Invited Paper

inter.noise 2010
noise and sustainability
13-16 June 2010 . Lisbon . Portugal
www.internoise2010.org

Living with high noise levels, is it sustainable?

Cecília Rocha[1], Álvaro Costa[1], António Carvalho[2]

Affiliation: {Laboratory of Transports, Laboratory of Transports, Laboratory of Acoustics, Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal}
e-mail: {carocha@fe.up.pt; afcosta@fe.up.pt, carvalho@fe.up.pt}

Abstract
This paper presents some final results of the economical evaluation of road traffic noise in Portuguese cities regarding, in particular, the costs and benefits of introducing noise mitigation measures for people living in urban areas.
Considering the initial externalities in two municipalities and the mitigation measures introduced were computed the final externalities. The difference between these two situations (*before* and *after* mitigation measures) allowed the estimate of the benefits derived from the noise reduction. The comparison between the cost and the benefit of those actions characterized the advantage/disadvantage of the investment.
The prospective analysis of noise externalities for Portugal and the referring economical value according to the three estimates of project HEATCO will allow commenting on the sustainability of these excessive noise levels.

Keywords: noise, externalities, annoyance, sustainability, mitigation.

1 Introduction

At the moment, almost all municipalities are revising their Municipal Master Plans (MMP). The legal changes concerning Noise [1], Territorial Management Instruments [2] and Strategic Environmental Assessment [3] showed the increasing relevance of environmental issues and induced severe adjustments on the programmed work mostly due to the implications of this inconsiderateness.
In addition, one could assist to an increasing concern regarding a sustainable development of the territory, which aims to ensure the preservation of the habitat without compromising the future. In this context and according to Agenda 21, the development strategies of each country, region or area "*should build upon and harmonize the various sectoral economic, social, and environmental policies and plans …*".

Considering noise as one of the key-indicators on the population well-fare it is important to quantify its influence over the territory, mostly in urban areas, and the related effects on the inhabitants living in nearby zones.
Following this line of research were estimated the costs of noise externalities in two situations: one before the implementation on noise mitigation measures and one after. The difference between those two situations in terms of annoyed population and the cost of annoyance (externalities) will determine the sustainability of living with high noise levels.

2 Legal Framework

Only in 1987 the first Portuguese Noise Code (RGR_{1987}) [4] and the Environmental Act [5] were approved. Until then, the Portuguese Constitution [6] was the only statutory document where *environment and welfare* was generically mentioned. Concerns about welfare, quality of life, environmental rights, nature and environmental protection and natural resources protection are stated on articles 9, 66 and 81 which also refer the National Authorities responsibilities.
Since then, was approved the second Noise Code [7] (RLPS) with the same scope of application but with a new acoustical parameter L_{Aeq}, later the Decree-Law n. 146/2006 [8], transposing the European Directive 2002/49/CE, 25th June into the Portuguese legislation, which changed once more the acoustical reference parameter (from L_{Aeq} to L_{den}), introduced three reference periods: day (7 h – 20 h), evening (20 h – 23 h) and night (23 h – 7 h) and also strategic noise mapping, action plans and the obligation for public information and participation. Finally, in January 2007, the third Noise Code [1] was approved (RGR_{2007}), harmonizing acoustical parameters, reference periods and noise limits as indicated on Table 1.

Table 1: *Maximum Noise limits* and *Form of occupancy* for Mixed and Sensitive zones [1]

Form of Occupancy	**Full day period (0 h – 24 h)**	**Nighttime period (23 h – 7 h)**
Mixed Zone	L_{den} = 65 dB(A)	L_n = 55 dB(A)
Sensitive Zone	L_{den} = 55 dB(A)	L_n = 45 dB(A)
Sensitive Zone close to an existent MTI	L_{den} = 65 dB(A)	L_n = 55 dB(A)
Sensitive Zone close to a MTI during design stage *(not for airports)*	L_{den} = 60 dB(A)	L_n = 50 dB(A)
Sensitive Zone close to a major airport during design stage	L_{den} = 65 dB(A)	L_n = 55 dB(A)
Sensitive Receivers on non classified zones	L_{den} = 63 dB(A)	L_n = 53 dB(A)

