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NOISE CONTROL FOR QUALITY OF LIFE

Monitoring and estimating of noise traffic in the transalpine corridors and related effects

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ABSTRACT

iMonitraf! is the name of an Alpine Space Project that lasted from 2009 to 2012. The project studied the effects of road and rail traffic along the Alps and involved the following regions: Rhône-Alpes, Piemonte, Valle d'Aosta, Central Swiss Cantons, Ticino, Tyrol, Trentino Alto Adige and Friuli Venezia Giulia.

About noise, the purpose of the work was to harmonize the measurement methods and to give a common guideline for the population exposure evaluation. The noise impact was evaluated using L_{DEN} and L_{night} parameters, while to evaluate the disturbance on the inhabitants living along the transalpine corridors the Annoyance concept was used. Results of noise measurements and population exposure are the main outputs of the Project. Furthermore, only for the Tarvisio corridor, a pilot study on noise modeling was made. The comparison between the L_{DEN} values and the relative degrees of Annoyance could be used as a method to check the traffic distribution strategies. During the Project, noise levels were consistent with traffic flow data in the measurement points and they haven't nearly changed over the years. The aim of the pilot study was to develop a methodology for noise modeling studies in alpine areas and the relative population exposure.

Keywords: Monitoring, Transalpine, Exposure

1. INTRODUCTION

1.1 The iMonitraf! Project

During the last years the traffic flows across the Alps, including road traffic and railways traffic, have registered an increase that clearly had bad influences on environment and quality of life along the most important transalpine corridors.

To face up to those problems, the involved nations and regions are evaluating and implementing transalpine traffic regulation measures. To improve their power and their effectiveness, those measures have to work synergistically and they have to lead to clearly positive effects on the environment and on the quality of life.

The iMonitraf! Project (http://www.imonitraf.org), carried out from 2009 to June 2012, fits in this topic.

iMonitraf! is the continuation of the previous Monitraf, carried out in the years 2005-2008.

In particular in the new project the indicator set, already found in the first Monitraf, was reviewed to simplify the data collection.

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Certainly one of the most important objectives of iMonitaf! was to create communication and cooperation networks between the different Partners, building a common and shared measures system that takes into account the specificity of the Alpine Regions. Another aim of the iMonitraf! Project was to pay greater attention to the environment and to the impact on the population living along the transalpine corridors. Among the indicators, distinctive of the different topics involving the European transport system, there are basic indicators, like traffic flow data, economic indicators, like toll and fuel prices, environmental indicators, like air quality and noise parameters…

During the Project an important role was played by the dialogue with the local political counterpart to obtain more attention within the national governments and within the Europe.

The implementation of shared measures on the traffic system management implies shared monitoring methodologies in different topics: transit monitoring, costs and tolls monitoring, environmental and quality of life monitoring.

1.2 The iMonitraf! Partners

The iMonitraf! Project concerned the following corridors: Fréjus, Mont-Blanc, Gottard, Brenner and Tarvisio. Both roads and railways were took into account in the studies.

The Regions involved in the Project were: Rhône-Alpes, Piemonte, Valle d'Aosta, Cantoni Svizzeri Centrali, Cantone Ticino, Tirolo, Alto Adige and Friuli Venezia Giulia (Figure 1).

