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Investment in noise reduction: a good option in Portugal?

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ABSTRACT

In Portugal like in the majority of European countries, a significant part of the population is exposed to excessive traffic noise levels which are downgrading their quality of life. Considering the relevance of this topic associated with a constant growth in road traffic volume and congestion, it was recognized the importance of the economical valuation of these severe noise levels. This paper aims to present some results of the ongoing investigation concerning this issue and to contribute to the body of knowledge and methodology in this field.

There are several innovative aspects on this research. There have been very few studies simultaneously concerned with monetary valuation of noise externalities, real estate income and infra-structure costs. In this analysis was evaluated the significance of investment in noise mitigation measures (increase in the infra-structure cost due to the constructions of noise alleviation measures - on the source and on noise path) regarding the reduction of noise externalities (associated to social, real estate and health related costs) and the minimization of real estate income loss (allied to the inability for construction of available building properties based on excessive noise and the consequent reduction on its patrimonial value).

This investigation was conducted over two municipalities representative of the majority of Portuguese cities in accordance with their spatial characteristics as well as territorial development, finances, population, building and road density. It is an important input for the selection, implementation and financing of future Noise Action Plans and Municipal Noise Reduction Plans.

1. INTRODUCTION

At the moment, almost all municipalities are revising their Municipal Director Plans (MDP). The legal changes concerning Noise (1), Real Estate Taxation (2), Territorial Management Systems (3) and Strategic Environmental Assessment of Territorial Management Plans (4) showed the increasing relevance of environmental issues and induced severe adjustments on the programmed work mostly due to the implications of this inconsiderateness.

The municipalities were obliged to generate Noise Maps, classify the urban territory regarding noise sensitivity of present and expected uses and perform strategic environmental analysis of the upcoming MDP, including population concerns that should be consulted through public participation mechanisms. One of the principal components of this strategic analysis is the preliminary detection of environmental issues, which could be avoided with the adoption of mitigation measures of diverse types. Regarding noise, some of the questioned measures involve territorial management change (redistribution of incompatible uses), traffic reorganization and traffic calming measures or modification of the regular dressing surfaces

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(replacement for “noise-friendly” surfaces).

In the selection of the “*best noise reduction procedures*” it is needed the identification of noise conflict areas and a decision about the responsibility of different agents (municipal or private actions). To this investigation were considered the mitigation actions already in-place, either from public or private implementation, in road infrastructures.

2. NOISE LEGAL FRAMEWORK

Until 1987, when the first *Portuguese Noise Code* (RGR) [5] and the *Environmental Act* [6] were approved, the *Portuguese Constitution* [7] was the only main statutory document where environment and welfare was mentioned. In fact, general concepts of welfare, quality of life, environmental rights, nature and environmental protection and natural resources protection were stated on articles 9, 66 and 81 and referred as National Authorities responsibilities.

Since then, was approved the second *Noise Code* [8] (RLPS) with the same scope of application but with a new acoustical parameter L_{Aeq}. The subsequent legal document was Decree-Law n.º 146/2006 [9], which transposed the European Directive 2002/49/CE, 25th June into the Portuguese legislation, that 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 introduced 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), 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 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 this new RGR, 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 director plans (MDP). It is stated that municipal director plans should guarantee environmental noise quality, promoting reasonable distribution of activities and noise sources as well as establishing noise classification areas (sensitive and mixed zones).

According to RGR, licensing or authorizing new dwellings is forbidden, as well as new schools, hospitals or similar social equipments and leisure spaces, while the settled environmental noise limits are exceeded. The only exceptions are new housing, in “consolidated urban areas”, with approved Municipal Noise Reduction Plan (MNRP) or where environmental noise limits are not exceed more than 5 dB(A). In this situation ought to be considered façade sound insulation reinforcement by 3 dB.

3. CASE STUDY MUNICIPALITIES

For the evaluation of road traffic noise cost were selected two cities in the north region of Portugal (Maia and Santa Maria da Feira) which can be considered as representatives of the great majority of the Portuguese counties.

Thus, the municipality of ***Maia*** intends to represent cities with a strong services sector and reveals a significant industrial presence, given its proximity to major transportation

infrastructures. The land use distribution demonstrates a dense urban occupation pattern (about 40% of the territory is classified as urban) and is densely populated (close to 1 700 inh/km^2).