MTI - major transportation infra-structure

With the RGR_{2007}, municipalities were advised to produce noise maps (L_{den} and L_n, at 4 m height) as a supportive planning tool for the elaboration, alteration and revision of Municipal Master Plans (MMP). It is stated that MMP should guarantee environmental noise quality, promote reasonable distribution of activities and noise sources and define adequate noise classification areas (sensitive and mixed zones).
With this purpose the RGR_{2007} forbid the *licensing or authorizing new dwellings, as well as new schools, hospitals or similar social equipments and leisure spaces*, until the environmental noise levels are accomplished.
The exception to this rule refers to new housing in "*consolidated urban areas*" with approved Municipal Noise Reduction Plan (MNRP) or where environmental noise limits are not exceeded by more than 5 dB(A). This new dwellings ought to have an improved façade sound insulation by 3 dB(A) when compared to others buildings in regular situation.

3 General methodology

The methodology followed to evaluate the cost of noise externalities involved the development of several previous actions in order to obtain the needed data, regarding the *percentage of population exposed* to different noise levels and the costs related to each *class of annoyance and magnitude of the related health effects*.
The economical valuation of noise externalities and the estimate of the number of persons severely annoyed by traffic noise followed the principles stated in the European project HEATCO, in which are considered the subsequent steps:

- **Step 1**: quantification of the *number of persons exposed* to certain noise levels for the *Do-nothing* situation;
- **Step 2**: quantification of the *number of persons exposed* to certain noise levels for the *Do-something* situation;
- **Step 3**: preparation of *cost factors*, updating them on the basis of country GDP per capita growth, for the year of interest;
- **Step 4**: determination of *impact on the population*, regarding noise annoyance (multiplication of the percentage of people highly annoyed by the population exposed to each noise level);
- **Step 5**: determination of the *cost of road noise externalities* by multiplying the updated cost factors by the number of people exposed to each noise level, for both the *Do-nothing* Situation as to the *Do-something* Situation;
- **Step 6**: final result of *impact on the population* by subtracting the number of people highly annoyed for *Do-nothing* and *Do-something* situations;
- **Step 7**: the final result of the *cost of road noise externalities* is calculated subtracting the cost for the *Do-nothing* and *Do-something* situations.

For the economic evaluation of noise externalities in this context, the road traffic noise cost factors listed in HEATCO project for Portugal were applied for the three suggested estimate methodologies "***New Approach***", "***Central Values***" and "***High Values***", in €$_{PPP}$[1] , per person and per year, for the population exposed to road traffic noise previously calculated [9] [10] [11]. These methods are based on two types of public goods valuation techniques (like noise): *Revealed Preference* (RP) and *Stated Preference* (SP) techniques, which use individuals´ *willingness-to-pay* (WTP) to estimate their economic value:

- "*New approach*" (health and annoyance costs based on exposure-response functions);
- "*Central values*" (health-related costs and WTP for reducing annoyance based on stated preference studies);
- "*High Values*" (health-related costs and WTP for reducing annoyance based on hedonic pricing studies).

Since the cost factors listed on the project HEATCO have as base year 2002 and it is recommended to update these cost factors for the year of interest they were updated for the

[1] PPP – Purchasing Power Parity, indicator of price level differences across countries derived from the comparison between the prices of a "*basket of goods*" in different countries. This indicator eliminate the effect of price level differences and allows the conversion of national accounts aggregates of different countries into a comparable aggregates based on a "common currency" named *Purchasing Power Standard* (PPS). [21]

year 2007, based on the Gross Domestic Product (GDP) evolution between 2002 and 2007. These new updated factors, associated with the three estimates indicated in HEATCO, were calculated considering the *growth rates of GDP*, using the expenditure approach, whose reference unit was PPS (*Purchasing Power Standard*), whose results are indicated in Table 2.
Additionally, it is important to know the number of people exposed to noise (in this case, road traffic noise) who are highly annoyed must be provided together with the estimation of the costs of the noise externalities. To determine the number of persons highly annoyed, the HEATCO project recommends the consideration of dose-response relationships defined by the European Commission, Working Group WG2 – dose/response [12] for transportation noise (Table 2).