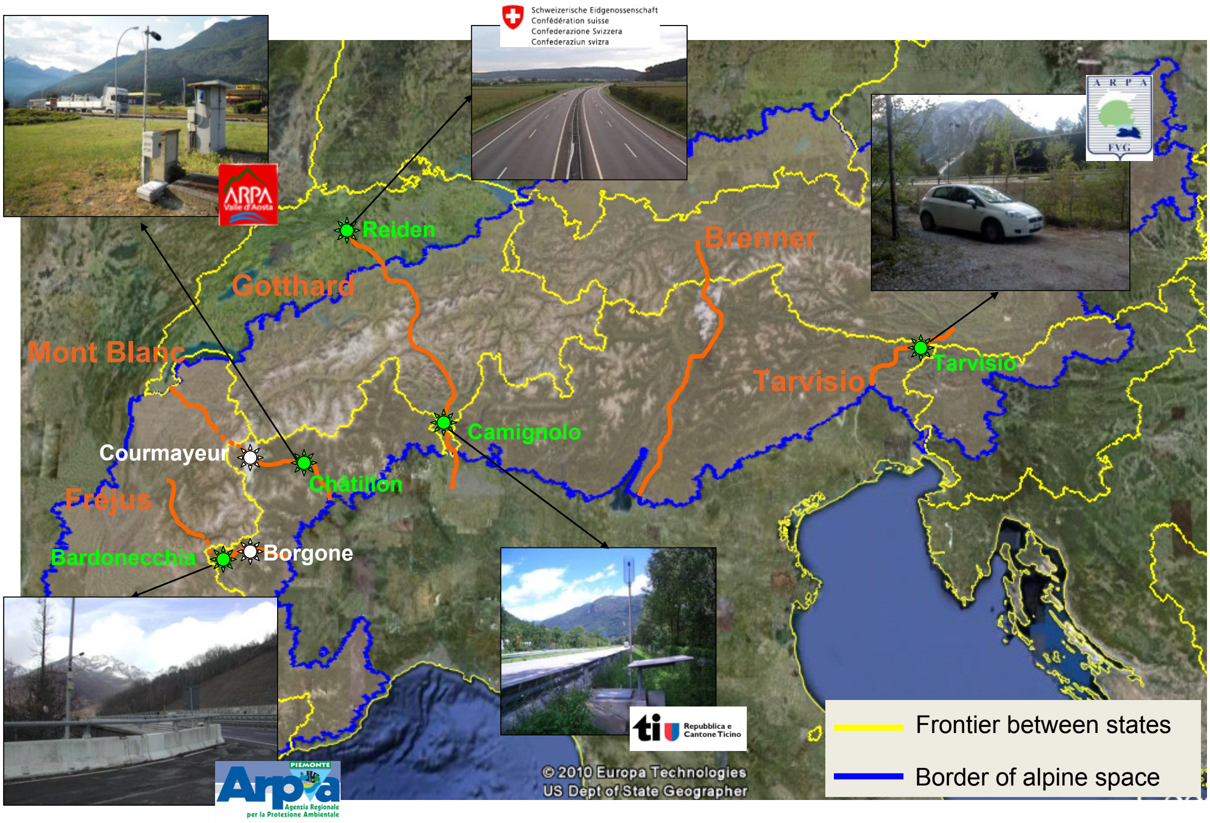

Figure 1 – The Alpine Space and the Partners involved in the noise monitoring campaigns

iMonitraf! was scheduled in six different Work Packages according to the different topics and aims of the Project. Three WPs had organisation and coordination aims: for those units the targets were to create a political network between the Partners, to establish a common monitoring system concerning the identified indicators and to encourage the knowledge and the information exchanges through an harmonised and common reading of the measures to be implemented.

The other Work Packages had a more technical meaning and they operate to evaluate the railways system competitiveness within the Alpine Crossing Exchange (ACE) and to involve other modal shift measures. On the other hand, the Partners involved in these WPs had to suggest and to analyse future traffic scenarios evaluating the impact on the environment and on the population.

On that way it is necessary to develop shared strategies and common actions to deal with the continuous increase of the transalpine traffic, taking into account the sustainable development.

Accordingly to those aspects, the role of the technical Partners, among which the Environmental Agencies of Valle d'Aosta and Friuli Venezia Giulia, was to manage the indicators, to collect the data, to standardize them and to make them comparable. Of course the work of the Environmental Agencies focused on the environmental indicators: air quality and noise.

In this paper only the feature concerning the noise impact of the transalpine corridors is going to be analysed. The analysis involved the current scenario, referred to 2010 and 2011, and some future provided scenarios, referred to the 2020.

The evaluations were made with the aim to develop shared monitoring methodologies and to quantify the disturbance on the population [1].

2. NOISE MONITORING

The first step of the analysis consisted in the collection of the data describing the present situation through measurements campaigns.

The noise data collection started in the previous Monitraf Project, but the outcomes weren't so noticeable because of a weak engagement of technical partners. In the continuation of the activity within iMonitraf!, thanks to the direct engagement of a greater number of technical Partners and Environmental Agencies, it would be possible to arrange specific noise monitoring campaigns.