Santa Maria da Feira is a municipality with an extremely relevant industry sector, although the services sector is also present, and represents an important part of the municipal economy. As for land use characteristics, there is a dichotomy of occupation spite the consideration of 34% of the territory as urban. The western part of the municipality is more densely occupied and its inner part is dedicated to others forms of occupancy less populated.

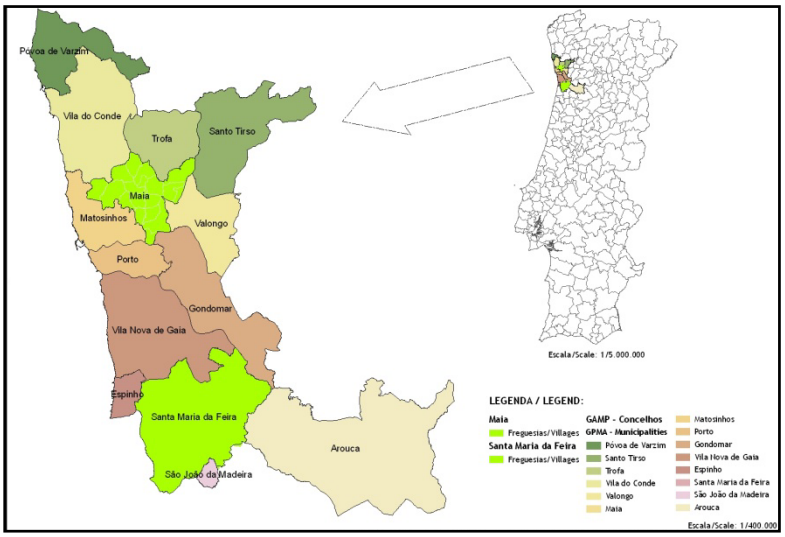

Figure 1: Case-study municipalities' location (Maia and Santa Maria da Feira)

Table 2: *Characteristic indicators of Portugal and Case Study municipalities* [10] [11] [12]

Characteristics	Portugal	Maia	S.M. Feira
Population	10 599 095	138 226	146 367
Parishes ("*freguesias*")	4 260	17	31
Population density (inh/km^2)	114	1 663	680
Road density (km/km^2)	10	0.35	0.19
Housing density (n.º houses/km^2)	55	586	244
Buildings density (n.º buildings/km^2)	34	294	182
Population exposed to $L_{den} \geq 65$ dB(A)		30 939 (22.4%)	8 905 (6.1%)
Activity Sector (%GDP):			
Primary: agriculture/fishing	2.4%	0.1%	0.3%
Industries	21.2%	39.5%	65.5%
Services	62.5%	60.4%	34.2%
Actual MDP	-	2009	1993
Area (km^2)	92 090	83	215
Land use: urban (ha)	481 082	3 267 (39%)	7 359 (34%)
Land use: industrial (ha)	75 151	769 (9%)	530 (2%)
Land use: public equipments and parks (ha)	37 837	982 (12%)	419 (2%)
IMI Tax		0.50%	0.50%
IMI income		€ 16 840 361	€ 11 361 210
Percentage of total revenue		20%	19%

4. ROAD TRAFFIC NOISE COST IN CASE-STUDY MUNICIPALITIES

A. Overview

One of the most important outcomes of this research is the comparative analysis between the investments needed to accomplish noise legal restrictions, to avoid health injuries and annoyance for the population in general and to minimize municipal taxes income loss.

For that purpose, were identified the relevant noise related costs, not only for the exposed persons and territory but also for the entities (public or private bodies) compelled to reduce environmental noise levels.

Between all possible conjugations of expenses were selected the following:

- ***noise externalities***, for the quantification of inhabitants associated costs;
- ***real estate costs***, for the evaluation of income taxes decrement;
- ***Infrastructure costs***, for the pricing of noise mitigation measures.

B. Noise Externalities

In Table 3 are presented some results for the estimate of road traffic noise externalities regarding ***health impairment*** (sleep disorders; weaken concentration skills and related working injuries or reduced productivity; diminished learning and understanding aptitude; hearing damage, stress episodes, cardiovascular diseases and psychiatric disorders) and ***annoyance*** ("feeling of resentment, displeasure, discomfort, dissatisfaction or offence" [13] experienced by citizens exposed to traffic noise).