Table 2: *Cost factors* for road traffic noise exposure, *updated to 2007* (€$_{2007\ PPP}$, per year and per person exposed)

L_{den}	Portugal				L_{den}	Portugal				L_{den}	Portugal			
dB(A)	%HA	N.A.	V.C.	V.E.	dB(A)	%HA	N.A.	V.C.	V.E.	dB(A)	%HA	N.A.	V.C.	V.E.
≥43	0.4	**4**			≥56	5.6	**14**	44	102	≥69	18.2	**28**	142	323
≥44	0.8	**5**			≥57	6.2	**14**	52	119	≥70	19.8	**29**	149	340
≥45	1.1	**5**			≥58	6.8	**16**	60	136	≥71	21.5	**71**	197	399
≥46	1.5	**6**			≥59	7.5	**17**	67	153	≥72	23.3	**78**	210	421
≥47	1.9	**7**			≥60	8.3	**18**	75	170	≥73	25.2	**84**	222	443
≥48	2.2	**7**			≥61	9.0	**19**	82	188	≥74	27.2	**90**	236	464
≥49	2.6	**8**			≥62	9.9	**20**	89	204	≥75	29.4	**96**	248	487
≥50	2.9	**8**			≥63	10.8	**20**	97	221	≥76	31.7	**102**	260	509
≥51	3.3	**10**	7	17	≥64	11.9	**22**	105	238	≥77	34.1	**109**	273	530
≥52	3.7	**11**	14	34	≥65	12.9	**23**	112	255	≥78	36.7	**115**	285	553
≥53	4.2	**11**	23	51	≥66	14.1	**24**	119	272	≥79	39.4	**121**	297	575
≥54	4.6	**12**	30	69	≥67	15.4	**25**	126	290	≥80	42.3	**127**	310	596
≥55	5.1	**13**	37	85	≥68	16.8	**26**	133	307	≥81	45.3	**135**	322	619

%HA – % of persons Highly Annoyed; N.A. – New Approach; C.V. – Central Values; H.V. – High Values

Gathering all information related to noise maps and noise exposure maps, for the situations *before* and *after* the implementation of noise mitigation measures and considering the cost factors related with road traffic noise, updated for 2007 and the percentage of highly annoyed persons, it was possible to estimate the cost associated with road traffic noise externalities and the number of persons annoyed.

4 Noise externalities

4.1 Introduction

Transport in general and road transportation in particular constitute one of the main sources of complains determining the development of several studies in order to quantify the related negative impacts. The harmful consequences of road transport are of diverse nature and its costs are not directly incurred by road users; instead, they are borne by a large proportion of the population living close to transport infrastructures or by public authorities/road concession holders through the implementation of noise reduction measures. These costs to society, not paid by users of transport systems, are labelled as **External Costs** or **Transport Externalities**.

These adverse effects may have different degrees of severity and/or recovery dependency, not only due to the *type* and *intensity* of the exposure to environmental factors, but also on the *endogenous characteristics* of each individual exposed.
These illnesses may assume a severe magnitude and, in specific situations, may cause the loss of human lives. Actually, the study of the *European Federation for Transport and Environment* [13] estimated that, approximately, half of the European Union population (about 210 million people) is exposed to severe environmental noise levels ($L_{den} \geq 55$ dB(A)) generated by road traffic and around 245 000 citizens in the EU25[2] experienced cardiovascular illnesses related with noise, from which about 20% (50 000 individuals) suffered fatal heart attacks. It is also emphasized that in EU22[3] over 40 billion Euros (0.4% of total GDP) are spent annually on social costs of traffic noise and that road traffic is responsible for approximately 90% of this value.
The noise externalities were estimated taking into consideration two primary aspects: ***health impairment*** and ***annoyance***, usually suffered by the population in general and, in particular, by those who experience directly those negative impacts.

4.2 Estimate of the percentage of population exposed to noise

4.2.1 Data Analysis

The process of selecting and reducing the number of variables used in the estimate of the costs of noise externalities and infra-structure costs) involved the use of two techniques: Chromatic Analysis (CA) and Principal Components Analysis (PCA). *Chromatic Analysis* is a non-statistical approach that uses visual interpretation of data to achieve the final result required (reducing the number of variables, see Figure 1).

Figure 1 - Comparative *chromatic analysis* of the five preferred variables

At a statistical level, *Principal Components Analysis* was used which enabled the identification of behaviour patterns in a particular data set, stressing similarities and differences and enabling reduction in the original data complexity without significant loss of information. With these two techniques was possible to reduce the number of variables under analysis from the initial **twenty-three** to the final **five** variables selected considered to be the most appropriate for characterizing municipal environmental noise and to assist with the quantification of costs related with traffic noise: *Population Density* (PD), *Living Quarter's Density* (LQD), *Buildings Density* (BD), *Percentage of area of land for urban uses* (PLUU), *Road density* (RD).

