a series of changes in the behaviour of the people exposed due to a general sense of disturbance (annoyace).

Starting from the last point, the first part of this document describes the state of art about annoyance, while the second one focuses the attention on application of annoyance concept to iMonitraf! case. In this way, a methodology for estimating noise impact on population is carried out for iMonitraf! corridors, producing general way to proceed for the current scenario, starting therefore from monitoring campaigns, and for future scenarios, as a predictive parameter.

There are different methods for evaluating the degree of annoyance, the Environmental Noise Directive (2002) based on the study of Miedema and others[1], suggests to evaluate the percentage of annoyed people by noise in relation to a different traffic source: rail, road and aircraft.

1.1 Degree of disturbance calculation: L_{DEN} Method[1]

The formulations are experimental curves cube, obtained on the basis of the average parameter L_{DEN},

$$L_{DEN} = 10 \cdot log\left[\left(\frac{12}{24}\right) \cdot 10^{\frac{L_D}{10}} + \left(\frac{4}{24}\right) \cdot 10^{\frac{L_E+5}{10}} + \left(\frac{8}{24}\right) \cdot 10^{\frac{L_N+10}{10}}\right]$$

in which the parameter

- L_D is the sound pressure level A-weighted during the day (7.00-19.00)
- L_E is the sound pressure level A-weighted during the evening (19.00-23.00)
- L_N is the sound pressure level A-weighted during the night (23.00-7.00).

This method analyses the percentage of annoyed people as %HA, highly annoyed, %A simply annoyed and %LA lightly annoyed.

1.1.1 Highly Annoyed (%HA)

Therefore, the highly annoyed people percentage is expressed depending on L_{DEN} value and on the kind of noise traffic source, as follow:

- For aircraft

  $$\%HA = -9{,}199 \cdot 10^{-5}(L_{DEN} - 42)^3 + 3{,}932 \cdot 10^{-2}(L_{DEN} - 42)^2 + 0{,}294(L_{DEN} - 42)$$

- For road

  $$\%HA = 9{,}868 \cdot 10^{-4}(L_{DEN} - 42)^3 - 1{,}436 \cdot 10^{-2}(L_{DEN} - 42)^2 + 0{,}512(L_{DEN} - 42)$$

- For rail

  $$\%HA = 7{,}239 \cdot 10^{-4}(L_{DEN} - 42)^3 - 7{,}851 \cdot 10^{-3}(L_{DEN} - 42)^2 + 0{,}169(L_{DEN} - 42)$$

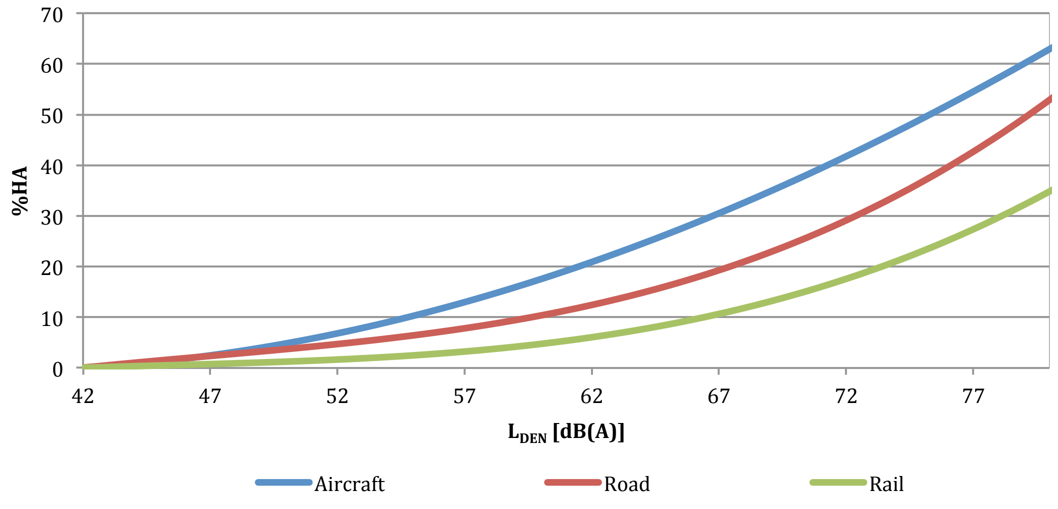


Chart 1.1 – %HA-L_{DEN} curves per kind of source traffic.

These curves are approximation of experimental data starting from L_{DEN} = 42 dB(A), under this value, it is possible to assume that there isn't people annoyed by noise.

1.1.2 Simply Annoyed (%A)

These relations evaluate the correlation between L_{DEN} and the percentage of the people simply annoyed by noise, in relation to different sources. The value of L_{DEN} = 37 dB(A) corresponds to the null percentage of annoyed people. Therefore:

- For aircraft

  $$\%A = 8{,}558 \cdot 10^{-6}(L_{DEN} - 37)^3 + 1{,}777 \cdot 10^{-2}(L_{DEN} - 37)^2 + 0{,}1221(L_{DEN} - 37)$$

- For road

  $$\%A = 1{,}795 \cdot 10^{-4}(L_{DEN} - 37)^3 - 2{,}110 \cdot 10^{-2}(L_{DEN} - 37)^2 + 0{,}5353(L_{DEN} - 37)$$

- For rail

  $$\%A = 4{,}583 \cdot 10^{-4}(L_{DEN} - 37)^3 + 9{,}482 \cdot 10^{-3}(L_{DEN} - 37)^2 + 0{,}2129(L_{DEN} - 37)$$

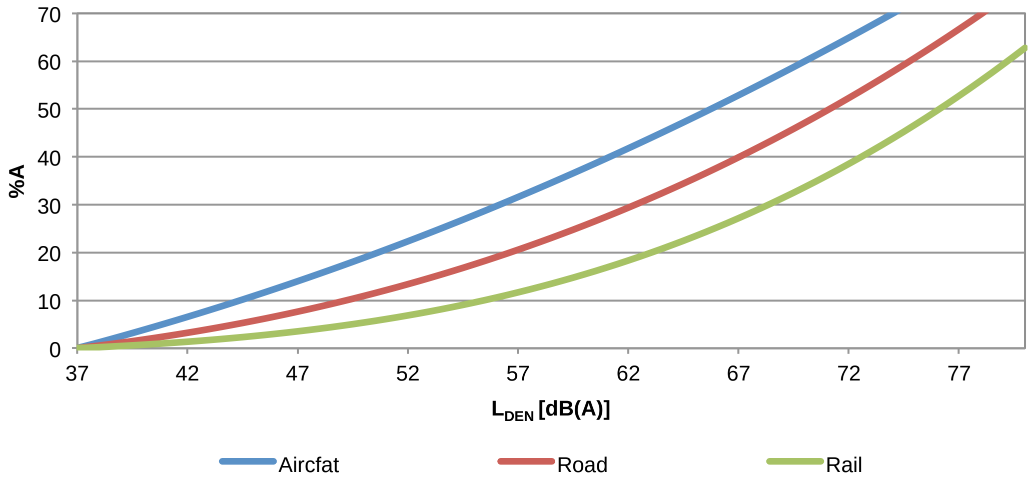


Chart 1.2 -– %A-L_{DEN} curves per kind of source traffic.

1.1.3 Lightly annoyed (%LA)

The method analyses also a percentage of people lightly annoyed by traffic noise. The value of L_{DEN} = 32 dB(A) corresponds to the null percentage of annoyed people.

- For aircraft

  $$\%LA = -6{,}158 \cdot 10^{-4}(L_{DEN} - 32)^3 + 3{,}410 \cdot 10^{-2}(L_{DEN} - 32)^2 + 1{,}718(L_{DEN} - 32)$$

- For road

  $$\%LA = -6{,}235 \cdot 10^{-4}(L_{DEN} - 32)^3 + 5{,}509 \cdot 10^{-2}(L_{DEN} - 32)^2 + 0{,}6693(L_{DEN} - 32)$$

- For rail

  $$\%LA = -3{,}229 \cdot 10^{-4}(L_{DEN} - 32)^3 + 4{,}871 \cdot 10^{-2}(L_{DEN} - 32)^2 + 0{,}1673(L_{DEN} - 32)$$

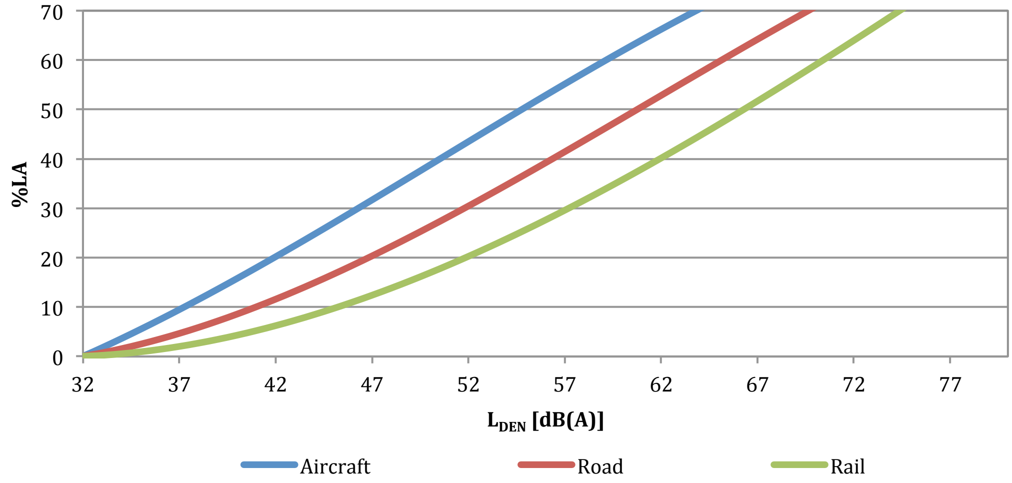


Chart 1.3 - %LA-L_{DEN} curves per kind of source traffic.

1.1.4 Remarks

L_{DEN} parameter isn't much suitable for estimating non-continuous noise, like aircraft noise.

In terms of percentage of annoyed people, the indicator %HA is more restrictive than the others (%A and %LA) and for this reason the psycho-acoustician prefers working with it[2]. The %HA generally estimates in a good way the exposed population, however for low noise levels it tends to underestimate it[3]. %LA is a parameter that can create misunderstanding because it gives high values of exposed people.

1.2 Degree of disturbance calculation: L_{DN} Method[1]

The L_{DN} parameter is based on sound pressure level L_{Aeq} dividing the day in two parts, the day-time (7-22) and the night-time (22-7) expressed by the following formulation:

$$L_{DN} = 10 \cdot log\left[\left(\frac{15}{24}\right) \cdot 10^{\frac{L_D}{10}} + \left(\frac{9}{24}\right) \cdot 10^{\frac{L_N+10}{10}}\right]$$

According with previous method, the curves are obtained on experimental basis, with a polynomial function.

1.2.1 Highly Annoyed (%HA)

- For aircraft

  $$\%HA = -1{,}395 \cdot 10^{-4}(L_{DN} - 42)^3 + 4{,}081 \cdot 10^{-2}(L_{DN} - 42)^2 + 0{,}342(L_{DN} - 42)$$

- For road

  $$\%HA = 9{,}994 \cdot 10^{-4}(L_{DN} - 42)^3 - 1{,}523 \cdot 10^{-2}(L_{DN} - 42)^2 + 0{,}583(L_{DN} - 42)$$

- For rail

$$\%HA = 7{,}158 \cdot 10^{-4}(L_{DN} - 42)^3 - 7{,}774 \cdot 10^{-3}(L_{DN} - 42)^2 + 0{,}163(L_{DEN} - 42)$$

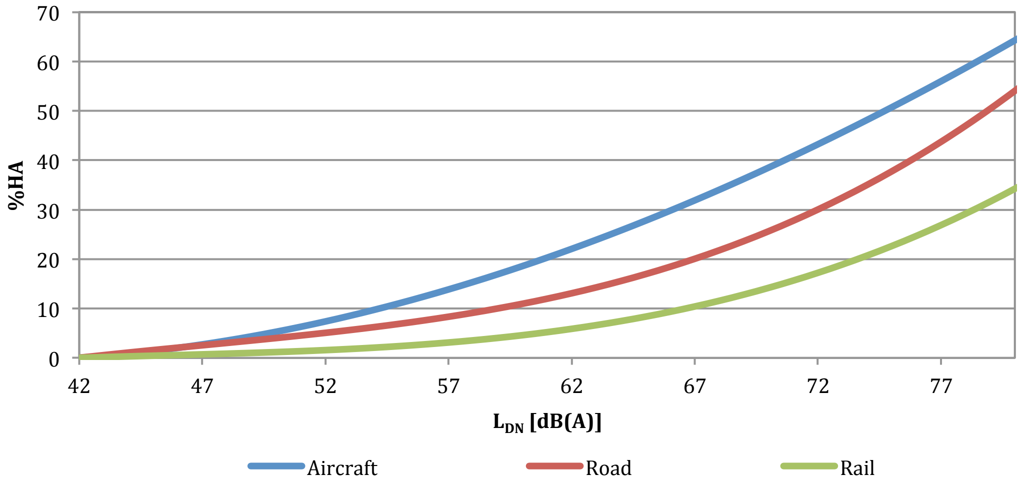


Chart 1.4 – %HA-L_{DN} curves per kind of source traffic.

1.2.2 Simply Annoyed (%A)

- For aircraft

$$\%A = 1{,}460 \cdot 10^{-5}(L_{DN} - 37)^3 + 1{,}511 \cdot 10^{-2}(L_{DN} - 37)^2 + 0{,}1346(L_{DN} - 37)$$

- For road

$$\%A = 1{,}732 \cdot 10^{-4}(L_{DN} - 37)^3 + 2{,}079 \cdot 10^{-2}(L_{DN} - 37)^2 + 0{,}566(L_{DN} - 37)$$

- For rail

$$\%A = 4{,}552 \cdot 10^{-4}(L_{DN} - 37)^3 + 9{,}400 \cdot 10^{-3}(L_{DN} - 37)^2 + 0{,}212(L_{DN} - 37)$$

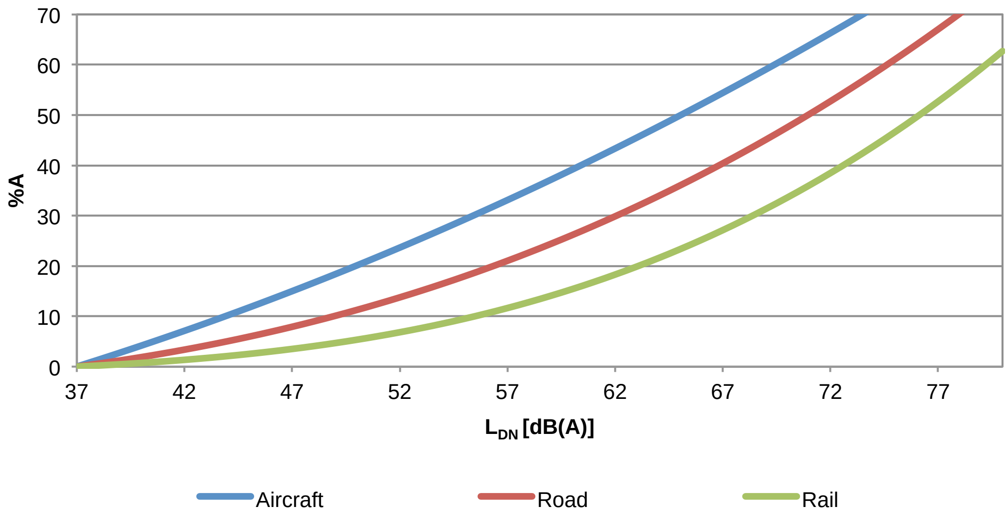


Chart 1.5 –– %A-L_{DN} curves per kind of source traffic.

1.2.3 Lightly annoyed (%LA)

- For aircraft

$$\%LA = -5{,}741 \cdot 10^{-4}(L_{DN} - 32)^3 + 2{,}863 \cdot 10^{-2}(L_{DN} - 32)^2 + 1{,}912(L_{DN} - 32)$$

- For road

$$\%LA = -6{,}188 \cdot 10^{-4}(L_{DN} - 32)^3 + 5{,}379 \cdot 10^{-2}(L_{DN} - 32)^2 + 0{,}723(L_{DN} - 32)$$

- For rail

$$\%LA = -3{,}343 \cdot 10^{-4}(L_{DN} - 32)^3 + 4{,}918 \cdot 10^{-2}(L_{DN} - 32)^2 + 0{,}175(L_{DN} - 32)$$

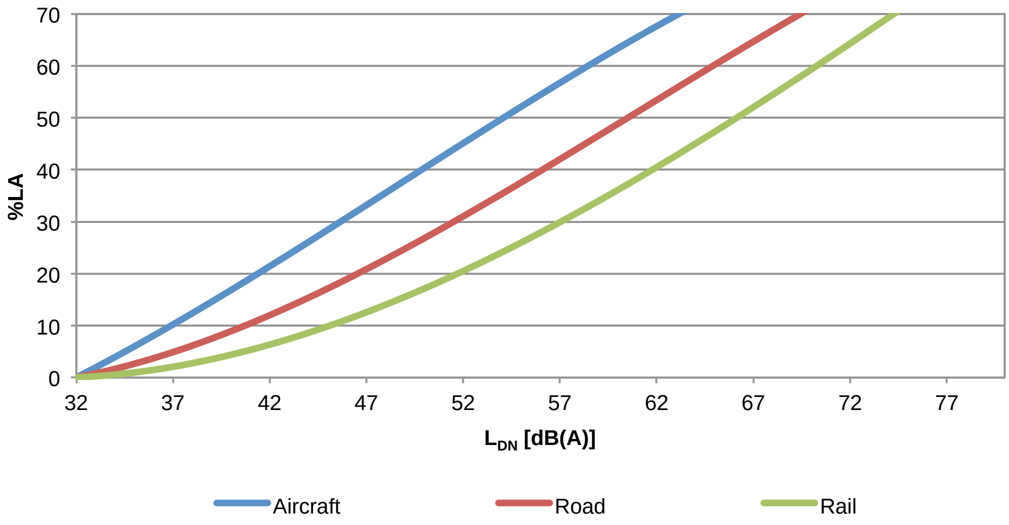


Chart 1.6 - %LA-L_{DN} curves per kind of source traffic.