The economical valuation, by person and by year, was computed with HEATCO methodology (noise cost factor tables) [14], [15], [16] taking into consideration the results obtained from noise dispersion models applied both for the Initial (Do-nothing) and Final (Do-something) Situations and described in a previous communication [17]. These noise cost factor tables include both health and annoyance costs in two situations: "*New approach*" (health and annoyance based on dose-response functions); "*Central value*" (health and direct WTP for reducing annoyance based on 'stated preference' studies).

Table 3: *Summary table for global external noise cost due to traffic noise* [17]

Noise Classes	Maia		S.M. Feira	
	Before NMM	***After NMM***	***Before NMM***	***After NMM***
Exposed population:				
$L_{den} \geq 75$ dB(A)	5 192	3 894	36	27
$65 \leq L_{den} < 75$ dB(A)	25 747	24 528	8 869	8 449
$55 \leq L_{den} < 65$ dB(A)	49 656	44 691	18 473	15 458
$45 \leq L_{den} < 55$ dB(A)	26 154	31 385	30 794	32 728
$L_{den} < 45$ dB(A)	5 471	7 722	71 906	73 416
"New approach"				
Exposed population from 43 dB(A)	107 684	105 821	64 016	63 165
Average cost per year and per exposed person	€ 33.13			
External cost	***€ 2 341 238***	***€ 2 148 695***	***€ 727 971***	***€ 683 055***
Exposed population difference	-1 863		-851	
External cost difference	€ -192 543		€ -44 916	
"Central Values"				
Exposed population from 51 dB(A)	96 371	92 047	40 020	36 090
Average cost per year and per exposed person	€ 90,58			
External cost	***€ 5 852 054***	***€ 5 323 812***	***€ 1 698 843***	***€ 1 528 121***
Exposed population difference	-4 324		-3 930	
External cost difference	€ -528 242		€ -170 722	

NMM - noise mitigation measures

C. Real Estate Cost

In Portugal, regarding the present Noise Code, it is forbidden to construct new dwellings or other sensitive buildings in areas where environmental noise levels are excessive. Due to these restrictions, usually induced by third parties, property owners are not allowed to build in their own "*land for construction*", losing not only their construction rights but also their expected profit.

One of the tools they have to reduce their financial loss is to ask for a building permit. The municipality will be obliged to deny it, based on severe noise levels and the landowner will be able to request for a change in the property classification for real estate taxes purpose. The

impact of this kind of alterations (*regular urban property* into *other urban property*) is extensive, not only for private ownership but also for the municipalities that will see one of their most relevant sources of financial support largely reduced.

To evaluate the economical impact of this limitations to municipal budget (reduction on real estate taxes income) was employed the methodology described in a previous paper [18], modeled in view of three main areas: *Territorial Management*, *Noise* and *Real Estate Taxation*. This methodology involves the calculation of an initial patrimonial value for all municipal available "*land for construction*" in noise conflict zones (equations (1) and (2)) and later, a recalculation of the patrimonial value for the same area but considering its inadequacy for building purposes, which means, as "*other urban property*" (equation (3)).

$$V_{t\,\text{regular urban property}} = V_c \times A \times C_a \times C_{L\,\text{housing}} \times C_q \quad (1)$$

$$A = (A_a + 0.3\,A_b) \times \%T + (0.025\,A_c + 0.005\,A_d) \quad (2)$$

$$V_{t\,\text{other urban property}} = V_c \times A_T \times C_{L\ \text{housing}} \times 0.005 \quad (3)$$

V_t – Patrimonial value
V_c - Construction value
A – Equivalent area
C_a - Area function coefficient
$C_{Lhousing}$ - Housing location coefficient
C_q - Quality and comfort coefficient
A_a - Construction area: private
A_b - Construction area: complementary
A_c - Remaining allotment area: *Proximity area*
A_d - Remaining allotment area: *Distant area*
%T - Location coefficient for land value
A_T - Allotment area

The results of that assessment, concerning the annual income loss in municipal real estate taxation, are pointed out in Table 4.