[2] EU25 refers to EU27 except Cyprus and Malta
[3] EU22 refers to EU27 except Cyprus, Estonia, Latvia, Lithuania and Malta

The *Cluster Analysis* was used to group the municipalities into classes, ensuring that all municipalities in the same class share similar characteristics and differ from the particularities of other clusters, which means, "natural groupings" of municipalities and the detection of outliers and extremes. With this process were defined *three clusters* (Figure 1) and, given the characteristics of the two clusters referring to the largest and most urbanized municipalities, was decided that they should be reduced to two clusters. One represented by *Maia* and the other one by *Santa Maria da Feira*, the two case study municipalities.

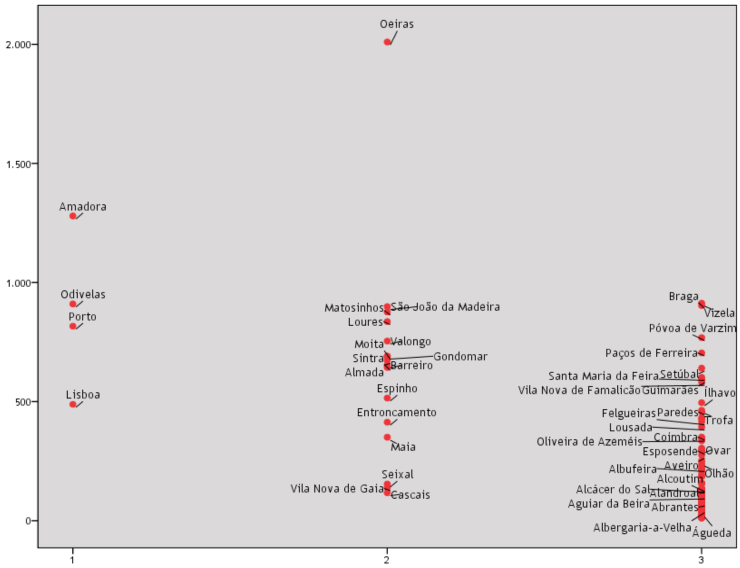


Figure 1 - Municipalities gathered in *three clusters*, according to the *distance to cluster centre*

4.2.2 Prediction Model

Taking into consideration the available data and its quality, information on the population exposure to environmental noise according to the Equivalent Continuous A-weighted Sound Pressure Level, L_{Aeq} was collected.

Table 3: Prediction model selected to estimate the percentage of the population exposed to noise, by classes of noise exposure

$L_{Aeq} \leq 45$ dB ⇨ $R^2 = 0.57$	**P** $_{\leq 45}$ = 73.177 – 0.667 ***RD*** – 0.009 ***PD*** + 0.037 ***LQD*** – 0.058***BD***– 0.565 ***PLUU***	(1)
$45 < L_{Aeq} \leq 50$ dB ⇨ $R^2 = 0.36$	**P** $_{45\_50}$ = 11.485 + 0.176 ***RD*** + 0.005 ***PD*** – 0.016 ***LQD*** – 0.012 ***BD*** + 0.418 ***PLUU***	(2)
$50 < L_{Aeq} \leq 55$ dB ⇨ $R^2 = 0.45$	**P** $_{50\_55}$ = 7.217 + 0.220 ***RD*** + 0.008 ***PD*** – 0.026 ***LQD*** + 0.032 ***BD*** + 0.061 ***PLUU***	(3)
$55 < L_{Aeq} \leq 60$ dB ⇨ $R^2 = 0.62$	**P** $_{55\_60}$ = 4.488 + 0.094 ***RD*** + 0.002 ***PD*** – 0.008 ***LQD*** + 0.030 ***BD*** – 0.034 ***PLUU***	(4)
$60 < L_{Aeq} \leq 65$ dB ⇨ $R^2 = 0.44$	**P** $_{60\_65}$ = 2.763 + 0.080 ***RD*** – 0.003 ***PD*** + 0.004 ***LQD*** + 0.007 ***BD*** + 0.014 ***PLUU***	(5)
$65 < L_{Aeq} \leq 70$ dB ⇨ $R^2 = 0.60$	**P** $_{65\_70}$ = 1,048 + 0,055 ***RD*** - 0,004 ***PD*** + 0,009 ***LQD*** + 0,002 ***BD*** + 0,054 ***PLUU***	(6)
$70 < L_{Aeq} \leq 75$ dB ⇨ R2 = 0.58	**P** $_{70\_75}$ = 0,065 + 0,023 ***RD*** - 0,001 ***PD*** + 0,002 ***LQD*** - 0,002 ***BD*** + 0,048 ***PLUU***	(7)
$L_{Aeq} > 75$ dB ⇨ $R^2 = 0.54$	**P** $_{> 75}$ = - 0,061 + 0,011 ***RD*** **+** 0,001 ***PD*** - 0,002 ***LQD*** + 0,004 ***BD*** - 0,012 ***PLUU***	(8)