1.2.4 Remarks

There are no linear relation between L_{DN} and L_{DEN}. The difference between the two metrics depends on the time pattern of the noise exposure. The possible differences are restricted if it is assumed that the noise level does not increase during the evening and the night, if L_{Aeq} (7.00-19.00) > L_{Aeq} (19.00-22.00) > L_{Aeq} (22.00-23.00) > L_{Aeq} (23.00-7.00). This assumption will hold for the vast majority of situations.

On the basis of expectations derived from time patterns of noise level, we can assume[1]

- *Aircraft $L_{DEN} = L_{DN} + 0{,}6$*
- *Road $L_{DEN} = L_{DN} + 0{,}2$*
- *Rail $L_{DEN} = L_{DN}$*

1.3 Sleep disturbance: annoyance during night (L_N)[4]

Another way for measuring the degree of disturbance is to consider the people annoyed during night sleeps. The experimental formulations are based on L_N, the sound pressure level during night time (23.00-7.00).

1.3.1 High Sleep Disturbed (%HSD)

The estimation of the high sleep disturbed people percentage (%HSD) is expressed with the following experimental relations:

- For aircraft:

$$\%HSD = 18{,}147 - 0{,}956L_N + 0{,}01482(L_N)^2$$

- For road

$$\%HSD = 20{,}8 - 1{,}05L_N + 0{,}0146(L_N)^2$$

- For rail

$\%HSD = 11{,}3 - 0{,}55L_N + 0{,}00759(L_N)^2$

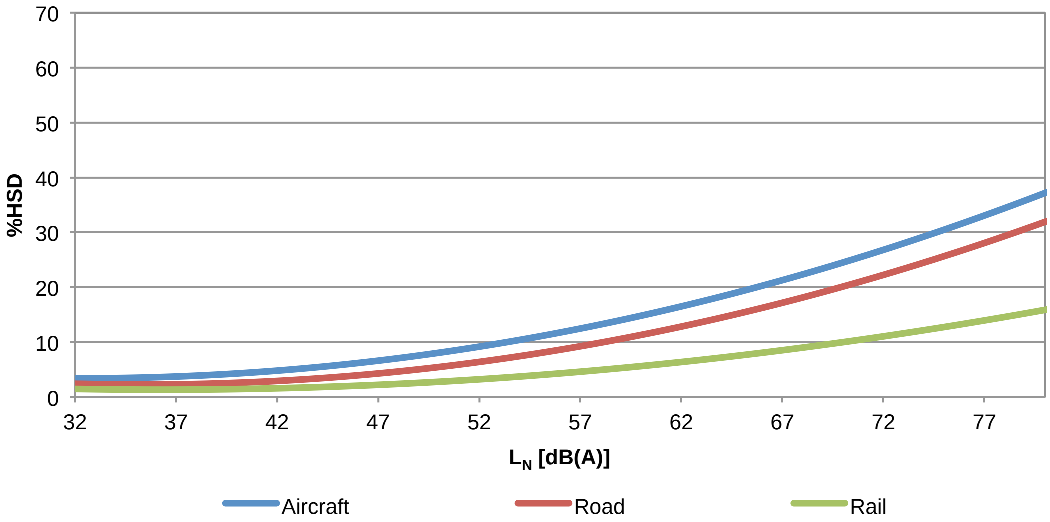


Chart 1.7 - %HSD-L_N curves per kind of source traffic.

1.3.2 Sleep Disturbed (%SD)

- For aircraft:

$\%SD = 13{,}714 - 0{,}807L_N + 0{,}01555(L_N)^2$

- For road

$\%SD = 13{,}8 - 0{,}85L_N + 0{,}0167(L_N)^2$

- For rail

$\%SD = 12{,}5 - 0{,}66L_N + 0{,}01121(L_N)^2$

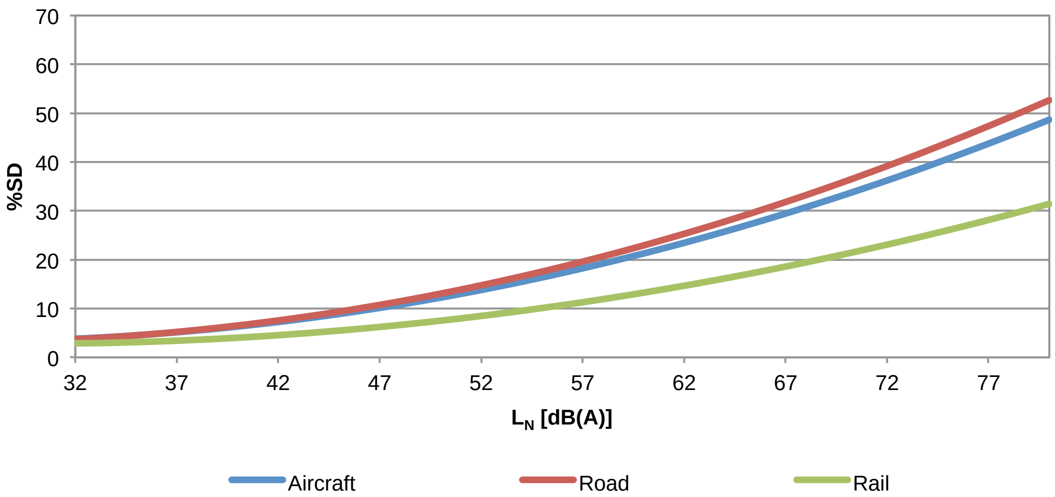


Chart 1.8 - %SD-L_N curves per kind of source traffic.

1.3.3 Lightly Sleep Disturbed (%LSD)

- For aircraft

  $\%LSD = 4{,}465 - 0{,}411L_N + 0{,}01395(L_N)^2$

- For road

  $\%LSD = -8{,}4 - 0{,}16L_N + 0{,}01081(L_N)^2$

- For rail

  $\%LSD = 4{,}7 - 0{,}31L_N + 0{,}01125(L_N)^2$

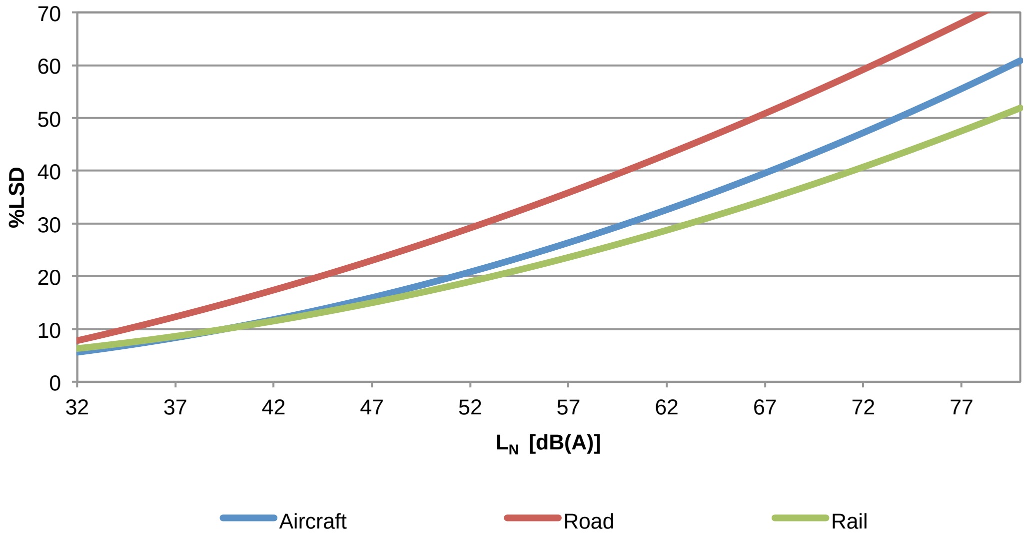


Chart 1.9 - %LSD-L_N curves per kind of source traffic.

1.3.4 Remarks

L_N is a parameter based on L_{Aeq} calculated between 23.00, in the night and 7.00, in the early morning. Therefore L_N, although more correct than L_{DEN} during night time, is not enough representative for events producing micro-structural sleep fragmentation, sleep reduction and alteration, as the low frequencies and high intensity impulsive events.

The WG for the WHO Europe NNGL suggests to the states members joining to the others index both a number of noise events exceeding a threshold expressed in SEL and the frequencies spectrum characterizing those events.

1.4 Multiple exposure annoyance[5]

For evaluating annoyance resulting from exposure to multiple noise sources, the *annoyance equivalent model* is used. This model resembles the toxic equivalents models used in toxicology to describe the toxicity of certain mixtures.

The *annoyance equivalent model* can be seen as an elaboration of the energy summation models. Instead of summing the sound energy from the individual sources directly, the noise is translated from individual sources into the equally annoying sound energy levels of a reference source and then these levels are summed.

Imagining two different sound sources *A* and *B*, the sound level from those sources are L_A and L_B, respectively. If source *A* is selected as reference source, in order to calculate the total noise annoyance, L_B is transformed into the equally annoying level of *A*, L'_B. Then L_A and L'_B are added on an energy basis giving *L*.

The corresponding annoyance from the two combined sources is found by using the exposure –relationship of *A*, with the sound pressure level *L*.

In principle, the reference source is not arbitrary. However, the choice of reference source is not important when it can be assumed that one of the transportation sources can be taken as reference, because the relationships between sources are supposed linear and with nearly equal slopes for transportation sources. The equally annoying level of the reference source can be approximated by adding a source dependent bonus (or penalty) to the level of the source considered.

Road traffic is chosen as reference source. Then, using the individual exposure-annoyance relationships from the references, the assessment of total noise level and the corresponding percentage annoyed can be broken down in the following step, in relation to L_{DEN} or L_{DN}. For L_N, this methodology isn't provided.

If using L_{DEN}

1. Evaluate L_{DEN} for aircraft, road and railway traffic (L_{air}, L_{road}, L_{rail})
2. Calculate the annoyance level for aircraft and railway
   a. $A_{air} = 2{,}17 \cdot L_{air} - 91{,}4$
   b. $A_{rail} = 2{,}1 \cdot L_{rail} - 110{,}1$
3. Calculate the equally annoying road traffic levels for aircraft and railway
   a. $L'_{air} = \frac{A_{air}+107}{2{,}22}$
   b. $L'_{rail} = \frac{A_{rail}+107}{2{,}22}$
4. Calculate the total noise level
   $$L = 10 \cdot log\left(10^{\frac{L'_{air}}{10}} + 10^{\frac{L'_{road}}{10}} + 10^{\frac{L'_{rail}}{10}}\right)$$
5. Calculate the %HA, %A and %LA with the L_{DEN} formulation for road traffic.

If using L_{DN}

1. Evaluate L_{DN} for aircraft, road traffic and railway (L_{air}, L_{road}, L_{rail})
2. Calculate the annoyance level for aircraft and railway
   a. $A_{air} = 2{,}16 \cdot L_{air} - 89{,}7$
   b. $A_{rail} = 2{,}06 \cdot L_{rail} - 107{,}5$
3. Calculate the equally annoying road traffic levels for aircraft and railway
   a. $L'_{air} = \frac{A_{air}+105{,}7}{2{,}21}$
   b. $L'_{rail} = \frac{A_{rail}+105{,}7}{2{,}21}$
4. Calculate the total noise level
   $$L = 10 \cdot log\left(10^{\frac{L'_{air}}{10}} + 10^{\frac{L'_{road}}{10}} + 10^{\frac{L'_{rail}}{10}}\right)$$
5. Calculate the *%HA, %A* and *%LA* with the L_{DN} formulation for road traffic.

1.5 General remarks

The L_{DEN}, L_{DN} and L_N are the average parameters resulting from the elaboration of L_{Aeq} in the different parts of the day. Thus, the measure of noise estimates a representative value of the considered period of time that, in many cases, is not representative of the events that can create disturbance on the population. This method evaluates the amount of stress, or dissatisfaction, people experience when exposed to traffic noise, as an indication about the population potentially exposed to the bad effect of the traffic sources. Hence, it is necessary to pay attention using this indicator.

However, the *European Directive 2002/49/EC* on the control and manage of the environmental noise suggests creating annoyance maps, or information background for each country on the exposition to noise and its effects on the people exposed. Nowadays these curves are the only international standard.

The sensibility to noise is a social and cultural expression, and then it varies from country to country, from city to city. These dose-response curves would be more representative if obtained in relation to the application country.

Therefore, the estimation of the curves and their confidence interval can be further elaborated by incorporating study site as an extra level in the analysis. At local level, measures may be taken on the basis of the actual, individual response to noise exposure, therefore survey could be necessary.

2 Annoyance: The iMonitraf! case

In the iMonitraf! Project, a set of indicator was identified to characterize different matrix of transportation system. Among them, the *Indicator 12* , an environmental and health indicator, aims to estimate the effect of noise traffic on people living close to the alpine corridors crossing the frontier.

The chosen parameter for evaluating the impact on population is the annoyance because it expresses the amount of stress, or dissatisfaction, people experience when exposed to sounds from traffic sources.

The annoyance calculation is based on physical parameter L_{DEN}, which permits to link annoyance to values obtained in monitoring campaigns. For having homogeneous values of each corridor, the data collected during the monitoring campaigns are linked to relative number of vehicles.

Therefore for evaluating annoyed people, the methodology shown in *Chart 2.1* was developed during the project.

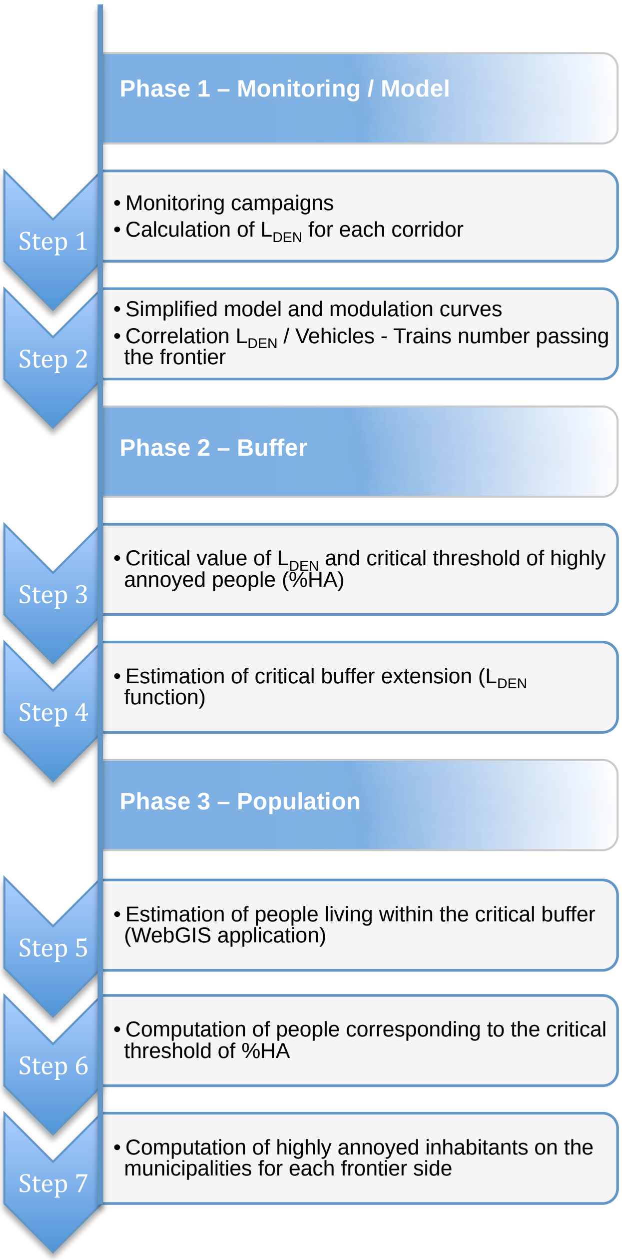


Chart 2.1 – Methodology to estimate affected population starting from L_{DEN}.

The simplified model approach is preferred to that one exclusively based on the monitoring campaigns because the measurement point gives only a punctual indication about the L_{DEN} level and, so, the respective annoyance value isn't representative about global conditions of the corridor. Furthermore:

- The monitoring campaigns for railway traffic aren't carried out due to technical difficulties.
- There is a lack of monitoring data about the Brenner corridor.
- For defying the future scenarios, it is necessary to use forecast data.