The monitoring campaigns were mostly focused on the noise due to road traffic and the data showed in the following 2.1 and 2.2 points are related only to roads. Concerning railways, the noise monitoring campaigns were used as the starting points for the development of a common modelling approach.

Considering that the monitoring points are situated along different corridors and in different nationalities, to standardise the geometrical and acoustical characteristic of each monitoring point and to conform each methodology and data processing, it was be necessary to draw up shared monitoring guidelines.

2.1 Common monitoring guidelines

The Project Partners directly engaged in the noise monitoring campaigns were the Department of the Territory of the Republic and Canton of Ticino and the Italian Environmental Agencies, ARPA Valle d'Aosta, ARPA Friuli Venezia Giulia and ARPA Piemonte.

During the Project the drawing up of detailed and specific guidelines was committed to an external expert team, that took into account the previous monitoring experience of the Partners involved and that gives some requirements to respect to have a substantial number of data to process a statistical analysis and to make the results as comparable as possible [2].

The guidelines pointed out a methodology for the noise monitoring campaigns concerning road traffic in an international context.

To have a substantial number of data and at the same time to not engage too much the Partners in the data collections activities, the campaigns were performed to make at least one weekly measurement per season. In addiction to noise levels, each campaign had to provide traffic flow data, to allow to standardise the results, and meteorological data, to validate the outputs.

All noise levels were standardised at a 10 meters distance from the road axis and at a 4 meters height.

According with the European Directive 2002/49/EC, the L_{DEN} indicator was considered to assess the mean noise levels:

$$L_{DEN} = 10\ Log\left(\frac{12}{24}\cdot 10^{\frac{L_{Day}}{10}} + \frac{4}{24}\cdot 10^{\frac{L_{Evening}+5}{10}} + \frac{8}{24}\cdot 10^{\frac{L_{Night}+10}{10}}\right) \quad (1)$$

Where:

- L_{Day}: is determined over the day period: from 7:00 to 19:00;
- $L_{Evening}$: is determined over the evening period: from 19:00 to 23:00;
- L_{Night}: is determined over the night period: from 23:00 to 7:00.

2.2 Monitoring points and results

The monitoring points were chosen in line with the previous Monitraf Project and they were placed as close as possible to the main road, identifying a corridor section as homogeneous as possible, referring to vehicles number, running speed, road slope and surface, etc…

The location of the monitoring points are shown in the previous Figure 1.

In Figure 2 the noise monitoring results are reported. The data, for the years 2010 and 2011, are expressed in terms of L_{DEN} parameter as the yearly average value.

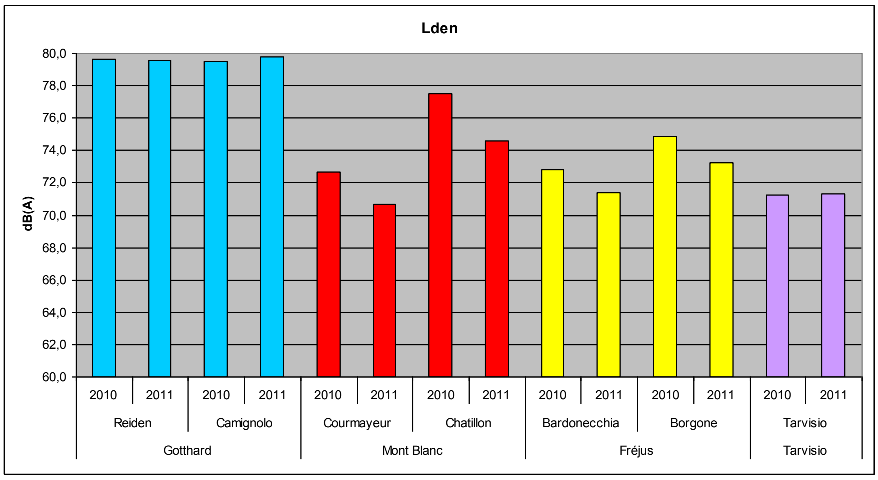

Figure 2 – Noise levels resulting from the monitoring campaigns along the transalpine corridors

Some remarks to highlight about the results are:

- noise levels are consistent with traffic flow data in the measurement points. Some deviations may be caused by parameters excluded by normalization, like vehicles speed, road surface, etc…
- a flaw of the analysis is that measurement campaigns could only give a punctual value of L_{DEN}
- unfortunately there is a lack in the noise monitoring data concerning the Brenner corridor.