The suitable data covered 140 municipalities and was organized in environmental noise exposure classes of 5 dB(A), including the percentage of the population exposed in each class [14]. Performing a more accurate analysis of this data was considered that some municipalities should be excluded as they were not representative for the missing municipalities.
In fact, most of the excluded cities had peculiarities as location in highway junctions or along major roads (see Figure 2). These singular characteristics, which were related to their classification as *outliers*[4], led to their exclusion as they did not represent the majority of the Portuguese municipalities for whom data was missing.

4.2.3 Quality of the Prediction Model

To determine the quality of the model structure were used, between the available criteria, the following three methods:

- *GFI ("Goodness-of-Fit");* [15] *and* [16] *for the calculation expression, cited by* [17]*;*
- *AGFI ("Adjusted Goodness-of-fit") ;* [16] *cited by* [17]*;*
- *RMSR* (standardized Root-Mean-Square Residual);* [16] *cited by* [17]*.*

The *goodness-of-fit* is an index, which allows the evaluation of the quality of a statistical model taking into account the discrepancies between the initial observations and the values resulting from the model appliance. According to GFI the model is regarded as Reasonably adjusted if 0.90 < GFI < 0.95 and as very well adjusted if GFI ≥ 0.95. However, this index should be adjusted to take into account the degrees of freedom (*gl*) in the model and the number of nonredundant errors (*k*) resulting from the model, i.e., AGFI.
The last quality index used, RMSR*, was calculated using the average square of non-negligible residuals between the initial and estimated observations. According to RMSR*, the model is regarded as *Unacceptable*, if RMSR* ≥ 0.10, as *Good* if 0.05 ≤ RMSR* < 0.10 and as *Very Good* if RMSR* < 0.05.
The results of this evaluation shown a GFI = 0,997, a AGFI = 0,998 and a RMSR* = 0,026. Bearing in mind these figures and the relatively high percentage of non-negligible residuals (with an absolute value greater than 0.05) it may be considered that the model is well adjusted relative to the original data and may be considered representative of reality under study.

4.2.4 Percentage of population exposed to noise (results)

In particular to the maximum noise exposure class, L_{Aeq} > 65 dB, Figure 2 shows the results obtained for all municipalities.
With regard to the population distribution in the Portuguese territory:

- *there is a concentration of the population in areas served by "good" road infrastructures (principal network which includes roads with highway profile, whether they are highways, PIs or CIs);*
- *there is a concentration of the population in areas near to points of main road junctions.*

With regard to the distribution of the population affected by high noise levels arise that:

- *They are located mostly in coastal areas and in municipalities crossed by the principal road network;*

[4] *Outlier* - Observation that is numerically distant from the rest of the data, which means, uncharacteristic observation, usually distant from the average value by more than two standard deviations. [17]

- *The distribution is due to the concentration of the population in areas of roads intersection. Some municipalities located in isolated zones and affected by high noise levels are clearly identifiable.*

It should also be noted that, with respect to roads with a higher volume of traffic, there is an almost perfect overlap between areas with a high proportion of the population exposed to noise levels exceeding 65 dB(A) and the path of those roads.