Table 4: *Assessment table for real estate cost related to excessive traffic noise levels* [17] [18]

Characteristics	Maia	S.M. Feira
A (m^2)	1 407 554	62 463
V_c (€/m^2)	615	615
C_a (average)	0.97	1.00
C_q	1.00	1.00
$C_{L\ \text{dwellings}}$ (average)	1.19	0.96
$C_{L\ \text{land for construction}}$ (average)	0.25	0.19
Patrimonial value (Vt): Land for construction	€ 1 027 600 375	€ 36 529 805
Patrimonial value (Vt): Other properties	€ 27 144 811	€ 1 056 362
IMI tax (2007)	*0.50%*	*0.50%*
IMI revenue: Land for construction	€ 5 086 640	€ 182 252
IMI revenue: Other properties	€ 133 189	€ 4 918
IMI revenue variation	***€ 4 953 451***	***€ 177 334***

IMI – Imposto Municipal sobre Imóveis (Municipal Real Estate Tax)

D. Infra-structure Cost

The additional cost of the road infrastructure was evaluated considering all the investments carried out by concession holders for minimization purposes in noise conflict areas.

The mitigation measures of current use in Portugal, for the most part consequent from regulations regarding environmental noise, consist of noise-improved pavements, noise barriers and enhanced façade sound insulation in dwellings or other buildings with sensitive use, as a complementary solution.

The methodology employed to estimate this expenditure was described in the paper presented at Inter-Noise 2009 [17]. The unitary cost of these measures is summarized in Table 5, together with the *global additional cost* (Δ) for the construction and *global cost* for renewal of

special noise reduction pavements (considering as reference surface: *dense asphalt concrete*) and the *full investment cost* for noise barriers. The average renewal price is referred to the construction year through the consideration of discount rates in order to achieve the Present Value (PV) [19]:

Table 5: *Summary table with the implemented noise mitigation measures* [17] [20], [21]

Characteristics	€/m²	Maia	S.M. Feira
Pavement with improved Acoustical performance			
Reference Surface: DAC (dense asphalt concrete)	3 - 4		
PAC (porous asphalt concrete)	5 - 6	356.250 m² Δ = € 710.500	287.834 m² Δ = € 575.668
PERS (poro-elastic road surface)	4 - 5	472.450 m² Δ = € 472.450	-
Average cost for pavement renewal (each)	6 - 8	€ 2.493.750	€ 2.014.838
Noise Barriers			
Leca block wall with absorption (*Leca®Mursom*)	70 - 80	143.702 m² € 10.777.650	-
Metallic with absorption	120 - 140	-	17.622 m² € 2.290.860
Acrylic	140 - 150	1.650 m² € 239.250	1950 m² € 282.750

E. Results

After gathering all the information mentioned in the three previous points, there was the need to define a common evaluation period. The selected time horizon (20 years) is related with the standard lifetime expectancy of noise mitigations measures and pavements (with one renewal operation every 7 years) in Portugal. As a final point, was evaluated the difference between the noise related costs in the initial situation and after the investment and implementation in noise mitigation actions.

The results of those operations are specified in Table 6 and reveal some discrepancy between these two case-study municipalities. This disparity might be explained through the comparison of some key indicators: ***road density***, ***housing density***, ***population density***, ***buildings density*** and ***percentage of people exposed to L_{den} ≥ 65 dB(A)***.

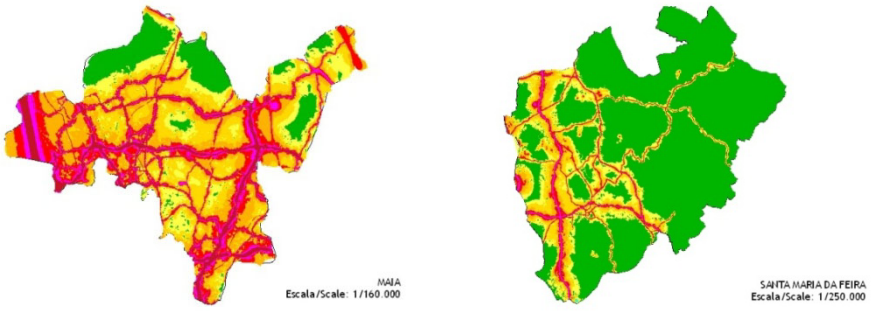

Figure 2: Noise Maps (L_{den}) from Maia (left) and Santa Maria da Feira (right)

In fact, if we attend to these five indicators jointly with L_{den} noise maps for these two cities (Figure 2), it is perceptible that Maia, with all those indicators significantly higher than S.M. Feira (between 1.5 and 3 times, according to the pertinent parameters) will obtain added benefits from the investment in noise mitigation measures.