2.1 Step 1: The monitoring campaigns: punctual values of Annoyance

Due to project choices, the annoyance is expressed as percentage of *Highly Annoyed People (%HA)* on the basis of L_{DEN} correlation, as follows for the different traffic sources:

- For road

$$\%HA = 9{,}868 \cdot 10^{-4}(L_{DEN} - 42)^3 - 1{,}436 \cdot 10^{-2}(L_{DEN} - 42)^2 + 0{,}512(L_{DEN} - 42)$$

- For rail

$$\%HA = 7{,}239 \cdot 10^{-4}(L_{DEN} - 42)^3 - 7{,}851 \cdot 10^{-3}(L_{DEN} - 42)^2 + 0{,}169(L_{DEN} - 42).$$

Generally, the percentage value of annoyed people starting from the monitoring campaigns gives an indication about the population potentially exposed to the effect of the traffic noise in a specific measurement point, as shown in the table and the chart below.

Corridor	Monitoring campaign	
	L_{DEN} [dB(A)]	Annoyance [%HA]
Fréjus - Bardonecchia	72,5	30,2
Montblanc - Courmayeur	72,3	29,8
Gotthard - Camignolo	75,6	38,4
Brenner - Vipiteno	78,9	49,1
Tarvisio	75,7	38,8

Table 2.1 - Monitoring levels of L_{DEN} linked to annoyance values.

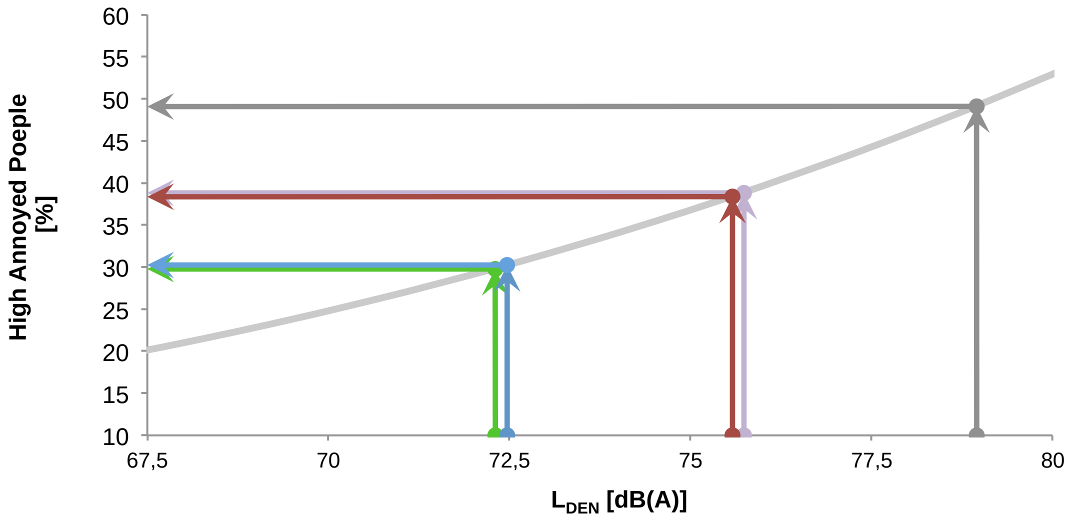


Chart 2.2 - Correlation between the L_{DEN} and the respective %HA

The data of L_{DEN} are validated on the basis of ***Indicator 6.***

2.2 Step 2: The simplified model

The aim of the *Indicator 12* is to evaluate the health effect due to noise traffic deriving from international business, so the considered traffic is the one crossing the border. The model is based on the heavy-duty vehicle fluxes, for road traffic, and on the tons split up into fright trains passage, for railway traffic. These values are linked to estimated level of $L_{DEN,}$ and they are the starting data. The values obtained in the monitoring campaigns are used for the calibration of the model.

The following methodology proposed will estimate the critical buffer dimension starting from traffic fluxes for each corridor and considered annoyance limit.

To achieve this goal the *NMPB-Routes-96* algorithm was implemented in CadnaA noise modelliing software, in accordance to the European laws and guidelines.

In this section, the simulation set up and the formulas bounding the traffic values to the noise levels are presented.

2.2.1 Setting up the road traffic simulations

Starting from straight road of *1 km* length and two measurement points, each one at *4 m* height from terrain and *10* and *20 m* distance from one side of the road, the simulation was built with the followings features:

- The terrain is flat.
- The road is *30 m* wide.
- The road has 0% inclination.
- Speed limit is *120 Km/h* for light vehicles and *80 Km/h* for heavy-duty vehicles.

The meteorological conditions, that are not very important at the distances used, are 50% favourable / 50% homogeneous. Simulations in other conditions were ran too, but the results were almost the same.

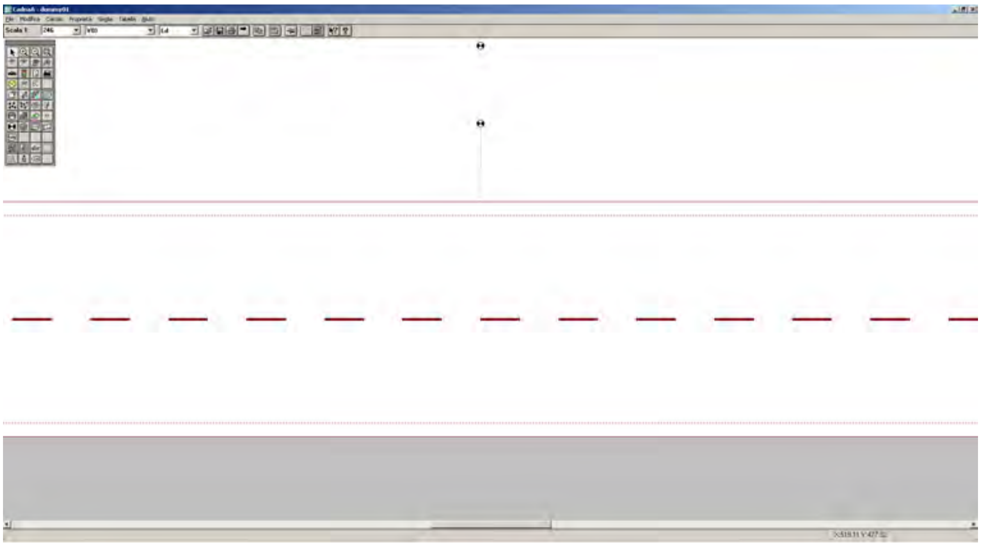


Figure 2.1 – The road simulation setup.

This very simple model has been used to obtain all the results on traffic noise.

Using this model, the desired traffic condition can be set up: the number of light vehicles N_L and the number of heavy vehicles N_H that travel in a *24 hour* period, and calculate the correspondent noise level L_x.

By using the model to estimate the real noise levels of a road approximations are being taken:

- The geometry of the terrain is ignored.
- No obstacle is present on the noise propagation path.
- The road surface is ignored.

Light Vehicles: graphs and formulas

Firstly, the levels for light vehicles traffic are calculated. Simulations are ran for some values of N_L and the correspondent noise levels L_x and noise energy $E = 10^{\frac{L_x}{10}}$ are calculated.
The resulting noise levels and the respective energy levels are shown in the following graphs.

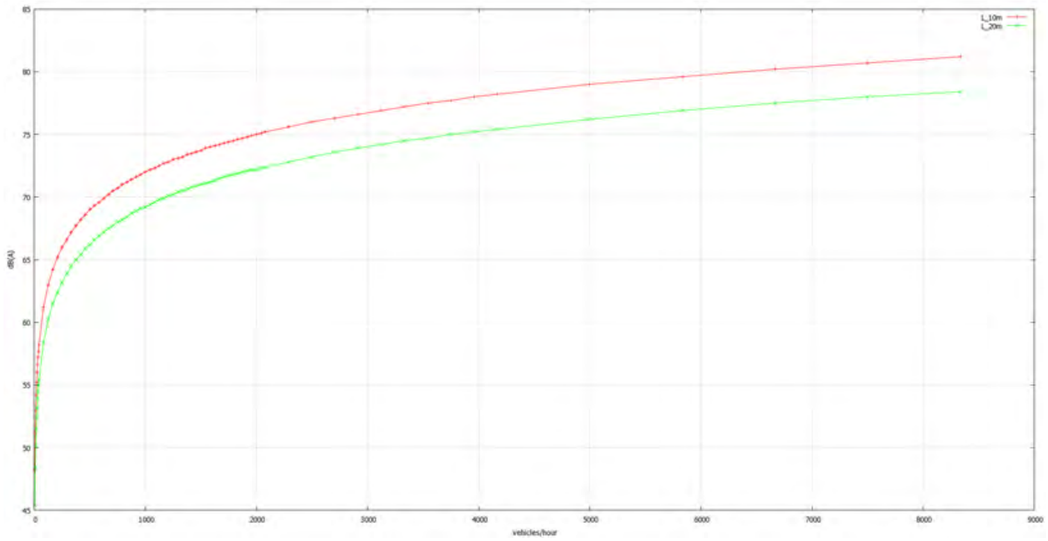


Figure 2.2 - Noise level obtained varying light vehicles traffic flux (at distances 10 and 20 meters from road).

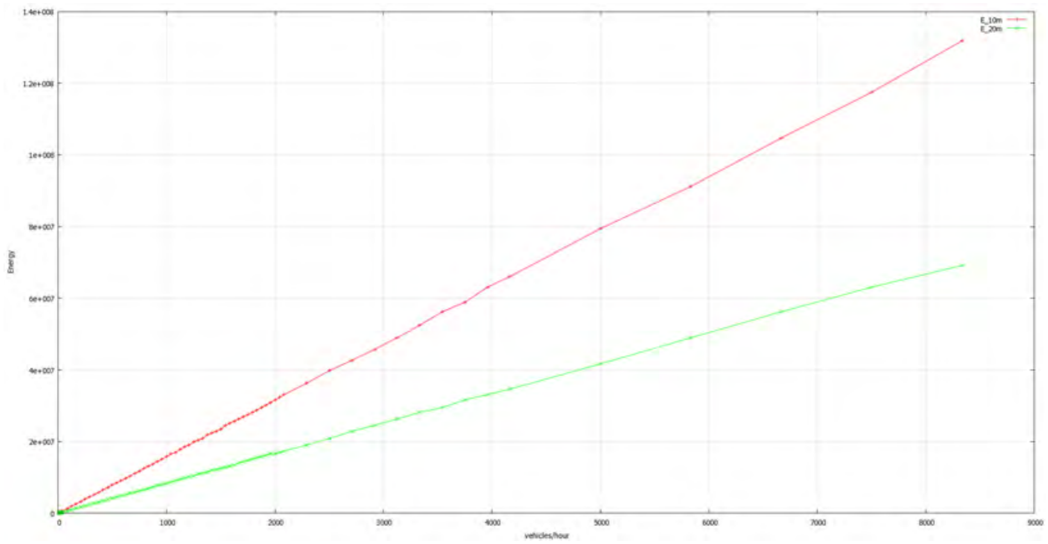


Figure 2.3 – Noise energy obtained varying light vehicles traffic flux (at distances 10 and 20 meters from road).

The fluctuations seen in the above graphs are due to rounding errors: in CadnaA the results are shown with one significant digit.

The best fitting line for the energy levels is calculated as $E = mN_L$

- *E* is the noise energy,
- N_L is the traffic,
- *m* is a parameter.

At 10 meters, we find m = 656.936. Asymptotic Standard Error ±0.4556 (0.06935%).

At 20 meters, we find is m = 349.246. Asymptotic Standard Error ±0.2767 (0.07923%).

The fitting line is in a good approximation.

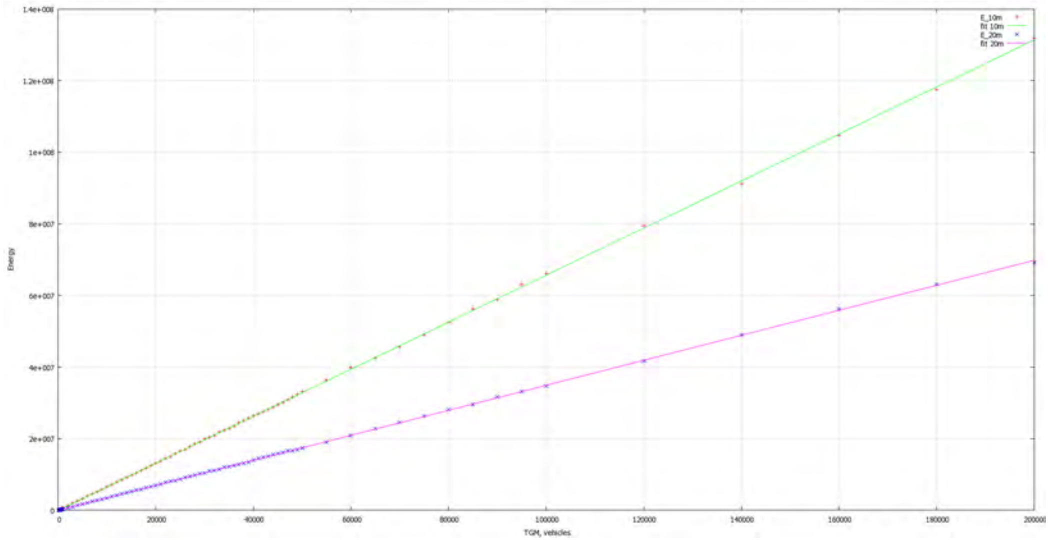


Figure 2.4 – Fitting lines at 10 and 20 meters and simulated values.

In a good approximation, the noise energy simulated at 10 and 20 meters distance from road (and 4 meters height) for a N_L traffic of light vehicles only is:

$$E_{L,10m} = 656.936 \cdot N_L$$

$$E_{L,20m} = 349.2466 \cdot N_L$$

To find the correspondent noise level, the formula $L_x = 10LogE_x$ has to be used.

Heavy duty Vehicles: graphs and formulas

The resulting noise levels and respective energy levels are shown in the following graphs.

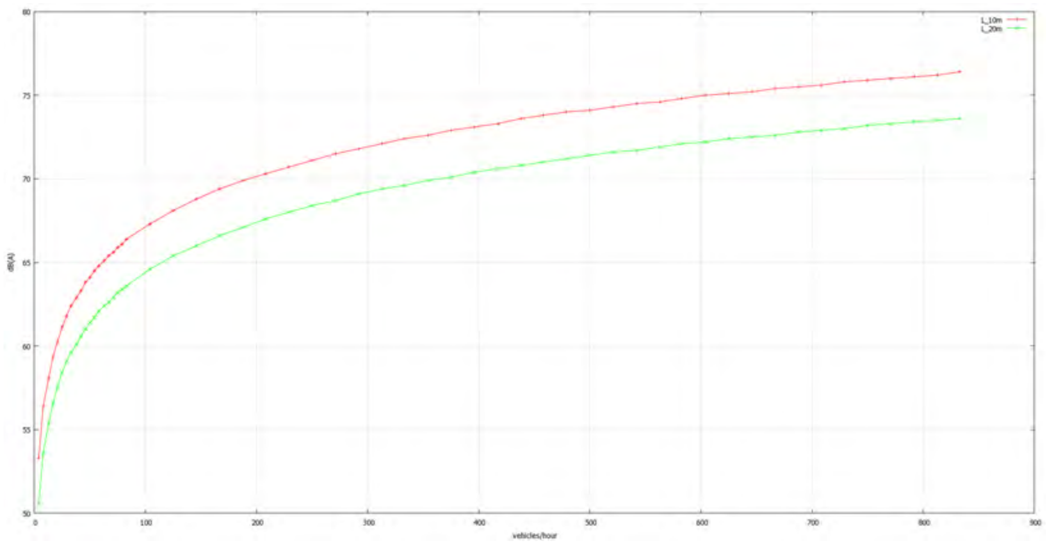


Figure 2.5 - Noise level obtained varying heavy duty vehicles traffic flux (at distances 10 and 20 meters from road).

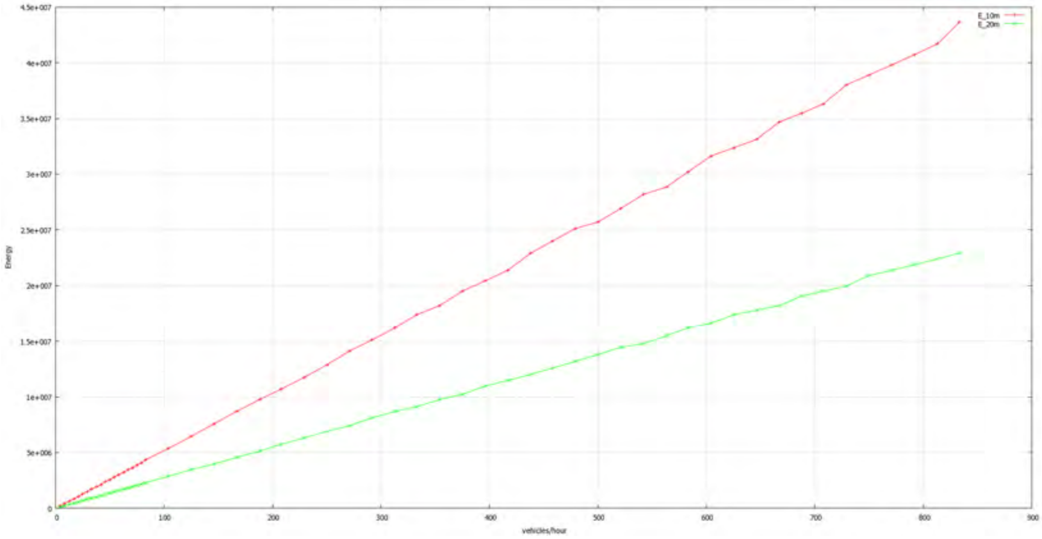


Figure 2.6 - Noise Energy obtained varying heavy duty vehicles traffic flux (at distances 10 and 20 meters).