3. NOISE EXPOSURE: THE ANNOYANCE

The quality of life is a topic increasingly present in the European Directives concerning the environment and the inhabitants that live in that environment.

In this direction the European Directive 2002/49/EC on the assessment, management and reduction of environmental noise, has the purpose to preserve areas with good sound quality and to reduce noise impact on population.

In the World Health Organization final report, "Burden of disease from environmental noise - Quantification of healthy life years lost in Europe, 2011" [3], 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 both to the damaging effect of noise and other environmental factor.

One of the objective of the "Health impact" indicator indentified within iMonitraf! is to estimate the effect of noise traffic on inhabitants living close to the alpine corridors.

The chosen parameter for this noise impact assessment is the Annoyance, because it expresses the amount of stress, or dissatisfaction, people experience when exposed to sounds from traffic source. The Annoyance is used tor defining a threshold, inside which the disturb exceeds a limit expressed in function of a critical value of L_{DEN}, on the basis of the WHO indications.

3.1 Evaluation of Annoyance: the methodology

The Annoyance should be expressed as percentage of Highly Annoyed People (%HA).

Within the iMonitraf! Project a methodology for evaluating potentially annoyed people, starting from the noise measured values, was developed. Taking into account the limitations of the monitoring campaigns and considering that one of the aims of the Project was to evaluate the transalpine traffic future scenarios, a further assessment, based on a simplified forecast model, was made.

Then, a critical value of L_{DEN} was identified to be $L_{DEN,crit}$ = 66 dB(A), that was obtained through the WHO final report recommendations for the different periods of the day: $L_{Day,crit}$ = 65 dB(A), $L_{Evening,crit}$ = 65 dB(A), $L_{Night,crit}$ = 55 dB(A). The chosen L_{DEN} value matches to a value of Annoyance, defined as critical threshold, equal to %HA =17.6 for roads and equal to %HA = 9.5% for railways: a first remark is that the railway noise is less disturbing than the road one (Figure 3) [4-5].

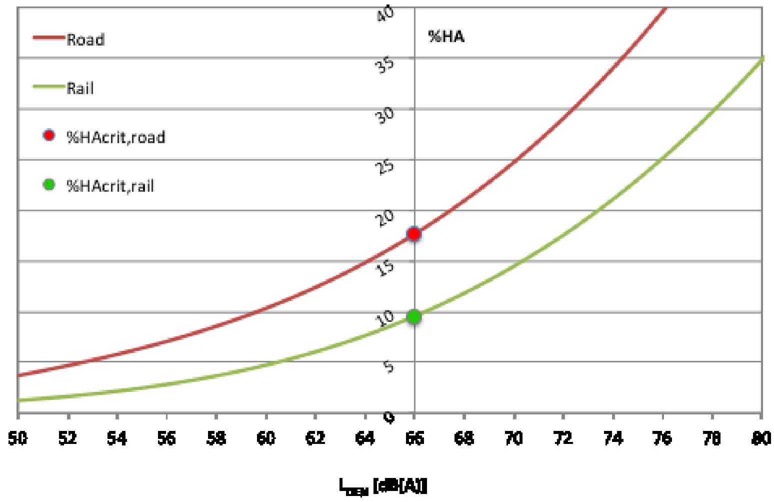

Figure 3 – Relations between %HA and LDEN, for road and railway traffic and indication of the threshold values

Referring to the L_{DEN} threshold value 66 dB(A) and using a shared WebGIS application, it was possible to define a buffer along each corridor, taking into account both roads and railways: to have an assessment of the highly annoyed inhabitants, the annoyance percentages, 17.6 for roads and 9.6 for railways, were applied to the population living inside the areas covered by the buffer.

It is to underline that the WebGis application, the cartography and the basic data used within the analysis, provided by the Corinne Land Cover data set, were the same for all the corridors, that leaded to homogeneous and comparable results.

3.2 Evaluation of Annoyance: the results

Using the described methodology it would be possible to assess the annoyed population. In the study the datum is referred to the municipalities crossed by the buffer provided by the analysis: the area covered by the buffer allowed to identify the population potentially exposed to the transalpine traffic noise.