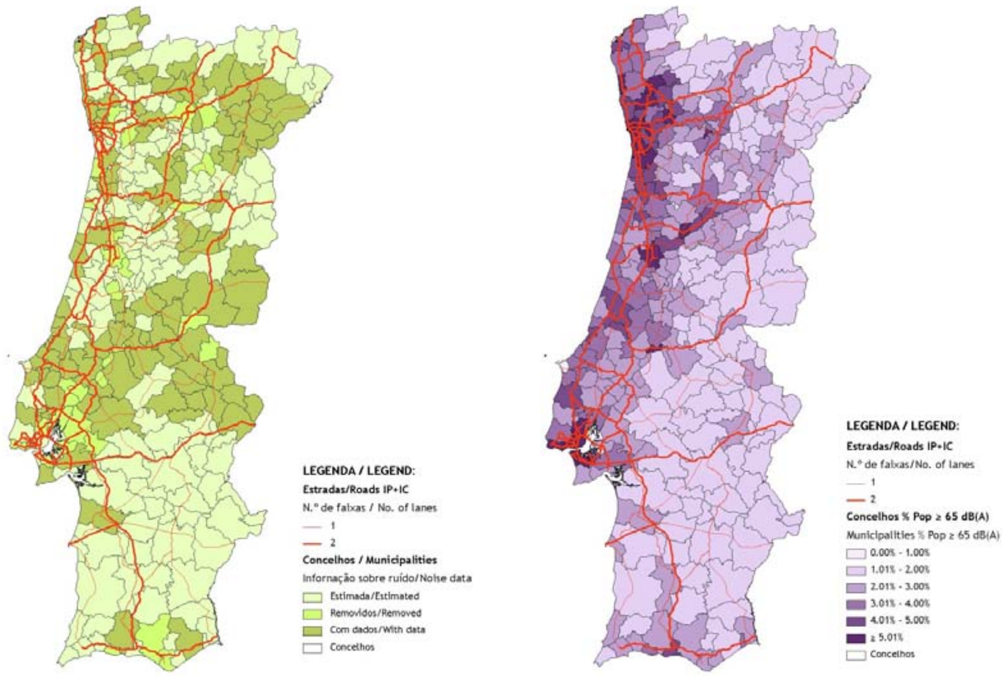


Figure 2 - Map of the *removed* municipalities for the prediction model (left) and map of the *population exposed to noise levels L_{Aeq} > 65 dB* (right)

4.3 Cost of noise externalities

4.3.1 Methodology

The methodology developed was supported by detailed and existing data for the municipalities that have been selected as case studies, *Maia* and *Santa Maria da Feira*. For these two municipalities, all the required information was available and the project HEATCO methodology could be applied in detail given the availability of disaggregated data on population noise exposure with the preferred indicator (L_{den}), by noise source and by decibel. It should be mentioned that in both cases, noise exposure data were obtained for "*real exposure*" and not by overlapping maps with population data and noise mapping information through processes of geographic information systems. The performed calculations had as input data the *population distribution by residential buildings* which, in turn, allocated residents to each floor within every housing building. Finally, the noise exposure by receiver and by noise source was calculated. With these calculations, both for the situation prior to and after the implementation of minimization measures, it was possible to determine the *population exposed by noise exposure level and by noise source*.
The subsequent task consisted of the application of the cost factors listed in the HEATCO project to the appropriate classes of noise exposure, which enabled the quantification of

external noise costs; in this case, encompassing the valuation of health[5] related problems and the experienced noise annoyance[6] [18].
As the principal achievement is the quantification of road traffic noise externalities for Portugal, the development of a methodology was required in order to:

- *made possible the conversion of the cost factors per dB(A) and per affected person in cost factors by classes of 5 dB(A) and by person exposed;*
- *allow the reassignment of the available and estimated data for the percentage of population exposed to noise (measured in L_{Aeq}) for each municipality, in new proportions representing an equivalent percentage related to noise assessment by noise indicator L_{den}.*

The first assignment, conversion of cost factors for noise exposure classes, has been carried out in a simplified way: the *average values of each class* of noise exposure were considered. The calculations for the classes of noise exposure were repeated but considering in each class the *sum of people exposed* to each decibel included in the respective exposure class. Comparing the results from the "regular" calculation procedure and from this "simplified" method, the deviation in results was not significant; 1% error for *Maia* and 3% in *Santa Maria da Feira*, taking into account in both situations the estimated so-called "*New Approach*".
The quality of this simplification cannot be reproduced when data is presented as a percentage of the population exposed to noise. One of the reasons for this happening is related to the fact that, for example, in the lower class corresponding to $L_{Aeq} \leq 45$ dB, all of the population exposed to all noise levels below 45 dB(A) is evaluated and not only the component of interest to this calculation, between 43 and 45 dB(A).