The best fitting line $E = mN_H$ is found for:

At 10 meters, m = 2157.11.Asymptotic Standard Error ±2.176 (0.1009%).

At 20 meters, m = 1149.09.Asymptotic Standard Error ±0.9231 (0.08034%).

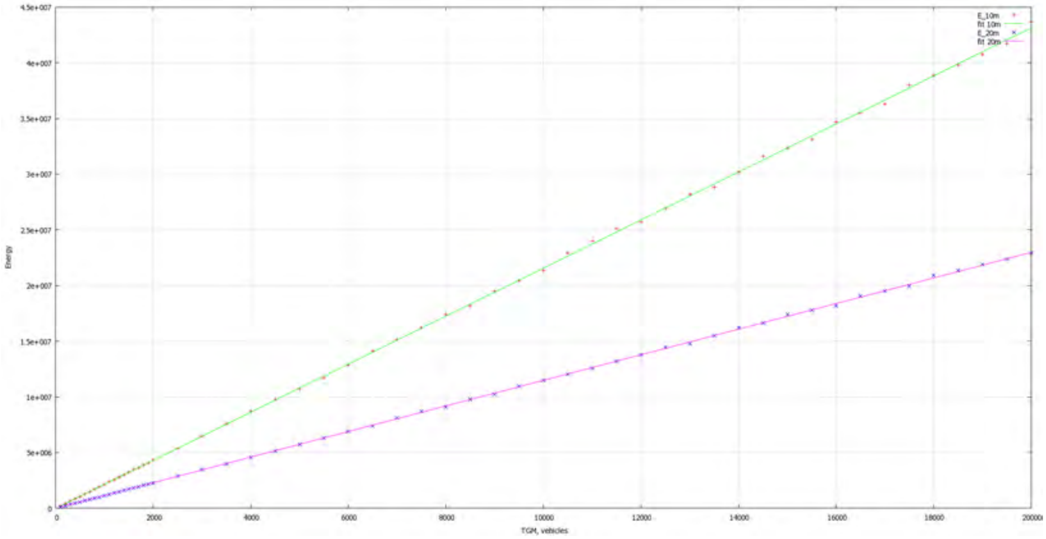


Figure 2.7 – Noise energy at 10 and 20 meters, with fitting line.

In conclusion, for heavy duty vehicles:

- $E_{H,10m} = 2157.11 \cdot N_H$
- $E_{H,20m} = 1149.09 \cdot N_H$,

which will be used to calculate the sound energy, and levels, for the heavy duty vehicles traffic.

Recalling the previous results for light vehicles, it is possible to state that, roughly:

1 Heavy Duty Vehicle = 3.3 Light Vehicles

The numbers of heavy-duty vehicles crossing the border for each corridor are reported in the table below with the respective level of L_{DEN} obtained by mean of modulation curves.

Corridor	ROAD	
	Estimated HVs Daily Traffic	$L_{DEN,rif}$ [dB(A)]
Fréjus	2058	72,5
Mont Blanc	1609	72,3
Gotthard	4319	75,6
Brenner	2584	78,9
Tarvisio	8105	75,7

Table 2.2 – Number of heavy duty vehicles crossing the border and correspondent L_{DEN} values.

2.2.2 Train Simulations

The train simulation model has been set up like the road one: a straight train line has been placed and two measurement points, at 10 and 20 meters distance from the train line, were created.

Terrain is flat, inclination is 0%. The algorithm used to run the simulations is Schall-03, because NMPB-Fer has been found to be non-reliable.

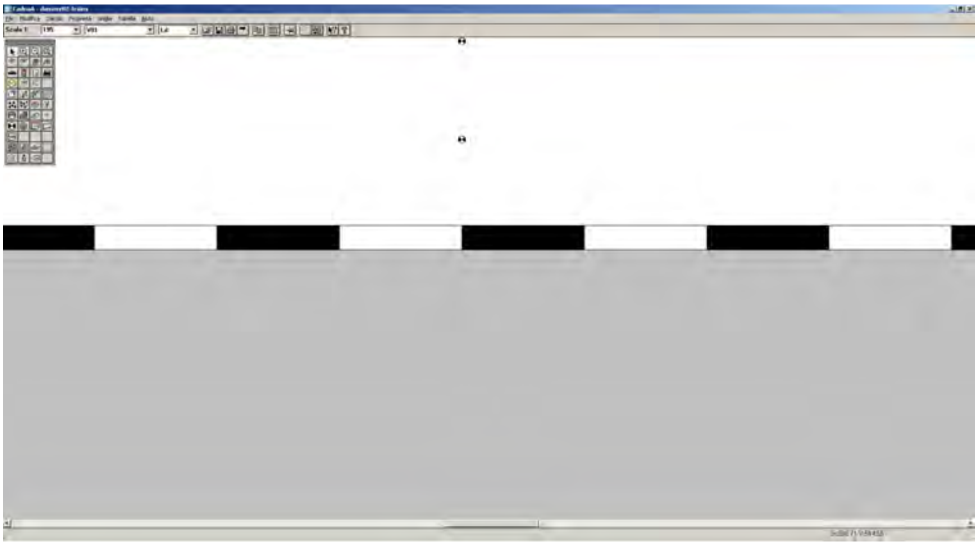


Figure 2.8 - Train Model: setup.

To run a train simulation, user has to set the following parameters:

- Number of trains that travel in the reference period (24 hours) *T.*
- Length of the trains *L*.
- Speed of the trains (*100 Km/h* for all the simulations).

Running few tests, it is possible to observe that the emission is calculated as a function of the product *LT* (that is: emission is proportional to the total number of travelling wagons).

Therefore the value of *L = 250 m is* used and the number of travelling trains is changed in the reference period. So, to use another “typical train length” for a corridor the *T* parameter has to be accordingly modified.

Note that it is necessary to transform the iMONITRAF*! Indicator 3* (total weight carried by trains) into a *LT* value. To do this, the typical number of wagons, how much weight can carry a wagon or, equivalently, a typical “linear density” (tons/meter) have to be estimated.

Again, annoyance is calculated on the basias of L_{DEN} (and not SEL).

Train Noise: Results

Plotting the levels and the energy:

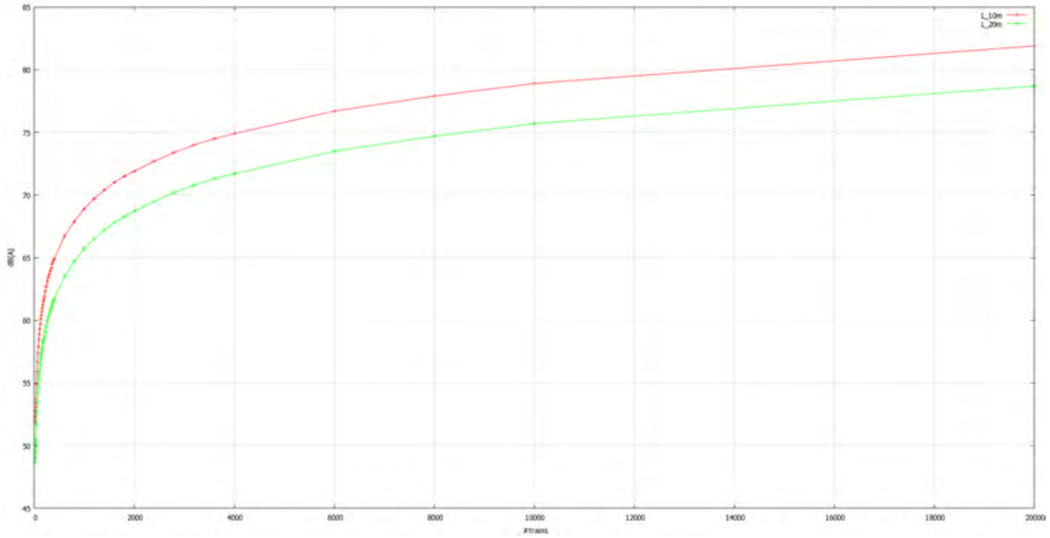


Figure 2.9 - Noise level for number of trains.

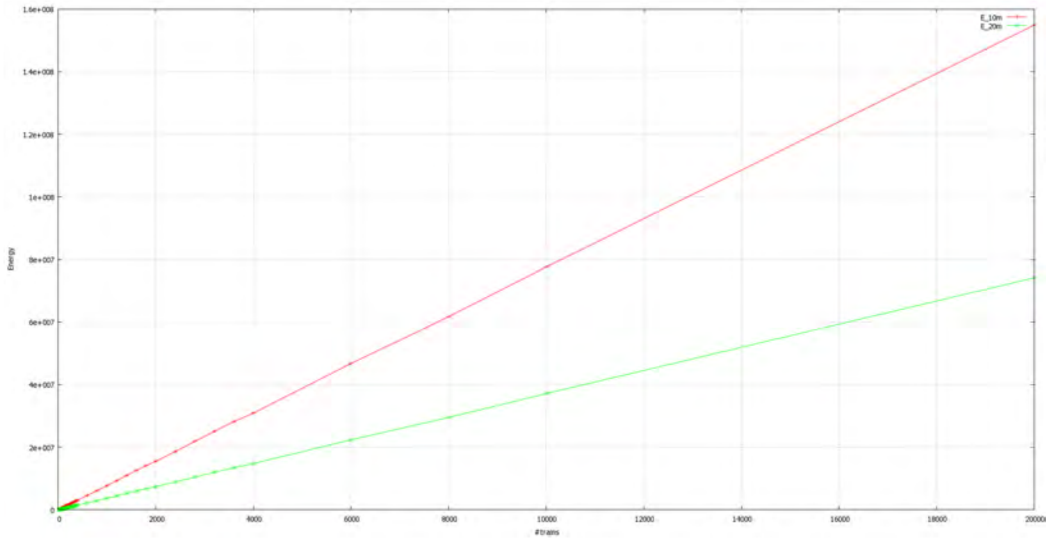


Figure 2.10 - Noise energy for number of trains.

Calculating the best fitting line that bounds the noise energy to the number of trains:

- $E = mN_{trains}$
- *m* = 7751.26
- Asymptotic Standard Error ±8.046 (0.0519%)

So it is possible conclude that, roughly:

1 Train = 11.8 Light Vehicles

1 Train = 3.6 Heavy Duty Vehicles

The tons are spilt up into fright trains passages per day and the L_{DEN} level is calculated, as shown in table below.

Corridor	RAIL	
	Estimated Freight Trains Daily Traffic	$L_{DEN,rif}$ [dB(A)]
Fréjus	10	70,7
Mont Blanc	-	-
Gotthard	81	74,8
Brenner	96	72,8
Tarvisio	60	68,2

Table 2.3 – Number of freight trains crossing the border and correspondent L_{DEN} values.

2.3 Step 3: Critical value of %HA

In the iMonitraf! case, the annoyance formulations are used for defining a threshold, within which the disturbance exceeds a limit expressed in function of a critic value of L_{DEN}. On the basis of the Guideline of the WHO (*Burden of disease from environmental noise - Quantification of healthy life years lost in Europe, 2011),* the limits fixed in the different periods of the day are:

- Day (7.00 - 19.00) 65 dB(A)
- Evening (19.00 - 23.00) 65 dB(A)
- Night (23.00 - 7.00) 55 dB(A)

The L_{DEN} is calculated starting from the formulation

$$L_{DEN} = 10log\left(\frac{12}{24}\cdot 10^{\frac{L_{Aeq,D}}{10}} + \frac{4}{24}\cdot 10^{\frac{L_{Aeq,E}+5}{10}} + \frac{8}{24}\cdot 10^{\frac{L_{Aeq,N}+10}{10}}\right)$$

and $\boldsymbol{L_{DEN,crit}}$ ***= 66dB(A)***. This value corresponds to $\boldsymbol{HA_{crit,road}}$***= 17,6%***, in terms of annoyed people for road and $\boldsymbol{HA_{crit,rail}}$***= 9,5%*** for railway traffic as shown in chart 2.2.

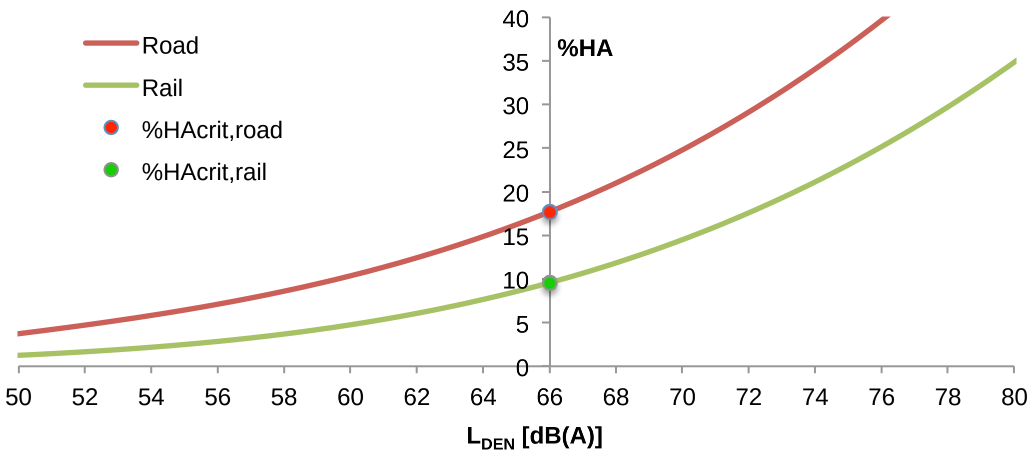


Chart 2.2 – Critical value of High Annoyed (%HA) people correspondig to L_{DEN}=66dB(A).

2.4 Step 4: Critical buffer extension

For estimating how many people is annoyed by traffic noise, the buffer is identified as critical threshold. Starting from the limits above calculated, the critical distance (d_{crit}) to which is reached $L_{DEN,crit}$ is calculated from the noise source.

In this section the process for defining d_{crit}.is explained.

The formulas for *10 meters* distance from road are used. At every other point the sound level can be obtained applying the standard distance attenuation formula.

1. Using the three traffic fluxes measured at the country border in Step 2, (N_L, N_H) for each of the three periods (Day-Evening-Night), it's possible to define:

   ROAD

   - The energy level E_L for light vehicles: $E_{L,10m} = 656.936 \cdot N_L$
   - The energy level E_H for heavy duty vehicles $E_{H,10m} = 2157.11 \cdot N_H$
   - The total energy Level $E_{TOT} = E_L + E_H$.
   - The noise level for that period $L_x = 10Log(E_{TOT})$

   RAIL

   - The noise level for that periods $L_x = 10Log(7751.26N)$.

2. Using L_D, L_E, L_N :

$$L_{DEN} = 10log\left(\frac{12}{24} \cdot 10^{\frac{L_{Aeq,D}}{10}} + \frac{4}{24} \cdot 10^{\frac{L_{Aeq,E}+5}{10}} + \frac{8}{24} \cdot 10^{\frac{L_{Aeq,N}+10}{10}}\right)$$

   (optionally, a correction to the levels obtained can be applied. Every corridor could have its own correction value, decided by the partner that monitors that corridor).

3. Using L_{DEN}:

   - For road

     $\%HA = 9,868 \cdot 10^{-4}(L_{DEN} - 42)^3 - 1,436 \cdot 10^{-2}(L_{DEN} - 42)^2 + 0,512(L_{DEN} - 42)$

   - For rail

     $\%HA = 7,239 \cdot 10^{-4}(L_{DEN} - 42)^3 - 7,851 \cdot 10^{-3}(L_{DEN} - 42)^2 + 0,169(L_{DEN} - 42).$

Finally, the distance where the level L_{DEN} reaches 66 dB(A), that is equivalent to annoyance %HA=17,6, for road traffic and %HA= 9,5 for railway traffic, is determinated, by means of the attenuation formula:

$$d_{crit} = \sqrt{\left(d_{rif}^2 + h_{rif}^2\right) \cdot 10^{\frac{(L_{DEN,rif} - L_{DEN,crit})}{5}} - h_{crit}^2}$$

where:

- h_{crit} and d_{crit} are the distances at which is reached $L_{DEN,crit}$ = *66dB(A*).
- d_{rif} and h_{rif} are, respectivly, the distance (*10 m*) and the height (*4 m*) of microphone after harmonization.
- $L_{DEN,rif}$ is sound pressure level obtained in *Step 3* starting from the monitoring campaigns.

The results, reported in table below, show the buffer size for each corridor.

Corridor	d_{crit} (Buffer) [m]	
	Road	Rail
Fréjus	47,6	31,5
Mont Blanc	45,8	-
Gotthard	97,6	81,2
Brenner	212,3	51,9
Tarvisio	101,3	17,3

Table 2.4 – Buffer size for road and rail of each corridor.

2.5 Step 5: Estimation of people living within the buffer

Using the methodology, it's possible to estimate the number of inhabitants living in places affected by noise levels higher than the desired one. With *WebGIS* application the number of inhabitants living within the buffer d_{crit} can be identified for road and railway traffic.

<u>**For road traffic**</u>

Corridor	Side	Number of inhabitants	Total Number of inhabitants
Fréjus	**Piemonte**	342	2829
	Rhône-Alpes	2487	
Mont Blanc	**Valle d'Aosta**	1927	4401
	Rhône-Alpes	2474	
Gotthard	**Canton Ticino**	11577	21113
	Zentralschweiz	9536	
Brenner	**Trentino**	33445	56210
	Tirol	22765	
Tarvisio	**Friuli**	561	561
	Kärnten	0	

Table 2.5 – People living within the critical buffer of road.