The current scenario data, based on the results of the monitoring campaigns, gives a quite precise indication of the situation along the transalpine corridors.

The Work Package 6 of the iMonitraf! Project provides some future scenarios referred to the 2020, on the basis of the more common assumption of the traffic flow trends. Among them, to carry out a noise trend analysis, only the BAU (Business As Usual) and the ACE (Alpine Cross Exchange) scenarios were considered. The BAU scenario is performed considering a growth of the transits constant during the years, instead the ACE scenario takes into account the crossing exchange measure as it already happens in Switzerland.

On the contrary, the BAT (Best Available Technology) scenario wasn't considered, because the best technologies implementation involves only partly the noise pollution topic.

In addiction, only the changes on heavy vehicles for roads and train freight for railways along the corridors were took into account as provided variations: both light vehicles and passengers trains were considered unchanged.

The results provided in Table 1 include the disturbance generated by both road and rail traffic on the population living inside the buffer areas. The results, in terms of percentages, are referred to the total inhabitants of the municipalities crossed by the buffers.

Table 1 – Percentage of highly annoyed population (%HA) in the current and in the forecasted scenarios

Corridor	Side of the pass	2010		2020	
		%HA per municipality	%HA per municipality per corridor	%HA per municipality per corridor (BAU)	%HA per municipality per corridor (ACE)
Gotthard	Canton Ticino	1.15%	1.00%	1.05%	1.03%
	Zentralschweiz	0.84%			
Mont Blanc	Valle d'Aosta	0.47%	0.41%	0.49%	0.51%
	Rhône-Alpes	0.38%			
Fréjus	Piemonte	0.47%	0.37%	0.40%	0.43%
	Rhône-Alpes	0.35%			
Brenner	Trentino	1.04%	1.01%	1.33%	0.92%
	Tirol	0.97%			
Tarvisio	Friuli	0.48%	0.39%	0.42%	0.48%
	Kärnten	0.00%			

The data show the variation in terms of Annoyance (%HA) of the disturbance on the inhabitants along the involved corridors for the provided scenarios, in comparison to the current situation. It would seem that few inhabitants, compared with the total municipalities populations, are annoyed by the transalpine traffic noise. Furthermore it doesn't seem that the provided 2020 noticeable changes in traffic flows could affect so much the percentage of annoyed population.

4. PILOT STUDY

Within the iMonitraf! Project, only for the Tarvisio corridor, a pilot study on noise modeling was made. The Pilot study consists in the application of mathematical models to calculate the noise emissions generated from the roads and rails, the propagation of noise and the final impact on the inhabitants.

For this purpose it has been created a three-dimensional scenario containing the geometry of the whole Tarvisio corridor in the proximity of the noise sources. Afterwards, acquired the traffic data of all the infrastructures, the simulation has been run to define the noise level in the whole study area. Finally, using the demographic data of the resident population, it has been possible to estimate how many people are affected by each noise class, like defined in the 2002/49/CE Directive [6].

The Pilot study has two main goals: to model, through the noise propagation software, the existing situation of the alpine region of Friuli Venezia Giulia analyzing the state of the environment and the impact of noise on the inhabitants, and, then, to conduct the same type of analysis on some possible future scenarios. In the iMonitraf! Project, indeed, many propositions to modify the traffic fluxes and compositions have been advanced, such as for instance night driving ban for heavy duty vehicles, shifting the load from road to rail or using different toll fees for different "EURO" class vehicles.

An additional general view is to develop a methodology that permits, having the required information about the geometry, infrastructure and inhabitants of any alpine area, to set up simulations and noise pollution studies with low uncertainty and high accuracy.

4.1 Data source and development of the digital environment

The scenario object of this study has been set up using the commercial software for noise propagation CadnaA [7], used in the Udine department of the Friuli Venezia Giulia Environmental Agency. To support the analysis of the results and of the components of the scenario, the software packages ESRI ArcGIS and Google Earth has been used.

The data of each part of the built model have been obtained from different sources and have been provided by the national, regional and municipal offices. The parts that constitute the model created to study the impact of the noise pollution on the population are reported in Table 2.