Table 4: *Cost factors*, updated to 2007, in PPP units, by *classes of 5 dB(A)*

L_{den} in dB(A)	< 45	[45; 50[	[50; 55[	[55; 60[	[60; 65[	[65; 70[	[70; 75[	≥ 75
New Approach	5	7	10	14	20	25	69	113
Central Values	-	-	18	51	87	124	199	279
High Values	-	-	41	117	200	283	405	541

As explained before, the cost factors of the HEATCO project were updated to the base year 2007. Table 4 shows the values for 2007 (in Purchasing Power Parity - PPP units) together with the "*new average*", "Central" and "High" values to be used in the estimate of noise externalities by municipality, by classes of 5 dB(A) (except for the first and last classes). This *regrouping* of municipalities was related to the case study municipalities to be used:

- *Maia*, for clusters 1 and 2;
- *Santa Maria da Feira*, for cluster 3.

The following step involved the conversion of the *L_{Aeq} data into L_{den} data*, referring the percentage of population exposed to each class of noise exposure. To achieve that goal, the percentages of population exposed to a given noise level class was established using a relationship between the percentages of each class for L_{Aeq} and $L_{den.}$ This was derived using the two case study municipalities (for which all information was available) as a reference value. Those relationships are indicated in Table 5.

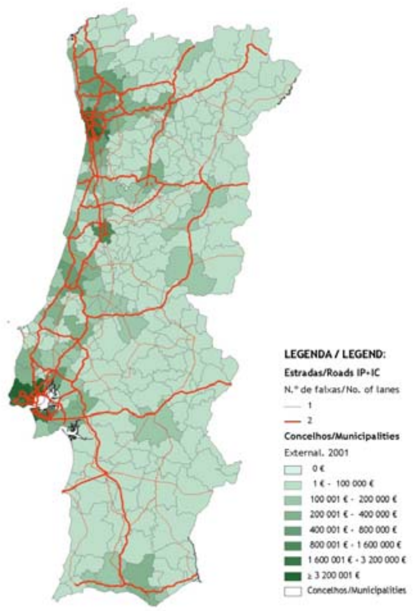
[5] *Health impacts* caused by long term exposure to excessive noise levels and mostly related to extreme or long term stress situations like hypertension and myocardial infarction
[6] Annoyance experienced by citizens reflecting their disturbance and malaise, when exposed to road traffic noise

Table 5: Conversion factors between L_{Aeq} and L_{den} for the exposure classes under evaluation

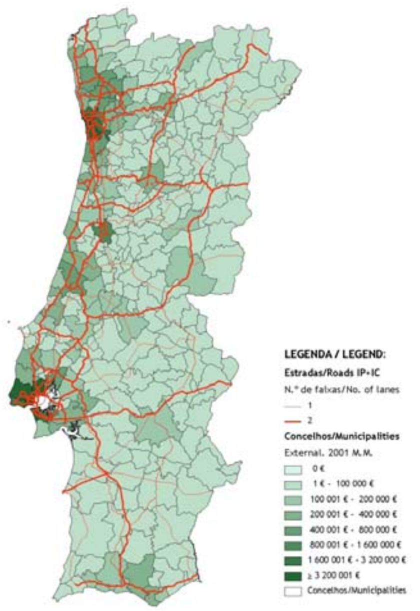
Municipalities	$L_{Aeq} < 43$	$43 \le L_{Aeq} < 45$	$45 \le L_{Aeq} < 50$	$50 \le L_{Aeq} < 55$	$55 \le L_{Aeq} < 60$	$60 \le L_{Aeq} < 65$	$65 \le L_{Aeq} < 70$	$70 \le L_{Aeq} < 75$	$L_{Aeq} \ge 75$
Maia									
% exposure (L_{Aeq}) *estimated with the forecast model*	31.0		21.0	20.0	12.0	6.0	4.0	3.0	3.0
Average % exposure (L_{den}) [NA]	-	0.8	6.2	15.3	22.8	18.1	12.1	9.1	4.3
Average % exposure (L_{den}) [CV/HV]	-	-	-	13.1	23.0	18.3	12.2	9.2	4.3
Conversion Factor (L_{Aeq} to L_{den})									
"New approach" – [NA]	-	0.025	0.297	0.765	1.896	3.021	3.018	3.042	1.425
"Central Values"/"High Values" [CV/HV]	-	-	-	0.657	1.918	3.055	3.052	3.076	1.441
Santa Maria da Feira									
% exposure (L_{Aeq}) *estimated with the forecast model*	50.0		20.0	15.0	7.0	3.0	2.0	2.0	1.0
Average % exposure (L_{den}) [NA]	-	4.3	10.9	11.7	7.7	5.9	5.3	1.2	0.03
Average % exposure (L_{den}) [CV/HV]	-	-	-	9.3	7. 7	5.9	5.3	1.2	0.03
Conversion Factor (L_{Aeq} to L_{den})									
"New approach" – [NA]	-	0.086	0.547	0.779	1.102	1.953	2.666	0.592	0.026
"Central Values"/"High Values" [CV/HV]	-	-	-	0.620	1.103	1.955	2.669	0.592	0.026