Maia is a municipality with almost all possible noise sources' types and an important territorial occupation; on the other hand, ***Santa Maria da Feira*** has a considerable part of the territory (almost two thirds) dedicated to natural reserves, thermal-water areas and prospective

construction areas, with the road network as primary mode of transportation and multiple industrial plants not concentrated in industrial areas.

Table 6: *Summary results for road traffic noise related costs* [17]

	"New Approach" Maia	"New Approach" S.M. Feira	"Central Values" Maia	"Central Values" S.M. Feira
Noise externalities with no noise-reduction actions (20 years)	*€ 46 824 760*	*€ 14 559 420*	*€ 117 041 080*	*€ 33 976 860*
Health and Annoyance costs/year	€ 2 341 238	€ 727 971	€ 5 852 054	€ 1 698 843
Real Estate Cost with no noise-reduction actions (20 years)	*€ 99 069 020*	*€ 3 546 680*	*€ 99 069 020*	*€ 3 546 680*
reduction municipal IMI income/year	€ 4 953 451	€ 177 334	€ 4 953 451	€ 177 334
	€ 145 893 780	***€ 18 106 100***	***€ 216 110 100***	***€ 37 523 540***
Noise externalities with noise-reduction actions (20 years)	€ 42 973 900	€ 13 661 100	€ 106 476 240	€ 30 562 420
Health and Annoyance costs/year	€ 2 148 695	€ 683 055	€ 5 323 812	€ 1 528 121
Real Estate Cost with noise-reduction actions (expected for 20 years)	€ 66 046 013	€ 1 773 340	€ 66 046 013	€ 1 773 340
reduction in municipal IMI income/year	€ 3 302 301	€ 88 667	€ 3 302 301	€ 88 667
	€ 109 019 913	**€ 15 434 440**	**€ 172 522 253**	**€ 32 335 760**
Additional infrastructure cost				
Pavement (including 2 renewals)	€ 6 170 450	€ 4 605 344	€ 6 170 450	€ 4 605 344
Noise Barriers	€ 11 016 900	€ 2 573 610	€ 11 016 900	€ 2 573 610
	€ 17 187 350	**€ 7 178 954**	**€ 17 187 350**	**€ 7 178 954**
Population (inhabitants per municipality)	112 220	130 078	112 220	130 078
Initial Noise Externalities and reduction IMI income (per inhabitant)	€ 1 300	€ 139	€ 1 926	€ 288
Investment in noise mitigation measures (per inhabitant)	€ 153	€ 55	€ 153	€ 55
Remaining Noise Externalities and reduction IMI income (per inhabitant)	€ 971	€ 119	€ 1 537	€ 249
True Cost of Road Traffic Mitigation *(per inhabitant and year)*	***€ 9***	***-€ 2***	***€ 12***	***-€ 1***
True Cost of Road Traffic Mitigation *(per inhabitant)*	***€ 175***	***-€ 35***	***€ 235***	***-€ 15***

5. ROAD TRAFFIC NOISE COST IN PORTUGAL

A. Methodology

As mentioned on paragraph 4, the final purpose of this research is the comparative analysis between investments in noise mitigation actions and the lessening of noise externalities and municipal taxes income loss. For the two case-study municipalities were evaluated *noise exposed population*, *noise externalities*, *real estate costs* and i*nfrastructure costs*. Presently, the objective is to estimate those values for the global territory (in the case of noise exposed population there is some information available) [22].

To achieve that target, was analyzed all existing data for the Portuguese municipalities concerning *road density*, *housing density*, *population density*, *buildings density* and *Municipal Director Plan land use percentage as urban area* with statistical techniques as *Factor Analysis*, *Principal Components Analysis*, *Cluster Analysis* and *Multivariate Regression Analysis*.