Table 2 - Parts constituting the model

Model Part	**Data Source**
Buildings	Technical Regional map – **Scale 1:5000**
Ground Absorption	CORINE Land Cover
Noise Barriers	Technical Regional map – **Scale 1:5000**
Rails	Technical Regional map – **Scale 1:5000**
Roads	Technical Regional map, regional road graph
Terrain	Technical Regional map – **Scale 1:5000 with height precision of 5 m**
Study Area	GIS Elaborations on Technical Regional map
Inhabitants	Municipalities
Traffic fluxes: roads	Autostrade S.p.a.
Traffic fluxes: rails	Ferrovie dello Stato Italiane Group

Since the iMonitraf! Project studied the international traffic, in agreement with all the Project Partners, it was decided to consider only the highways as noise sources and to neglect the local roads.

For the buildings, Insiel S.p.a. provided the information about the geometry and the position of all the buildings in the analyzed area.

After having set up the geometry, the street name, the civic number and city name of each building were identified and, finally, for each of them the inhabitants data obtained from each municipality were used. The total number of buildings and inhabitants expected in each municipality is shown in the following Table 3:

Table 3 - Number of inhabitants and buildings for each municipality in the Tarvisio corridor

Municipality	Buildings	Inhabitants in the scenario	Total number of inhabitants in municipality
Dogna	43	22	200
Moggio Udinese	71	1.823	1.842
Resiutta	87	314	320
Trasaghis	114	24	2.337
Cavazzo Carnico	158	160	1.102
Amaro	228	847	850
Chiusaforte	268	710	710
Malborghetto Valbruna	667	967	967
Venzone	824	2.213	2.223
Pontebba	846	1.522	1.535
Tarvisio	1.570	2.062	4.683
TOTAL	4.876	10.664	16.769

4.2 Calibration procedure and results of the simulation

In order to calibrate the model, many short and long term measurements were conducted.

The calibration procedure was done in accordance to UNI 11143-2 that states that the simulated level must not differ for more than 0.5 dB from the measured one. [8]

After the calibration phase, the long term measurements were used to verify the results. UNI 11143-2 states that the maximum acceptable difference between the simulated levels and the measured ones in this phase of the work is 1.5 dB.

In the two years of the project a total of twenty measurements were carried out, six of those were short term noise monitoring measurements conducted with the traffic counter.

The measurement uncertainty as defined by UNI/TR 11326/2009 [9] for all the noise campaigns is 0.41 dB. It is extremely important to note that the effects of measurement uncertainty were in the end not considered in the calibration process and that the raw data were used for it.

For the short term measurements, during from 1 to 3 hours, traffic counts (number of light and heavy duty vehicles of each lane and mean speed of each defined vehicle class) were performed with the purpose to calibrate the model.

Before performing the simulations, traffic flows of the two sound sources related to the road and railway were defined.

For the highway, the traffic data have been obtained by the infrastructure administrators that offer the flow through four different segments related to the different entrances/exits for the entire corridor.

The same procedure was obtained for the rail traffic. In this case *Trenitalia* and *Rete Ferroviaria Italiana S.p.A.* provided the train traffic data for all the subclasses and for all the days of the week in the three reference periods (*day*, *evening*, *night*).

For the railways model the uncertainty of the data was higher as in the road situation, in consideration to the difficulty of data retrieval and to the knowledge of the trains average speed in the different segments. Furthermore there weren't calibration measurements for the model. In this case it was considered that the majority of the railway on the Tarvisio corridor run in galleries and the visible parts are relative to the four corresponding railway stations located along the line (Gemona, Carnia, Pontebba and Tarvisio).

The calculation was made on a 10x10 meters grid and at a 4 meter height over the ground, considering both road and railway noise sources.

Obtaining the results for the noise map required about 48 hours.