<u>**For railway traffic**</u>

Corridor	Side	Number of inhabitants	Total Number of inhabitants
Fréjus	**Piemonte**	2435	6476
	Rhône-Alpes	4041	
Mont Blanc	**Valle d'Aosta**	-	-
	Rhône-Alpes	-	
Gotthard	**Canton Ticino**	18032	26202
	Zentralschweiz	8170	
Brenner	**Trentino**	19437	30528
	Tirol	11091	
Tarvisio	**Friuli**	402	402
	Kärnten	0	

Table 2.6 - People living within the critical buffer of rail.

The data relative to number of inhabitants are based on *Eurostat - Population on 1 January by sex and age groups*.

2.6 Step 6 – Step 7: Estimation of affected population

With the data of inhabitants living within the buffer, one can calculate the number of highly annoyed people in reference to the percentage of *17.6%,* for road traffic, and *9,5%* for railway traffic, for the two sides of the pass, as shown in tables below.

2.6.1 The NOW scenario

Corridor	Side	High Annoyed People	
		$N_{HA,ROAD}$	$N_{HA,RAIL}$
Fréjus	Piemonte	60	231
	Rhône-Alpes	438	384
Montblanc	Valle d'Aosta	339	-
	Rhône-Alpes	435	-
Gotthard	Canton Ticino	2038	1713
	Zentralschweiz	1678	776
Brenner	Trentino	5886	1847
	Tirol	4007	1054
Tarvisio	Friuli	99	38
	Kärnten	0	0

Table 2.7 – Highly annoyed inhabitants correspond to the critical threshold, in the current scenario.

Due to project choices, the affected population should be expressed as percentage value. Hence, for each corridor, the highly annoyed people can be related to inhabitants of total population living in the municipalities (*Mun*) of the whole corridor and expressed as percentage value for the two sides of the pass and for the entire corridor.

Corridor	Side	ROAD		RAIL		ROAD + RAIL	
		$N_{HA,ROAD}$ / Mun	$N_{HA,ROAD}$ / Mun	$N_{HA,RAIL}$ / Mun	$N_{HA,RAIL}$ / Mun	$N_{HA,RAIL+ROAD}$ / Mun	$N_{HA,RAIL+ROAD}$ / Mun
Fréjus	Piemonte	0,30%	0,39%	0,56%	0,36%	0,47%	0,37%
	Rhône-Alpes	0,41%		0,30%		0,35%	
Mont Blanc	Valle d'Aosta	0,47%	0,41%	-	-	0,47%	0,41%
	Rhône-Alpes	0,38%		-		0,38%	
Gotthard	Canton Ticino	1,29%	1,01%	1,02%	0,99%	1,15%	1,00%
	Zentralschweiz	0,80%		0,93%		0,84%	
Brenner	Trentino	1,59%	1,54%	0,49%	0,46%	1,04%	1,01%
	Tirol	1,47%		0,42%		0,97%	
Tarvisio	Friuli	1,29%	1,29%	0,18%	0,14%	0,48%	0,39%
	Kärnten	0,00%		0,00%		0,00%	

Table 2.8 – Percentage of highly annoyed people related to municipalities total inhabitants crossed by infrastructure, in the current scenario (numbers of inhabitants in the municipalities are reported in the ***Summary review*** *section).*

Note that for railway traffic the affected population is comparable with the road one; in fact the railway goes through the cities where there is a greater concentration of inhabitants than in rural sides.

2.6.2 The future Scenarios

The *Indicator 12* is obtained in relation to L_{DEN} value that is linked to traffic fluxes. In this sense, this indicator could be used to estimate the impact of future scenarios and, thus, it could be used as predictive parameter. The annoyance in future scenarios is estimated on the basis of traffic fluxes calculated in *WP6*.

The results are reported in red when parameters increase respect to the NOW scenario (2010), in green when they decrease or remain stationary. Table 2.9 shows these fluctuations.

Corridor	Scenarios	ROAD				RAIL				RAIL+ROAD
		Buffer [m]	L_{DEN} [dB(A)]	Estimated Daily HVs	%HA	Buffer [m]	L_{DEN} [dB(A)]	Estimated Daily Freight Trains	%HA	%HA
Fréjus	NOW	47,6	72,5	2058	0,39	31,5	70,7	10	0,36	0,37
	BAU/BAT	+9,8	+0,8	+576	+0,08	0	0	0	0	+0,03
	ACE	-3,6	-0,3	-211	+0,04	+11,4	+1,3	+5	+0,14	+0,06
Mont Blanc	NOW	45,8	72,3	1609	0,41					0,41
	BAU/BAT	+9,3	+0,8	+451	+0,08	NO railway crossing the frontier				+0,08
	ACE	+0,7	+0,1	+34	+0,03					+0,03
Gotthard	NOW	97,6	75,6	4319	1,01	81,2	74,8	81	0,99	1,00
	BAU/BAT	+6,6	+0,3	+1209	+0,03	0	0	0	0	+0,02
	ACE	-16,7	-0,8	-318	-0,18	+27	+1,2	+38	+0,07	-0,08
Brenner	NOW	212,3	78,9	2584	1,54	51,9	72,8	96	0,46	1,01
	BAU/BAT	+38,5	+0,7	+490	+0,26	0	0	0	0	+0,14
	ACE	-13,5	-0,3	-1236	-0,12	+19,2	+1,4	+45	+0,16	+0,01
Tarvisio	NOW	101,3	75,7	8105	1,29	17,3	68,2	60	0,14	0,39
	BAU/BAT	+20,3	+0,8	+2269	-0,13	0	0	0	0	+0,02
	ACE	-5,3	-0,2	-797	-0,08	+16,4	+2,8	+59	+0,14	+0,09

Table 2.9 – Fluctuations of the parameters in the BAU/BAT and ACE scenarios in relation to the NOW scenario.

2.7 Remarks

One of the critical points in the proposed methodology concerns the data collection. All the problems in finding data are related to institution giving the results of the monitoring campaigns (L_D, L_E, L_N and L_{DEN}) and the related numbers of vehicles.

Related to problems about considering heavy-duty vehicles in traffic fluxes during night time in the different countries linked to this study, the procedure doesn't take into account the sleep disturbance (***%HSD***).

Anyway, the degree of disturbance during night could be estimated in relation to the parameter L_N as a percentage of *Highly Sleep Disturbed **(%HSD)*** people, as follows for the different traffic sources:

- For road

  $$\%HSD = 20{,}8 - 1{,}05L_N + 0{,}0146(L_N)^2$$

- For rail

  $$\%HSD = 11{,}3 - 0{,}55L_N + 0{,}00759(L_N)^2.$$

In this case, the limit fixed is ***55dB(A)***, at which corresponds ***%HSD=8*** for road traffic and ***%HSD=4*** for railway traffic.

<u>*Note that*</u> the procedure for evaluating the buffer size and the people affected by night noise is identical to %HA.

3 Summary review

For each corridor, a synthetic review is presented for the all scenarios with an extract of the map, for better understanding the buffer concept.

3.1 The Frejus corridor

3.1.1 The NOW scenario

Road

Buffer dimension (distance from the axis): **47,6m**

People inside the buffer: **2.829**
Municipalities Total Inhabitants Piemonte side: **19.810**
Municipalities Total Inhabitants Rhôn-Alpes side: **107.737**

Highly annoyed people by traffic correspond to 17,6%: **498**
Highly annoyed people in the whole municipalities: **0,39%**

Rail

Buffer dimension (distance from the axis): **31,5m**

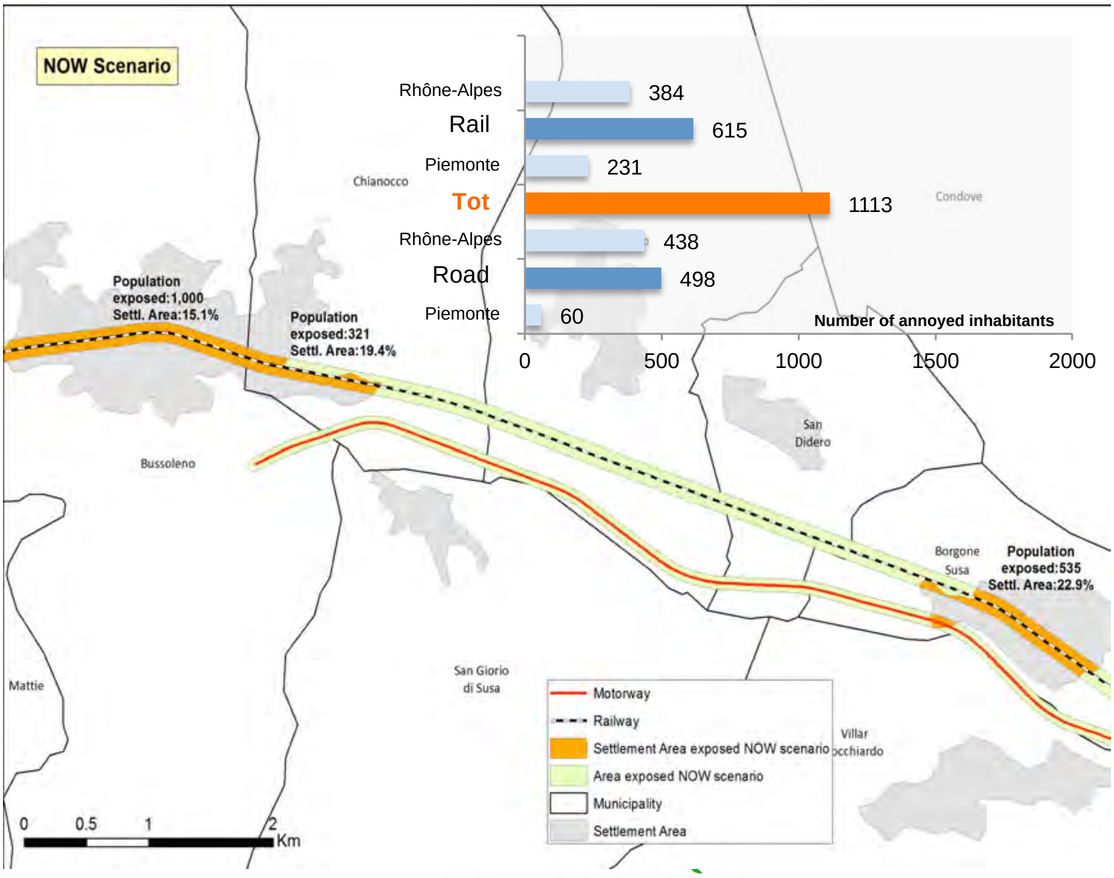
People inside the buffer: **6.476**
Municipalities Total Inhabitants Piemonte side: **41.664**
Municipalities Total Inhabitants Rhôn-Alpes side: **128.502**

Highly annoyed people by traffic correspond to 9,5%: **615**
Highly annoyed people in the whole municipalities: **0,36%**

Rail+Road

People inside the buffers: **9.305**
Municipalities Total Inhabitants*: **297.713**

Highly annoyed people by traffic noise: **1.113**
Highly annoyed people in the whole municipalities: **0,37%**



3.1.2 The BAU/BAT scenario

Road

Buffer dimension (distance from the axis): **57,4m**

People inside the buffer: **3.374**
Municipalities Total Inhabitants Piemonte side: **19.810**
Municipalities Total Inhabitants Rhôn-Alpes side: **107.737**

Highly annoyed people by traffic correspond to 17,6%: **594**
Highly annoyed people in the whole municipalities: **0,47%**

Rail

Buffer dimension (distance from the axis): **31,5m**

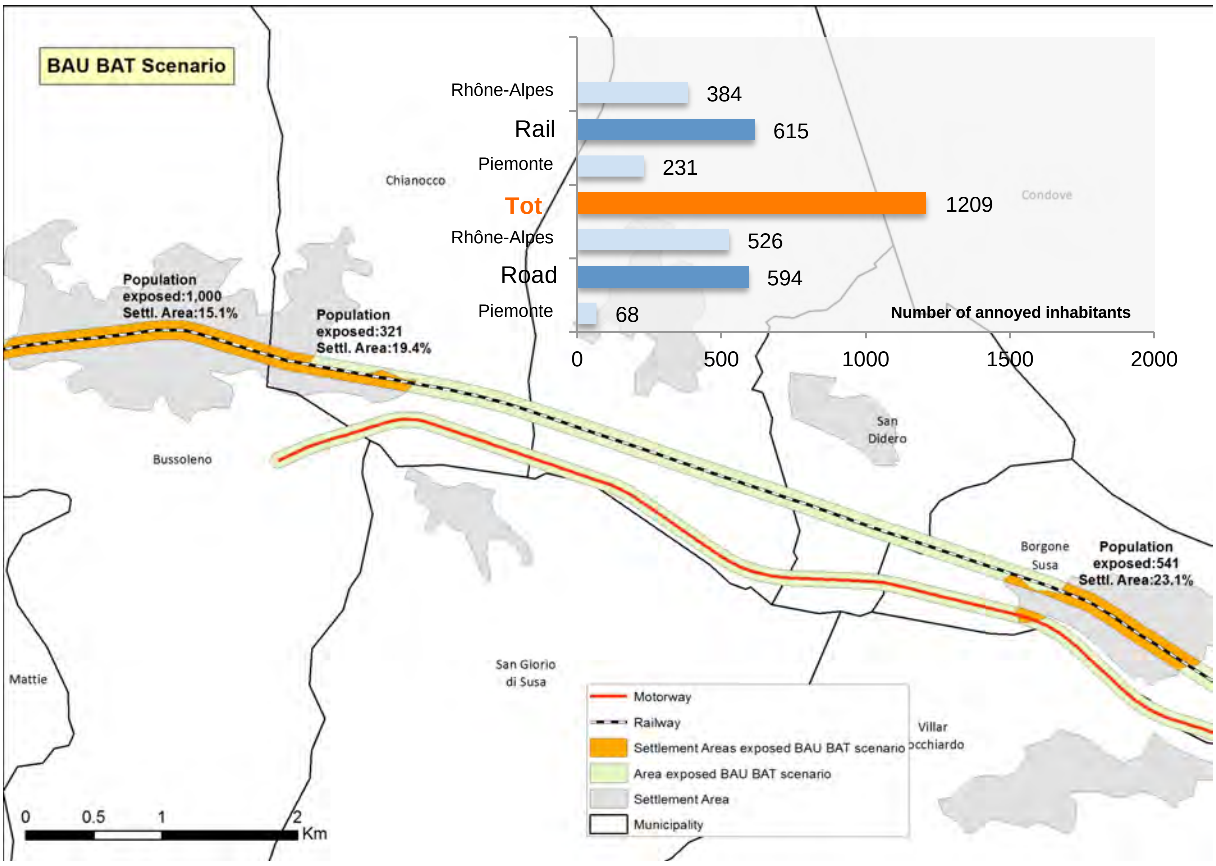
People inside the buffer: **6.476**
Municipalities Total Inhabitants Piemonte side: **41.664**
Municipalities Total Inhabitants Rhôn-Alpes side: **128.502**

Highly annoyed people by traffic correspond to 9,5%: **615**
Highly annoyed people in the whole municipalities: **0,36%**

Rail+Road

People inside the buffers: **9.850**
Municipalities Total Inhabitants*: **297.713**

Highly annoyed people by traffic noise: **1.209**
Highly annoyed people in the whole municipalities: **0,41%**



3.1.3 The ACE scenario

Road

Buffer dimension (distance from the axis): **44m**

People inside the buffer: **2.563**
Municipalities Total Inhabitants Piemonte side: **19.810**
Municipalities Total Inhabitants Rhôn-Alpes side: **107.737**

Highly annoyed people by traffic correspond to 17,6%: **451**
Highly annoyed people in the whole municipalities: **0,35%**