These techniques were applied to aggregate municipalities into groups with similar attributes (*clustering*) and also to explain those characteristics through a new set of variables linear combinations of the original (principal components). Then, considering multivariable regression methods, was derive noise exposed population to the municipalities for which there is no data available. Afterwards, the same concept was used to estimate the cost for noise mitigation actions (considering road density and percentage of exposed population over 65 dB(A) as key variables) and real estate taxes (regarding road density, percentage of urban areas and percentage of exposed population over 65 dB(A) as the most important parameters).

Finally, was estimated the *Total Cost of Noise in Portugal*, regarding investment in noise mitigation measures and the expected reduction of noise externalities and loss of municipal real estate taxes income.

B. Cluster Analysis

Cluster analysis (CA) is a multivariate statistical technique to classify objects into natural groupings according to its attributes. All the objects in a certain cluster share a similar behavior in relation to previously selected criteria [23] and differ from the ones belonging to other clusters. For clustering objects there are two algorithms: *hierarchical* (dendrogram) and *partitional* (K-means) [24].

In the *hierarchical clustering* was elected the agglomerative method where from a collection of *n* objects will be considered *n* clusters successively gathered (UPGMA – unweighted pair-group method using average approach) until all the objects are reassembled. The graphical representation of these operations is a tree diagram named *dendrogram*.

Partitional clustering was also applied and involved all available data (objects and its features) demanding a previous decision on the number of clusters. Each point is assigned to the nearest cluster center (centroid - average of all the points in the cluster) and this procedure is repeated until the assignment does not change.

This study considered both methods (Figure 3 and Figure 4).

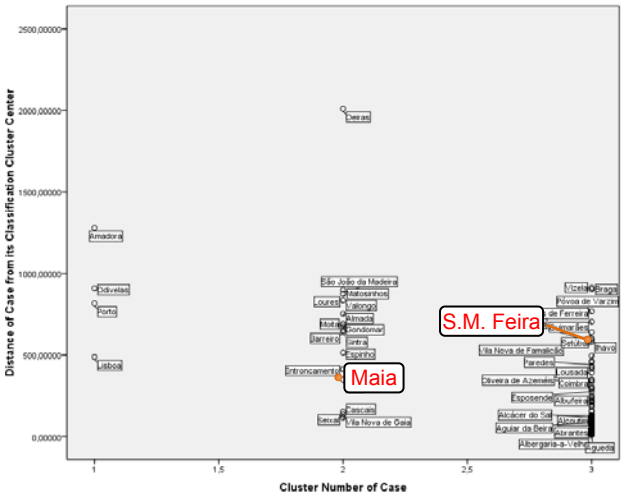

Figure 4: Results from K-means Cluster Analysis (3 clusters)

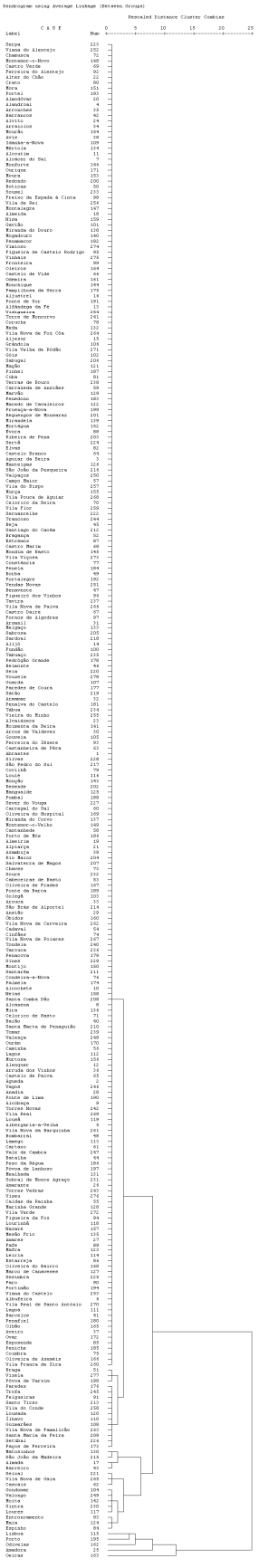

Figure 3: Dendrogram

C. Principal Components Analysis

For data reduction of correlated variables, there are several methods that can be appropriated, such as, *factor analysis*, which transforms each variable in a linear combination of factors whose intention is to simplify complex relationships between the available records.