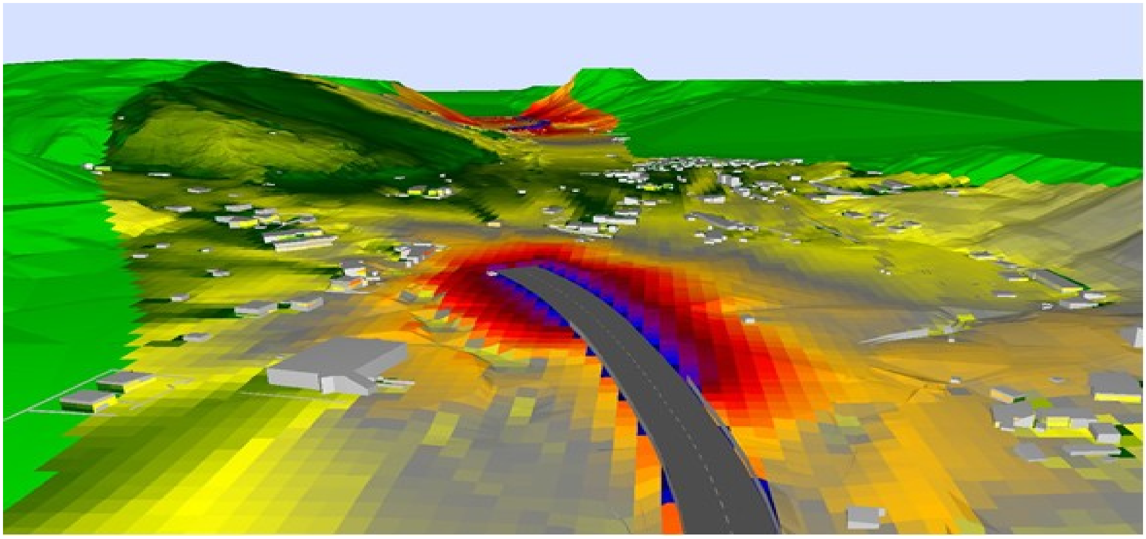

Figure 4 - 3D representation of the noise levels calculated in the scenario, example of a zone just outside Tarvisio city (space grid 10 meters)

Another simulation was run to calculate the façade noise for each building of the scenario. With this operation it was possible to calculate, using the inhabitants data provided by the various municipalities, the number of inhabitants exposed to the noise levels. The calculus of the noise level in the correspondence of the buildings façades took about 10 hours.

In order to complete the analysis, noise classes had to be defined: the classes defined in 2002/49/CE Environmental Noise Directive were chosen considering the total inhabitants for noise class and the buildings with and without the most silent façade. Since the total population isn't very high, the numbers aren't rounded to the hundreds digits.

The models used for the calculations were NMPB-Routes-96, for roads, and Schall03, for railways.

Performing the object-scan on the building façade, the following number of inhabitants have been found for the 5 dB noise classes defined by 2002/49/CE.

Table 4 - Total number of inhabitants that live in the noise classes defined by 2002/49/CE

Interval [dB(A)]		Value					Percentage			
min	max	L_{day}	$L_{evening}$	L_{night}	L_{DEN}		L_{day}	$L_{evening}$	L_{night}	L_{DEN}
-	50	3.298	4.358	3.586	2.444		63%	84%	69%	47%
50	55	951	627	1042	795		18%	12%	20%	15%
55	60	651	189	321	1.171		13%	4%	6%	23%
60	65	187	27	93	464		4%	1%	2%	9%
65	70	107	0	142	167		2%	0%	3%	3%
70	75	7	0	17	124		0%	0%	0%	2%
75	-	0	0	0	36		0%	0%	0%	1%

Furthermore, concerning the Annoyance assessment related to the L_{DEN} threshold value considered, in the actual 2012 situation there are 249 inhabitants (1.5% of total population) living in areas where L_{DEN} is equal or higher than 66 dB(A). The number of inhabitants affected by L_{Night} higher than 55 dB(A) is 573, 3.4 % of the total population.

The advantage in working with simulation models is the chance to make estimates of the noise levels by changing some parameters, such as the traffic flows. In the iMonitraf! Project, for example, it was possible to analyse the scenarios provided by the WP6 for the 2020. Also within the Pilot study only the BAU and the ACE scenarios were performed and in all the scenarios only heavy duty vehicles and freight trains numbers change.

These variations cause a different number of total vehicles and a different composition of vehicles on the highways, for each scenario it was therefore necessary to calculate the new total traffic values for all the segments and the new traffic profile during the hours of the day.

After the assessment of the present situation, other simulations were conducted to predict the variation of the noise levels in the future 2020 WP6 scenarios: for both scenarios BAU and ACE higher noise levels were found and the number of inhabitants affected by noise increased.