Rail

Buffer dimension (distance from the axis): **42,9m**

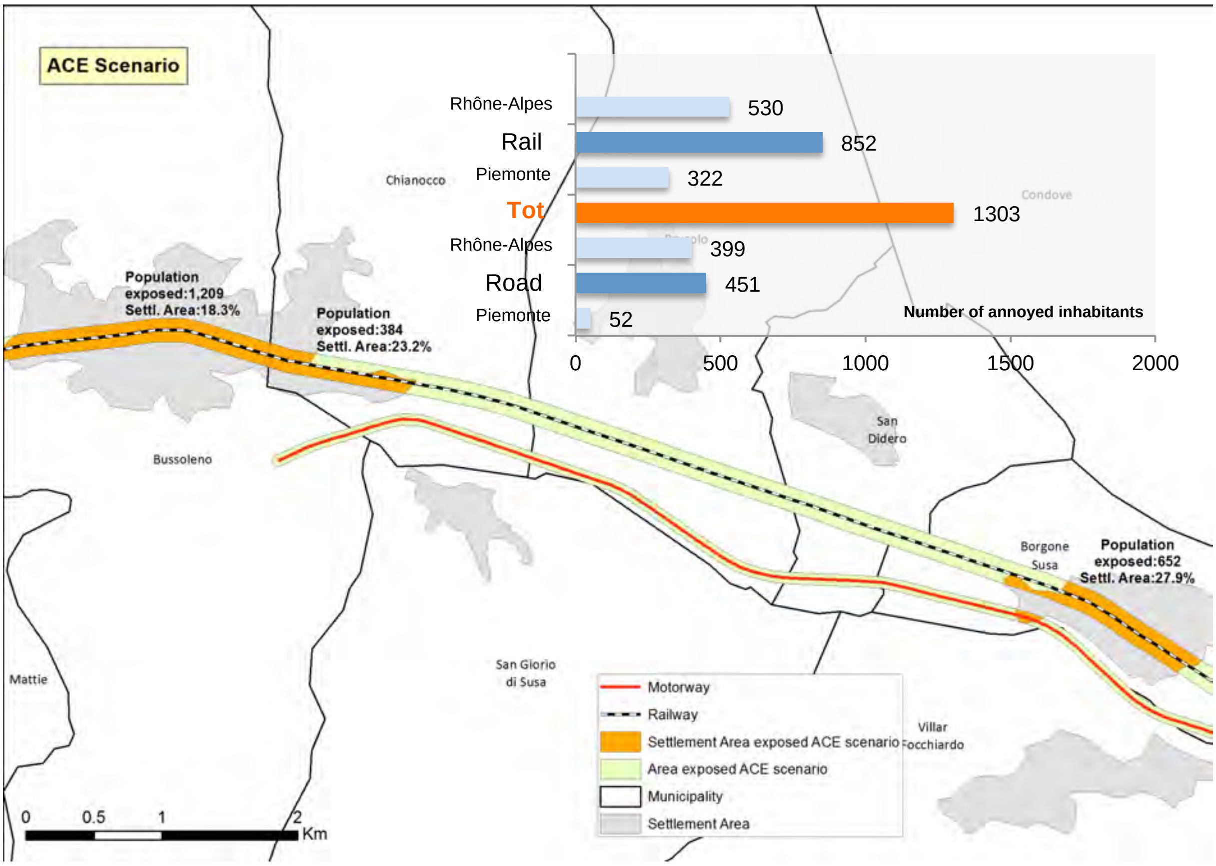
People inside the buffer: **6.476**
Municipalities Total Inhabitants Piemonte side: **41.664**
Municipalities Total Inhabitants Rhôn-Alpes side: **128.502**

Highly annoyed people by traffic correspond to 9,5%: **852**
Highly annoyed people in the whole municipalities: **0,5%**

Rail+Road

People inside the buffers: **8.967**
Municipalities Total Inhabitants*: **297.713**

Highly annoyed people by traffic noise: **1.303**
Highly annoyed people in the whole municipalities: **0,44%**



3.2 The Mont Blanc corridor

3.2.1 The NOW scenario

Road

Buffer dimension (distance from the axis): **45,8m**

People inside the buffer: **4.401**
Municipalities Total Inhabitants Valle d'Aosta side: **71.993**
Municipalities Total Inhabitants Rhôn-Alpes side: **115.402**

Highly annoyed people by traffic correspond to 17,6%: **774**
Highly annoyed people in the whole municipalities: **0,41%**

Rail

Buffer dimension (distance from the axis): **-**

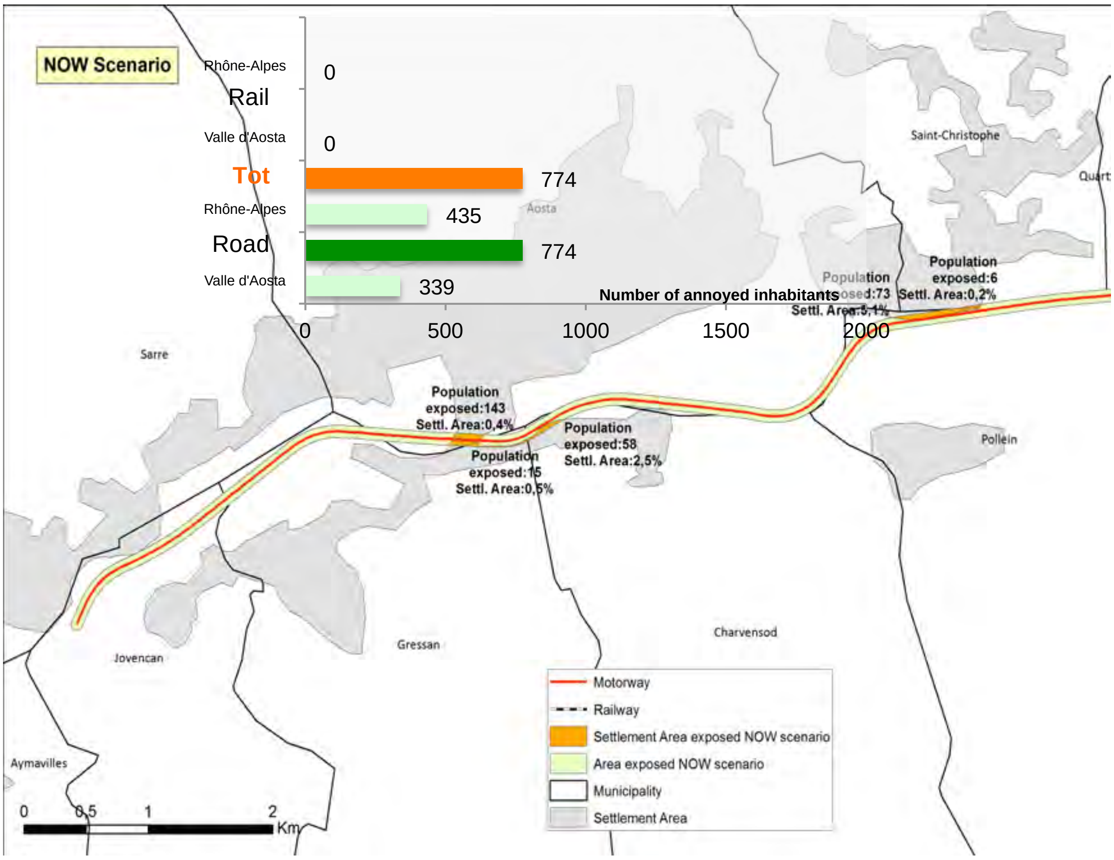
People inside the buffer: **-**
Municipalities Total Inhabitants Valle d'Aosta side: -
Municipalities Total Inhabitants Rhôn-Alpes side: -

Highly annoyed people by traffic correspond to 9,5%: **-**
Highly annoyed people in the whole municipalities: **-**

Rail+Road

People inside the buffer: **4.401**
Municipalities Total Inhabitants*: **187.395**

Highly annoyed people by traffic noise: **774**
Highly annoyed people in the whole municipalities: **0,41%**



3.2.2 The BAU/BAT scenario

Road

Buffer dimension (distance from the axis): **55,1m**

People inside the buffer: **5.247**
Municipalities Total Inhabitants Valle d'Aosta side: **71.993**
Municipalities Total Inhabitants Rhôn-Alpes side: **115.402**

Highly annoyed people by traffic correspond to 17,6%: **923**
Highly annoyed people in the whole municipalities: **0,49%**

Rail

Buffer dimension (distance from the axis): **-**

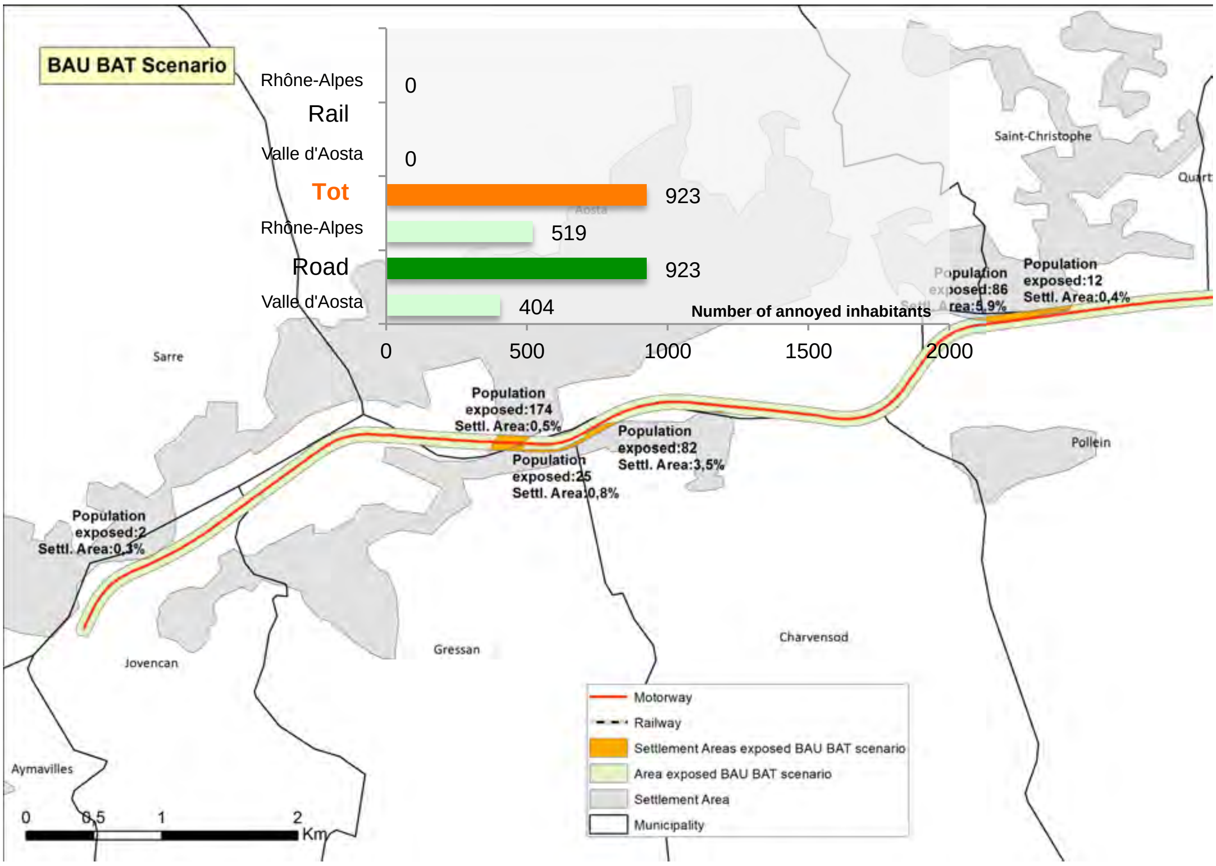
People inside the buffer: **-**
Municipalities Total Inhabitants Valle d'Aosta side: -
Municipalities Total Inhabitants Rhôn-Alpes side: -

Highly annoyed people by traffic correspond to 9,5%: **-**
Highly annoyed people in the whole municipalities: **-**

Rail+Road

People inside the buffer: **5.247**
Municipalities Total Inhabitants*: **187.395**

Highly annoyed people by traffic noise: **923**
Highly annoyed people in the whole municipalities: **0,49%**



3.2.3 The ACE scenario

Road

Buffer dimension (distance from the axis): **46,5m**

People inside the buffer: **4.480**
Municipalities Total Inhabitants Valle d'Aosta side: **71.993**
Municipalities Total Inhabitants Rhôn-Alpes side: **115.402**

Highly annoyed people by traffic correspond to 17,6%: **788**
Highly annoyed people in the whole municipalities: **0,45%**

Rail

Buffer dimension (distance from the axis): **-**

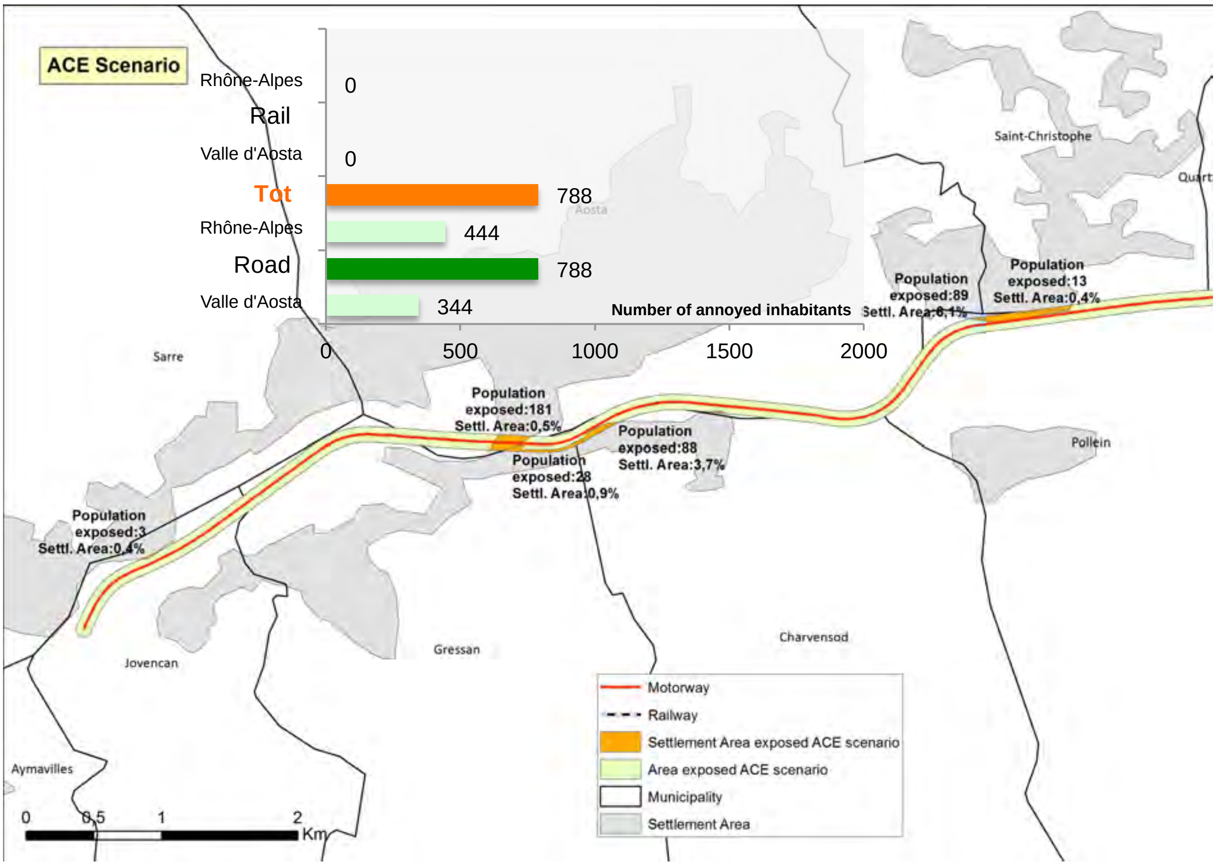
People inside the buffer: **-**
Municipalities Total Inhabitants Valle d'Aosta side: -
Municipalities Total Inhabitants Rhôn-Alpes side: -

Highly annoyed people by traffic correspond to 9,5%: **-**
Highly annoyed people in the whole municipalities: **-**

Rail+Road

People inside the buffer: **4.480**
Municipalities Total Inhabitants*: **187.395**

Highly annoyed people by traffic noise: **788**
Highly annoyed people in the whole municipalities: **0,45%**



3.3 The Gotthard corridor

3.3.1 The NOW scenario

Road

Buffer size (distance from the axis): **97,6m**

People inside the buffer: **21.113**
Municipalities Total Inhabitants Canton Ticino side: **157.967**
Municipalities Total Inhabitants Zentralschweiz side: **210.084**

Highly annoyed people by traffic correspond to 17,6%: **3.716**
Highly annoyed people in the whole municipalities: **1,01%**

Rail

Buffer size (distance from the axis): **81,2m**

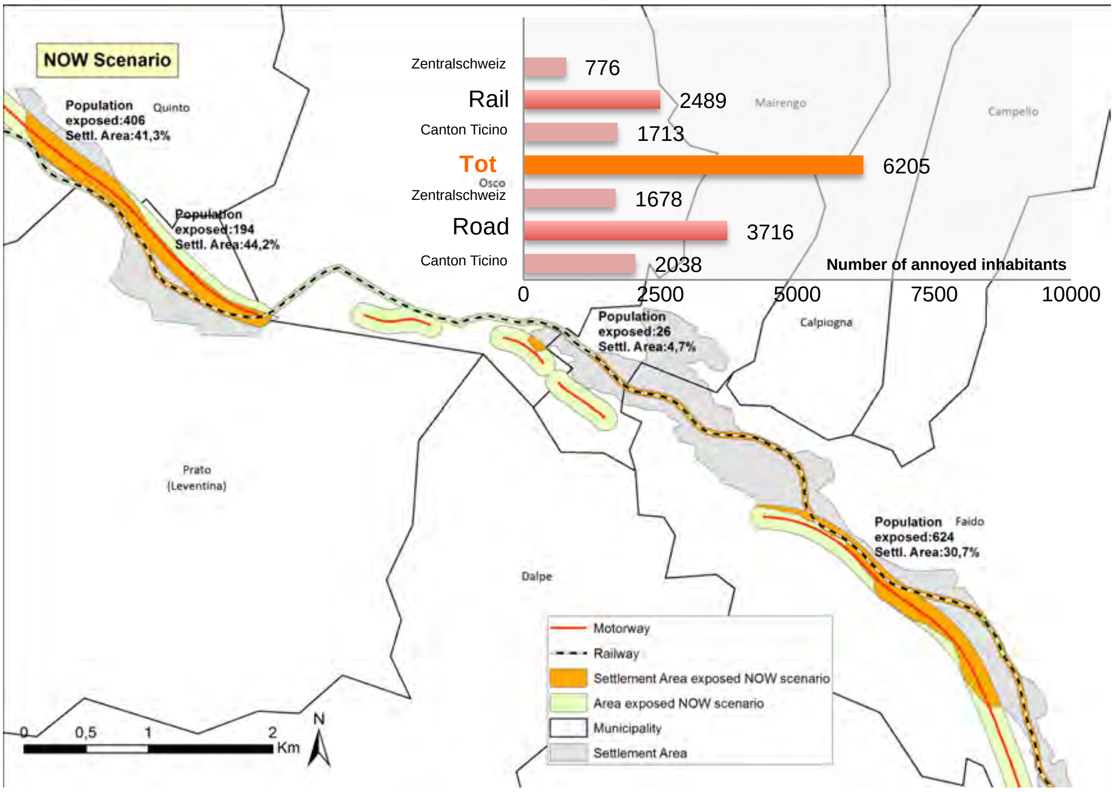
People inside the buffer: **26.202**
Municipalities Total Inhabitants Canton Ticino side: **167.160**
Municipalities Total Inhabitants Zentralschweiz side: **83.088**