In this study, was used the *principal component analysis*, another exploratory data analysis, which allows data reduction of multidimensional data sets through independent variables resulting from linear combinations of the original ones (designated as *principal components*) mostly for prediction purposes. The results of this method are typically analyzed in terms of component scores and loading factors.

D. Multivariate Regression Analysis

In order to estimate the number of Portuguese people exposed to traffic noise was performed a multivariate regression analysis, using selected data.

All the available variables, considering territorial management characteristics, population, area usage, noise exposed population for 140 municipalities (total of 279) was analyzed regarding its relevance for the purpose of this estimation: the projection of noise exposed population, by 5 dB(A) classes, for the remaining cities.

Then, using HEATCO methodology for health and annoyance costs, related with traffic noise, were accomplishing the results showed in Table 7, in line with the social costs derived for EU from traffic noise (0.35% GDP).

Table 7: *Summary results for road traffic noise related costs extended for Portugal*

	"New Approach"		
	Maia	**S.M. Feira**	**Portugal**
Noise externalities with no noise-reduction actions (20 years)	*€ 46 824 760*	*€ 14 559 420*	*€ 2 247 106 320*
Health and Annoyance costs/year	€ 2 341 238	€ 727 971	€ 112 355 316
Real Estate Cost with no noise-reduction actions (20 years)	*€ 99 069 020*	*€ 3 546 680*	*€ 2 323 434 240*
reduction municipal IMI income/year	€ 4 953 451	€ 177 334	€ 116 171 712
	€ 145 893 780	***€ 18 106 100***	***€ 4 570 540 560***
Noise externalities with noise-reduction actions (20 years)	*€ 42 973 900*	*€ 13 661 100*	
Health and Annoyance costs/year	€ 2 148 695	€ 683 055	
Real Estate Cost with noise-reduction actions (expected for 20 years)	*€ 66 046 020*	*€ 1 773 340*	
reduction in municipal IMI income/year	€ 3 302 301	€ 88 667	
	€ 109 019 920	**€ 15 434 440**	
Additional infrastructure cost			
Pavement (including 2 renewals)	€ 6 170 450	€ 4 605 344	
Noise Barriers	€ 11 016 900	€ 2 573 610	
	€ 17 187 350	**€ 7 178 954**	
Population (inhabitants per municipality)	112 220	130 078	10 126 880
Initial Noise Externalities and reduction IMI income (per inhabitant)	€ 1 300	€ 139	€ 451
Investment in noise mitigation measures (per inhabitant)	€ 153	€ 55	
Remaining Noise Externalities and reduction IMI income (per inhabitant)	€ 971	€ 119	
True Cost of Road Traffic Mitigation *(per inhabitant and year)*	***€ 9***	***-€ 2***	
True Cost of Road Traffic Mitigation *(per inhabitant)*	***€ 175***	***-€ 35***	

6. CONCLUSIONS

This on-going investigation demonstrated the relevance of noise abatement policies and noise mitigation actions.

Regarding only the “do-nothing” situation, it was possible to foresee a potential reduction of 14% on real estate taxes income for Portugal (116 millions of Euros per year).

At the same time, Portuguese population is expected to suffer from noise externalities and that social cost was estimated in 112 million of Euros. At the present, some approximate calculations on the influence and cost of mitigation measures are finalizing and final results will be disclosed on the conference.

REFERENCES

1. **MAOTDR, Ministério do Ambiente, do Ordenamento do Território e do Desenvolvimento Regional.** *Decreto-lei n.º 9/2007 de 17 de Janeiro.* [Diário da República Electrónico] Lisboa : INCM - Imprensa Nacional Casa da Moeda, 2007a. Regulamento Geral do Ruído/Third Portuguese Noise Code.

2. **MF, Ministério das Finanças.** *Decreto-Lei n.º 287/2003 de 12 de Novembro.* [Diário da República Electrónico] Lisboa : INCM - Imprensa Nacional Casa da Moeda, 2003. Código do Imposto Municipal sobre Imóveis e Código do Imposto Municipal sobre as Transmissões Onerosas de Imóveis.