For the BAU scenario, there are 254 inhabitants (1.5%) living in areas where L_{DEN} is higher than 66 dB(A) and 640 (3.6%) affected by noise higher than 55 dB(A) during night. The variation expected from the actual situation is therefore minimal.

For the ACE scenario, the results show 368 (2.2%) inhabitants living in areas where L_{DEN} is higher than the threshold value and 806 (4.8%) affected by noise higher than the threshold value during night. Due to the increase of train traffic and to a higher fraction of trains travelling during the night, the results for this scenario are much worse than in the actual situation and in the BAU scenario.

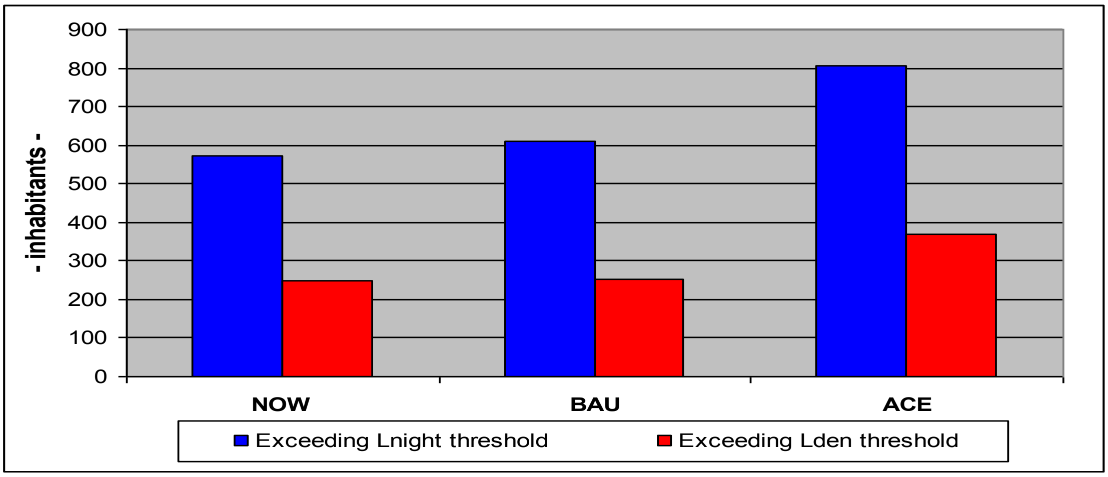

Figure 5: Number of inhabitants living in areas where the noise threshold is exceeded for the present situation

and the future scenarios

From the analysis of the scenarios it is possible to conclude that the situation of noise pollution on the Tarvisio corridor is expected to get worse in the next years. Therefore, it would be advisable to monitor the corridor in the future, in order to identify critical situations and to be able to take in a short time corrective actions, e.g. installing new noise barriers.

5. CONCLUSIONS AND REMARKS

The iMonitraf! Project, in addition to the concrete results, had given to the Partners, and in particular to the Environmental Agencies, the possibility to compare their experiences and to collaborate in different working domains: analysis and organisation activities, monitoring campaigns… According to this aspect, some difficulties emerged because of the differences between the Partners. For examples some of the problems were found in collecting and in analysing the data. Some of them were solved with the implementation of specific guidelines and with the development of a shared simplified methodology in evaluating different noise impact scenarios.

In particular, the chosen methodology based on the concept of the Annoyance allowed to give an indication on the population disturbance, according to different traffic flow scenarios. To achieve the analysis, general relations linking the L_{DEN} levels with the disturbance were used. However it would be more significant to use specific relationships obtained directly on the studied areas. The sensibility is a particular and distinguishing feature of each community: it would be opportune to take into account individual response to noise exposure through focused questionnaires on the concerned population.

Interesting results were given by the comparison between the data of the general study and the data provided by the Pilot study, supplying a deep analysis of the subject. Among them it was pointed out that the fist raw method applied on all the corridor generally underestimates the annoyed population, even if, the trend over the years is well described.

Further insights could be given by the usage of the investigated methodologies to other contexts and to extend the Annoyance analysis to the night period involving the L_{Night} parameter.

After the conclusion of iMonitraf! the Partners are staying in touch to continue sharing the data and the experiences: one of the activity in progress is for example the updating of the WebGIS developed within the Project.

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