Highly annoyed people by traffic correspond to 9,5%: **2.489**
Highly annoyed people in the whole municipalities: **0,99%**

Rail+Road

People inside the buffer: **44.871**
Municipalities Total Inhabitants*: **618.299**

Highly annoyed people by traffic noise: **6.205**
Highly annoyed people in the whole municipalities: **1,00%**



3.3.2 The BAU/BAT scenario

Road

Buffer size (distance from the axis): **104,3m**

People inside the buffer: **21.882**
Municipalities Total Inhabitants Canton Ticino side: **157.967**
Municipalities Total Inhabitants Zentralschweiz side: **210.084**

Highly annoyed people by traffic correspond to 17,6%: **3.851**
Highly annoyed people in the whole municipalities: **1,04%**

Rail

Buffer size (distance from the axis): **81,2m**

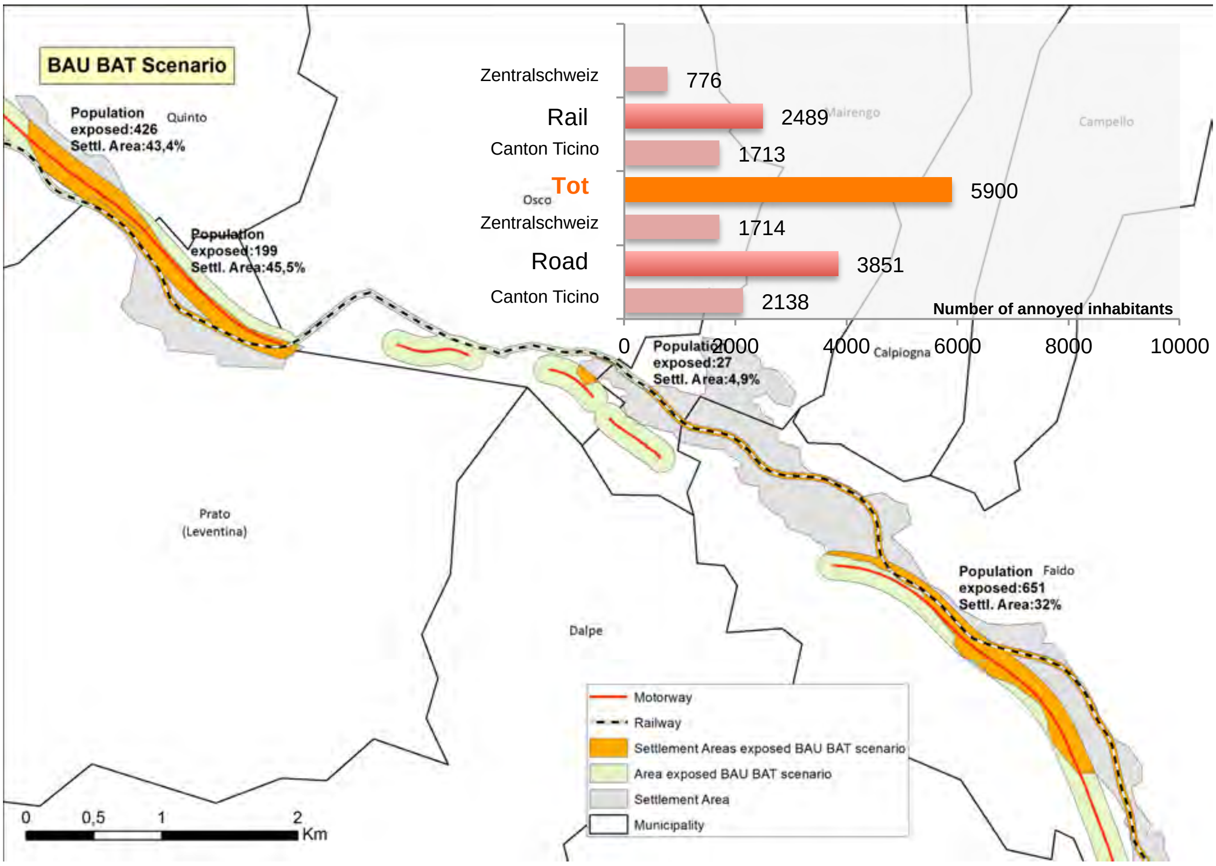
People inside the buffer: **26.202**
Municipalities Total Inhabitants Canton Ticino side: **167.160**
Municipalities Total Inhabitants Zentralschweiz side: **83.088**

Highly annoyed people by traffic correspond to 9,5%: **2.489**
Highly annoyed people in the whole municipalities: **0,99%**

Rail+Road

People inside the buffer: **48.084**
Municipalities Total Inhabitants*: **618.299**

Highly annoyed people by traffic noise: **6.340**
Highly annoyed people in the whole municipalities: **1,02%**



3.3.3 The ACE scenario

Road

Buffer size (distance from the axis): **80,9m**

People inside the buffer: **17.270**
Municipalities Total Inhabitants Canton Ticino side: **157.967**
Municipalities Total Inhabitants Zentralschweiz side: **210.084**

Highly annoyed people by traffic correspond to 17,6%: **3.040**
Highly annoyed people in the whole municipalities: **0,83%**

Rail

Buffer size (distance from the axis): **108,3m**

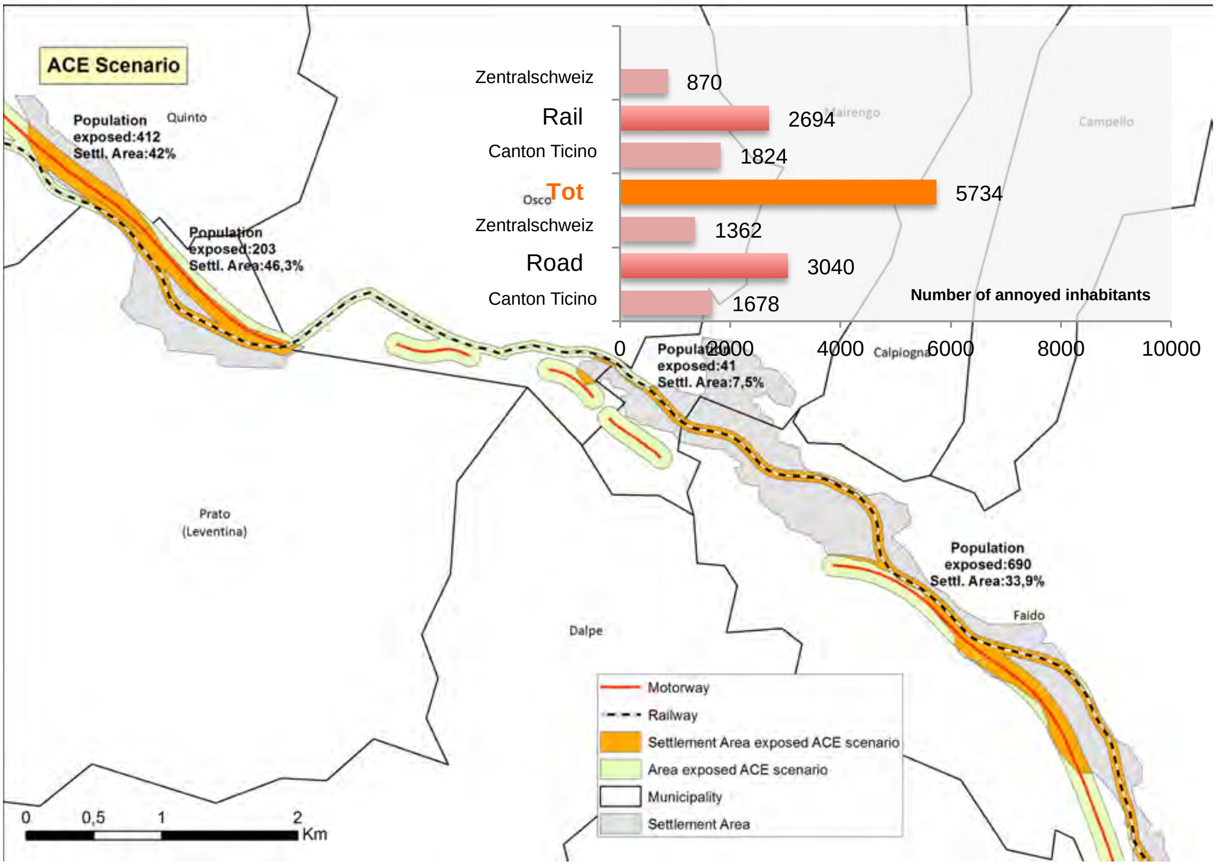
People inside the buffer: **28.358**
Municipalities Total Inhabitants Canton Ticino side: **167.160**
Municipalities Total Inhabitants Zentralschweiz side: **83.088**

Highly annoyed people by traffic correspond to 9,5%: **2.694**
Highly annoyed people in the whole municipalities: **1,07%**

Rail+Road

People inside the buffer: **45.628**
Municipalities Total Inhabitants*: **618.299**

Highly annoyed people by traffic noise: **5.734**
Highly annoyed people in the whole municipalities: **0,93%**



3.4 The Brenner corridor

3.4.1 The NOW scenario

Road

Buffer dimension (distance from the axis): **212,3m**

People inside the buffer: **56.210**
Municipalities Total Inhabitants Trentino side: **371.329**
Municipalities Total Inhabitants Tirol side: **271.761**

Highly annoyed people by traffic correspond to 17,6%: **9.893**
Highly annoyed people in the whole municipalities: **1,54%**

Rail

Buffer dimension (distance from the axis): **51,9m**

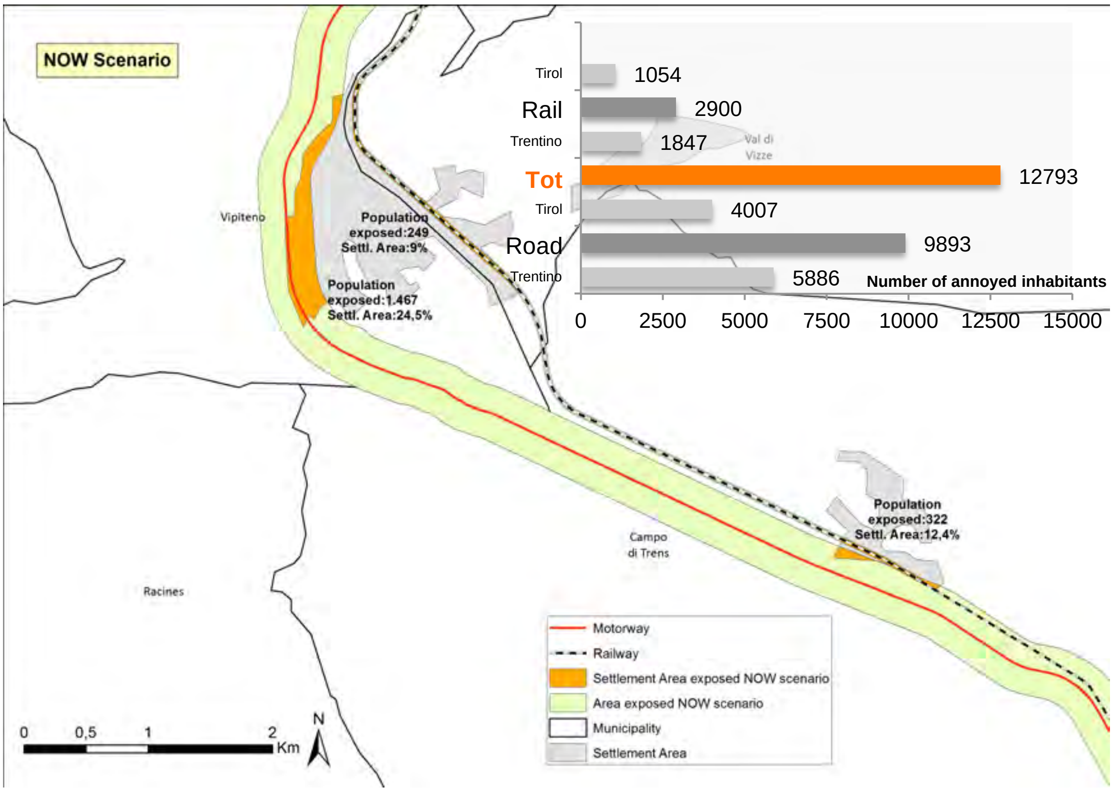
People inside the buffer: **30.528**
Municipalities Total Inhabitants Trentino side: **375.611**
Municipalities Total Inhabitants Tirol side: **251.922**

Highly annoyed people by traffic correspond to 9,5%: **2.901**
Highly annoyed people in the whole municipalities: **0,46%**

Rail+Road

People inside the buffer: **86.738**
Municipalities Total Inhabitants*: **1.270.623**

Highly annoyed people by traffic noise: **14.713**
Highly annoyed people in the whole municipalities: **1,15%**



3.4.2 The BAU/BAT scenario

Road

Buffer dimension (distance from the axis): **250,8m**

People inside the buffer: **67.121**
Municipalities Total Inhabitants Trentino side: **371.329**
Municipalities Total Inhabitants Tirol side: **271.761**

Highly annoyed people by traffic correspond to 17,6%: **11.813**
Highly annoyed people in the whole municipalities: **1,8%**

Rail

Buffer dimension (distance from the axis): **51,9m**

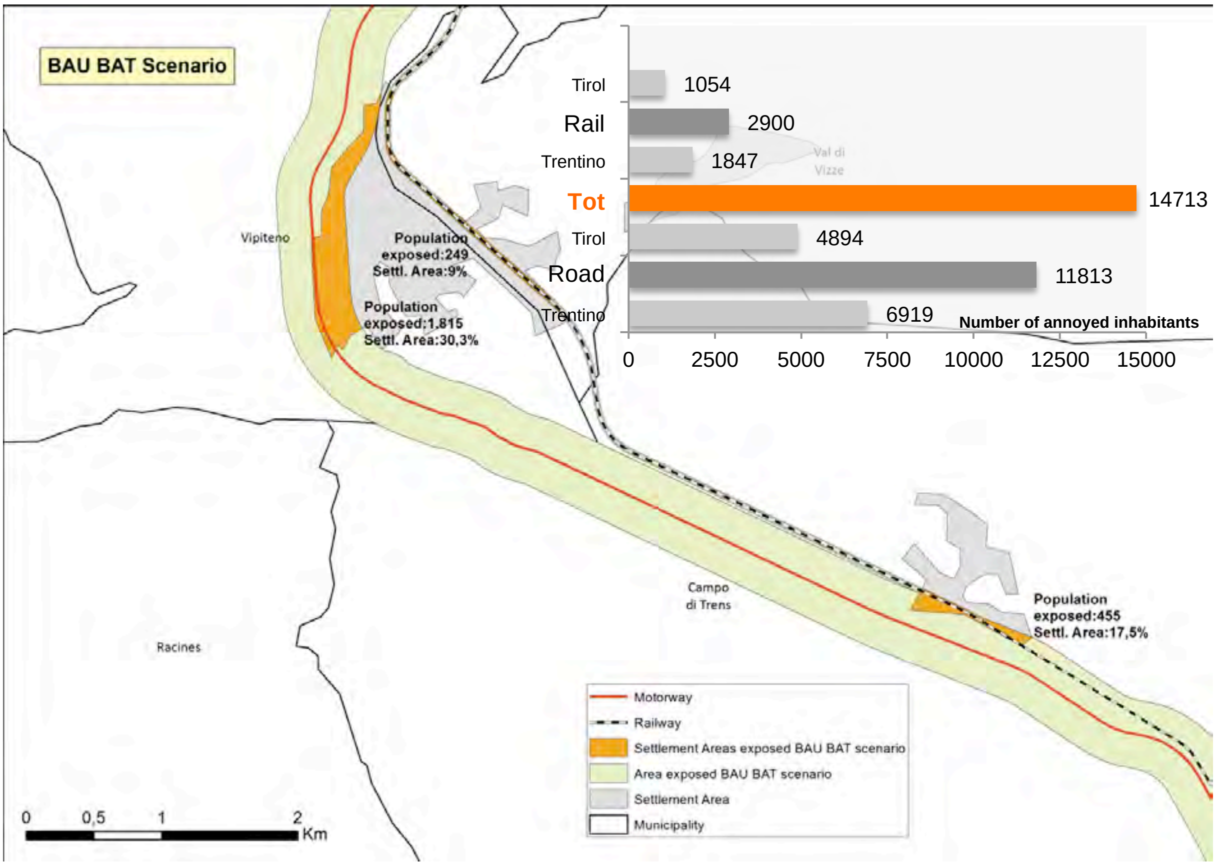
People inside the buffer: **30.528**
Municipalities Total Inhabitants Trentino side: **375.611**
Municipalities Total Inhabitants Tirol side: **251.922**