4.3.2 Noise externalities (results)

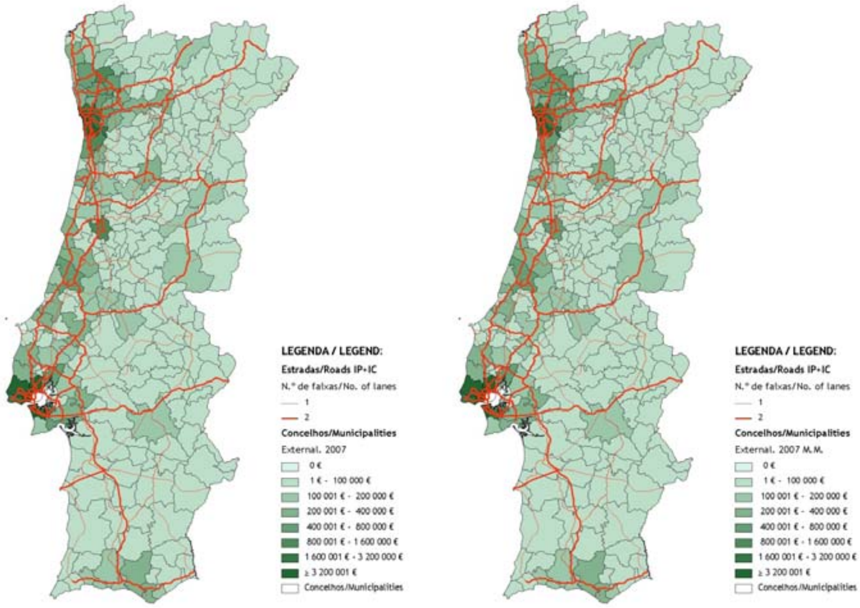
Finally, the value for road traffic noise externalities was calculated for each municipality and with the overall sum the global value for Portugal was achieved. Four situations were evaluated regarding the year and whether or not there was the implementation on noise mitigation measures. The results of those calculations are graphically shown in Figure 3.



2001 ***without*** noise mitigation measures



2001 ***with*** noise mitigation measures



2007 ***without*** noise mitigation measures | 2007 ***with*** noise mitigation measures

Figure 3 - Map of noise externalities economic value *with* and *without* the influence of noise mitigation measures, by municipality and by year

5 Conclusions

As expected the noise externalities increased between 2001 and 2007 mostly due to the constant growth in the road traffic volume. Another statement possible refers to the efficiency of the implemented noise mitigation measures. Figures on the right-hand side highlight the benefit on introducing those measures. There are several municipalities whose shade turned lighter meaning that economic valuation of noise externalities experienced a reduction.
The social costs of road traffic noise were estimated for three different approaches included in HEATCO project and adjusted for the available data. Those three approaches "new approach", "central values" and "High values" have as distinctive factor the method used to achieve the cost of a dB(A) concerning annoyance and health related problems.
The "high value" is based on Hedonic Pricing studies; the "central values" from the analysis of Stated Preference studies and the "new approach" in a methodology being introduced in EU also based on Stated Preference methods but, in this case, combined with the dose-response functions recommended by the European Commission and "calibrated" for six European countries (Germany, Hungary, Norway, Spain, Sweden and the United Kingdom).
Regarding these three estimates of noise externalities cost per year, the following results were obtained:

- *"New approach": 0.08% GDP2007;*
- *"Central values": 0.25% GDP2007;*
- *"High values": 0.67% GDP2007.*

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