Highly annoyed people by traffic correspond to 9,5%: **2900**
Highly annoyed people in the whole municipalities: **0,46%**

Rail+Road

People inside the buffer: **97.649**
Municipalities Total Inhabitants*: **1.270.623**

Highly annoyed people by traffic noise: **14.713**
Highly annoyed people in the whole municipalities: **1,15%**



3.4.3 The ACE scenario

Road

Buffer dimension (distance from the axis): **198,8m**

People inside the buffer: **51.042**
Municipalities Total Inhabitants Trentino side: **371.329**
Municipalities Total Inhabitants Tirol side: **271.761**

Highly annoyed people by traffic correspond to 17,6%: **8.983**
Highly annoyed people in the whole municipalities: **1,42%**

Rail

Buffer dimension (distance from the axis): **71,1m**

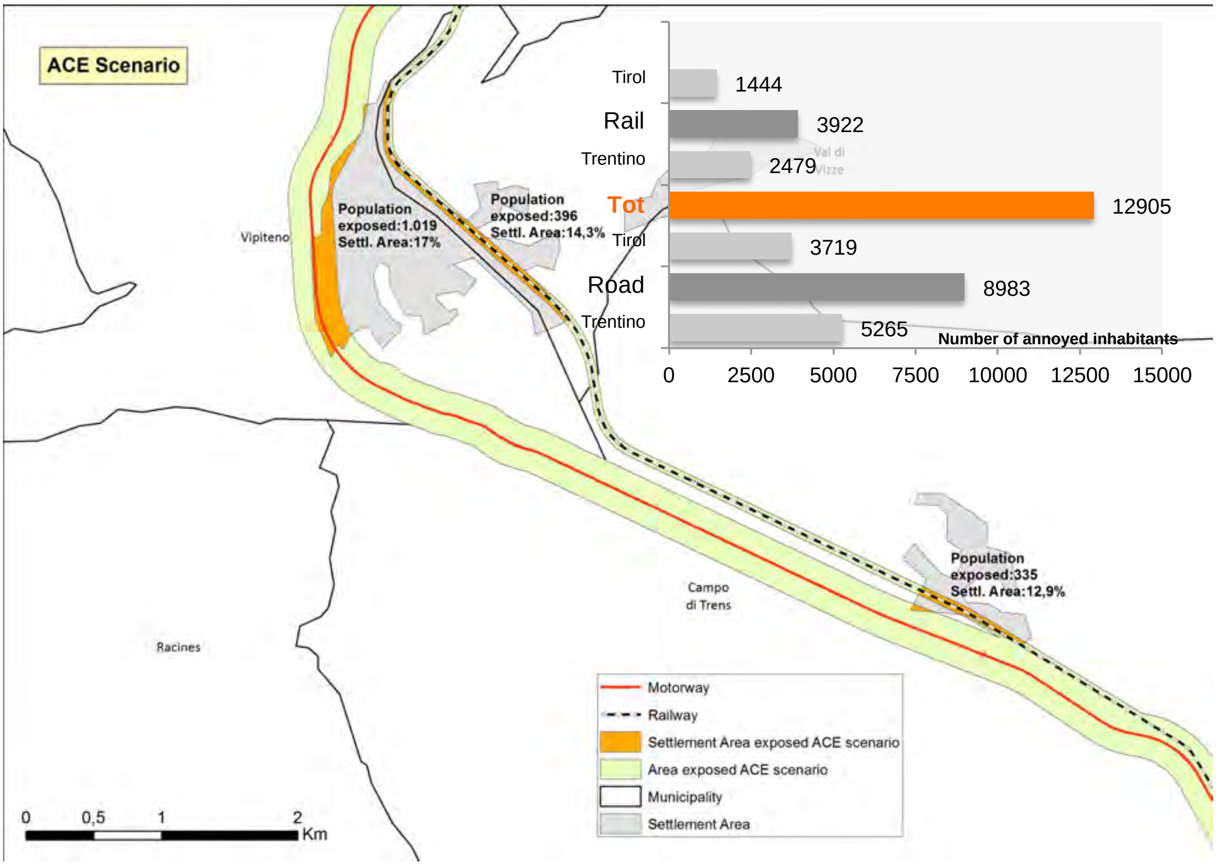
People inside the buffer: **41.285**
Municipalities Total Inhabitants Trentino side: **375.611**
Municipalities Total Inhabitants Tirol side: **251.922**

Highly annoyed people by traffic correspond to 9,5%: **3.922**
Highly annoyed people in the whole municipalities: **0,62%**

Rail+Road

People inside the buffer: **92.327**
Municipalities Total Inhabitants*: **1.270.623**

Highly annoyed people by traffic noise: **12.905**
Highly annoyed people in the whole municipalities: **1,02%**



3.5 The Tarvisio corridor

3.5.1 The NOW scenario

Road

Buffer dimension (distance from the axis): **101,3m**

People inside the buffer: **561**
Municipalities Total Inhabitants Friuli side: **7.669**
Municipalities Total Inhabitants Kärnten: **0**

Highly annoyed people by traffic correspond to 17,6%: **99**
Highly annoyed people in the whole municipalities: **1,29%**

Rail

Buffer dimension (distance from the axis): **17,3m**

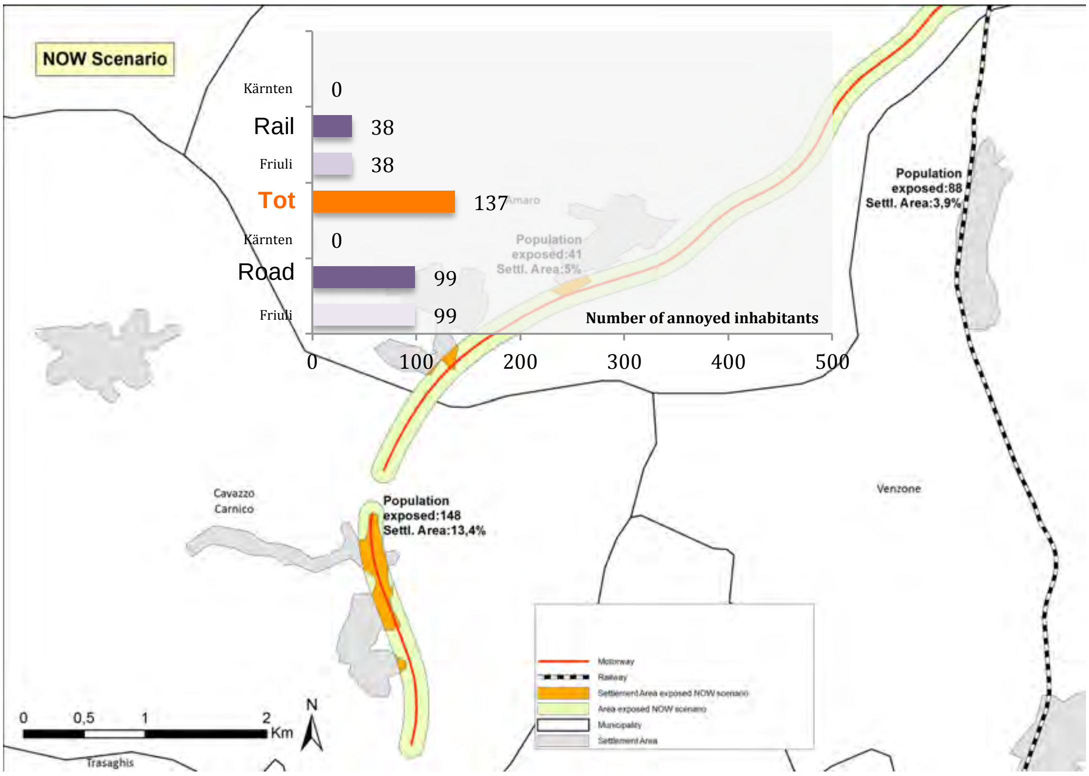
People inside the buffer: **402**
Municipalities Total Inhabitants Friuli side: **20.751**
Municipalities Total Inhabitants Kärnten side: **6.912**

Highly annoyed people by traffic correspond to 9,5%: **38**
Highly annoyed people in the whole municipalities: **0,14%**

Rail+Road

People inside the buffer: **963**
Municipalities Total Inhabitants*: **35.332**

Highly annoyed people by traffic noise: **137**
Highly annoyed people in the whole municipalities: **0,39%**



3.5.2 The BAU/BAT scenario

Road

Buffer dimension (distance from the axis): **121,6m**

People inside the buffer: **662**
Municipalities Total Inhabitants Friuli side: **7.669**
Municipalities Total Inhabitants Kärnten: **0**

Highly annoyed people by traffic correspond to 17,6%: **117**
Highly annoyed people in the whole municipalities: **1,16%**

Rail

Buffer dimension (distance from the axis): **17,3m**

People inside the buffer: **402**
Municipalities Total Inhabitants Friuli side: **20.751**
Municipalities Total Inhabitants Kärnten side: **6.912**

Highly annoyed people by traffic correspond to 9,5%: **38**
Highly annoyed people in the whole municipalities: **0,14%**

Rail+Road

People inside the buffer: **1.064**
Municipalities Total Inhabitants*: **35.332**

Highly annoyed people by traffic noise: **155**
Highly annoyed people in the whole municipalities: **0,41%**

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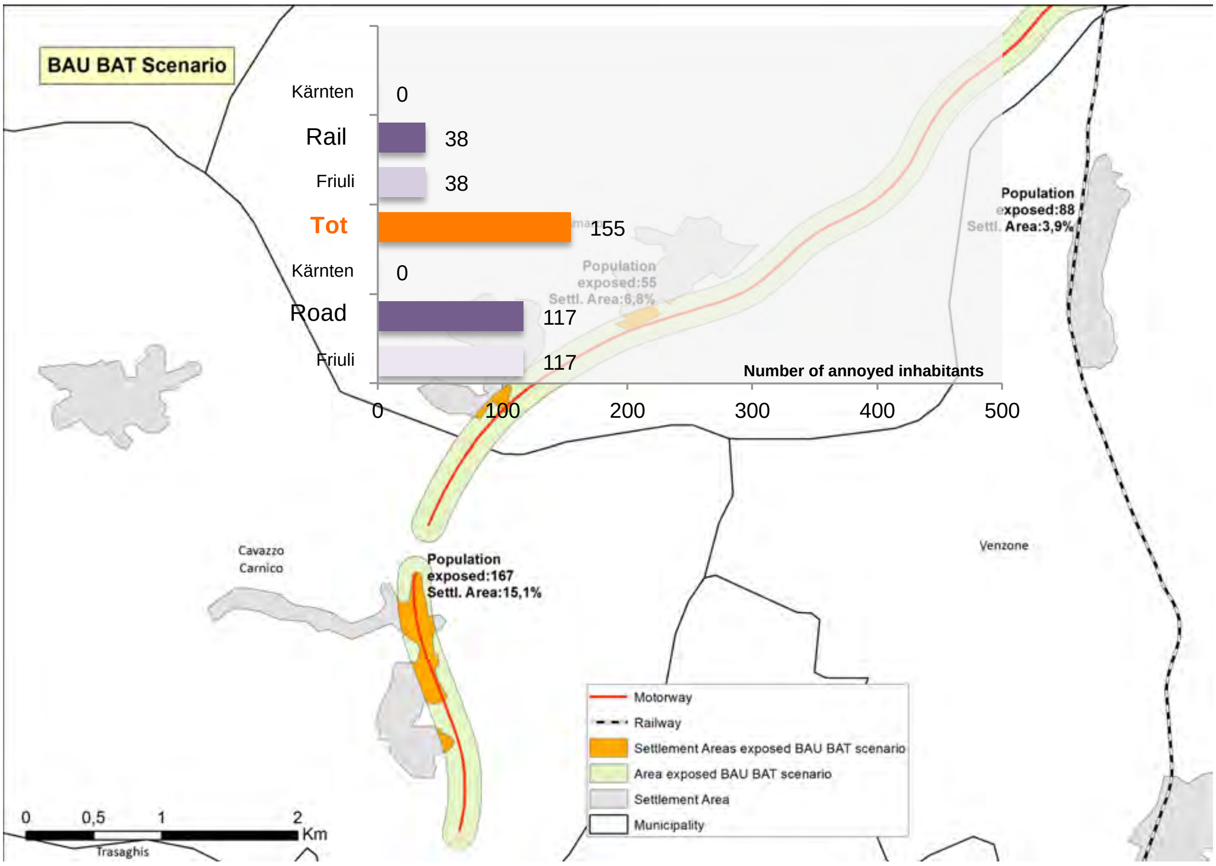


3.5.3 The ACE scenario

Road

Buffer dimension (distance from the axis): **95,9m**

People inside the buffer: **524**
Municipalities Total Inhabitants Friuli side: **7.669**
Municipalities Total Inhabitants Kärnten side: **0**

Highly annoyed people by traffic correspond to 17,6%: **92**
Highly annoyed people in the whole municipalities: **1,2%**

Rail

Buffer dimension (distance from the axis): **33,7m**

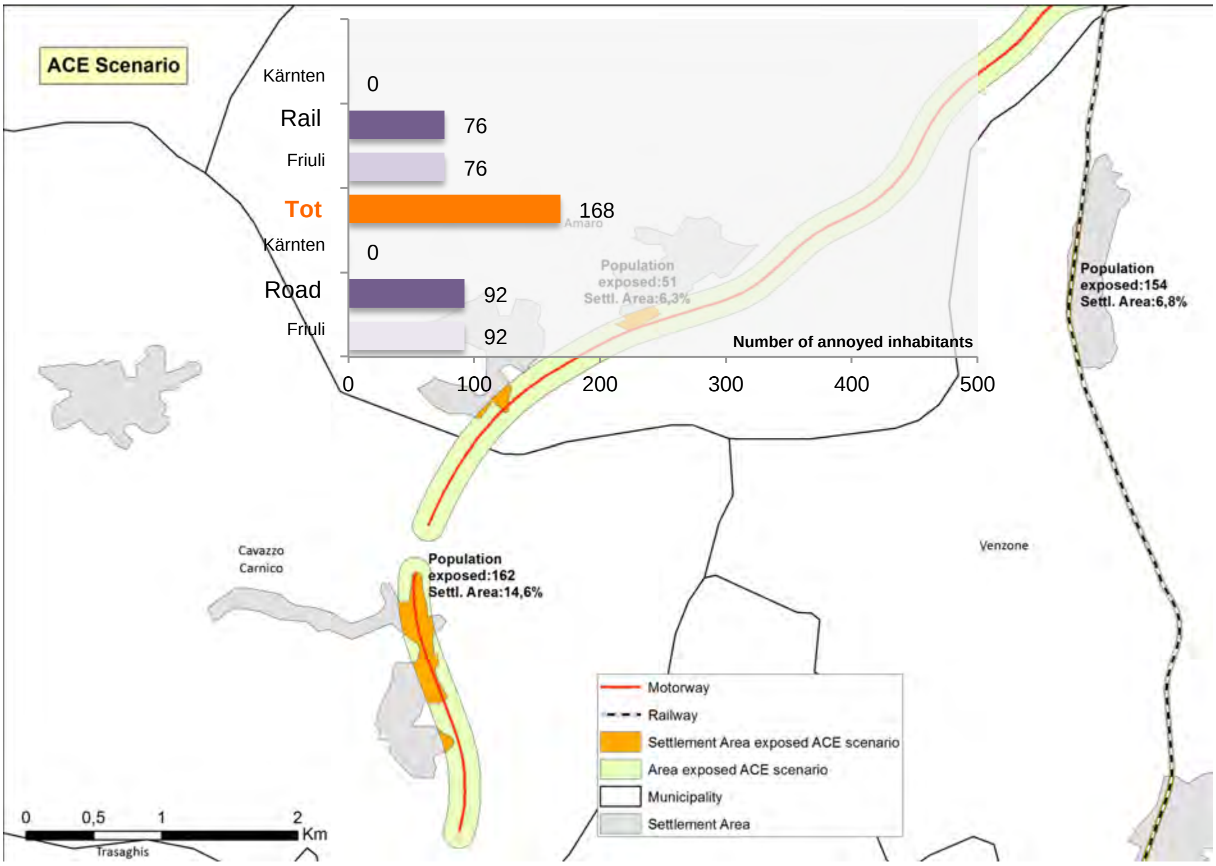
People inside the buffer: **802**
Municipalities Total Inhabitants Friuli side: **20.751**
Municipalities Total Inhabitants Kärnten: **6.912**

Highly annoyed people by traffic correspond to 9,5%: **76**
Highly annoyed people in the whole municipalities: **0,28%**

Rail+Road

People inside the buffer: **1.326**
Municipalities Total Inhabitants*: **35.332**

Highly annoyed people by traffic noise: **168**
Highly annoyed people in the whole municipalities: **0,48%**



* When road and railway pass in the same municipalities, the total inhabitants in the municipalities are countered twice for global state of annoyance (ROAD+RAIL), once for defining inhabitants affected by road noise and once for that affected by railway noise.

Note that for the Mont Blanc case the total inhabitants in the municipalities correspond to that one affected by road traffic only because there isn't a railway crossing the frontier, then there aren't affected inhabitants by railway traffic.

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