3. **MAOTDR, Ministério do Ambiente, do Ordenamento do Território e do Desenvolvimento Regional.** *Decreto-lei n.º 316/2007 de 19 de Setembro.* [Diário da República Electrónico] Lisboa : INCM - Imprensa Nacional Casa da Moeda, 2007c. 5ª alteração ao Regime Jurídico dos Instrumentos de Gestão Territorial.

4. —. *Decreto-lei n.º 232/2007 de 15 de Junho.* [Diário da República Electrónico] Lisboa : INCM - Imprensa Nacional Casa da Moeda, 2007b. Regime de Avaliação Ambiental de Planos e Programas.

5. **MPAT, Ministério do Plano e da Administração do Território.** *Decreto-lei n.º 251/87 de 24 de Junho.* [Diário da República Electrónico] Lisboa : INCM - Imprensa Nacional Casa da Moeda, 1987. Regulamento Geral sobre o Ruído/First Portuguese Noise Code.

6. **AR, Assembleia da República.** *Lei n.º 11/87 de 7 de Abril.* Lisboa : INCM - Imprensa Nacional Casa da Moeda, 1987. Lei de Bases do Ambiente/Environmental Act.

7. **PR, Presidência da República.** *Decreto de aprovação da Constituição de 10 de Abril.* [Diário da República Electrónico] Lisboa : INCM - Imprensa Nacional Casa da Moeda, 1976. Constituição da República Portuguesa/Portuguese Constitution.

8. **MAO, Ministério do Ambiente e do Ordenamento.** *Decreto-lei n.º 292/2000 de 14 de Novembro.* [Diário da República Electrónico] Lisboa : INCM - Imprensa Nacional Casa da Moeda, 2000. Regime Legal sobre a Poluição Sonora/Second Portuguese Noise Code.

9. **MAOTDR, Ministério do Ambiente, do Ordenamento do Território e do Desenvolvimento Regional.** *Decreto-lei n.º 146/2006 de 31 de Julho.* [Diário da República Electrónico] Lisboa : INCM - Imprensa Nacional Casa da Moeda, 2006. Directiva de Ruído Ambiente/Environmental Noise Directive.

10. **CMFeira, Câmara Municipal de Santa Maria da Feira.** *Relatório de gestão do ano de 2007.* [Relatório] Santa Maria da Feira : s.n., 2007.

11. **CMMaia, Câmara Municipal da Maia.** *Prestação de Contas 2007 – Relatório de Gestão.* Maia : Câmara Municipal da Maia, 2008.

12. **Innovation Point, SA.** FACT_sheet.Municipalities. *where-to-invest-in-portugal.com.* [Online] Innovation Point S.A., 2008. [Citação: 23 de Agosto de 2008.] http://where-to-invest-in-portugal.com/Default.aspx?CultureID=pt-PT.

13. **RIVM; Staatsen, BAM; Nijland, HA; Kempen, EMM van; Hollander, AEM de; Franssen, AEM; Kamp, I van.** *Assessment of health impacts and policy options in relation to transport-related noise exposures.* [Report] Bilthoven : RIVM, 2004. http://www.rivm.nl/bibliotheek/rapporten/815120002.pdf. RIVM rapport 815120002/2004.

14. **Bickel, P., et al.** *Deliverable 5 - Proposal for Harmonised Guidelines.* Stuttgart : HEATCO - Developing Harmonised European Approaches for Transport Costing and Project Assessment, 2006. Contract No. FP6-2002-SSP-1/502481.

15. **Bickel, P.** *Derivation of fall-back values for impacts due to noise.* [Annex E to HEATCO Deliverable 5] Stuttgart : HEATCO - Developing Harmonised European Approaches for Transport Costing and Project Assessment, 2006. Contract No. FP6-2002-SSP-1/502481.

16. **Navrud, S., Trædal, Y., Hunt, A., Longo, A., Greßmann, A., Leon, C., Espino, R., Markovitssomogyi, R., Meszaros, F.** *Economic values for key impacts valued in the Stated Preference .* [Deliverable 4] Stockholm : HEATCO - Developing Harmonised European Approaches for Transport Costing and Project Assessment, 2006. Contract No. FP6-2002-SSP-1/502481.

17. *The true cost of road traffic noise in Portugal.* **Rocha, C. and Carvalho, A.** Ottawa, Canada : I-INCE, International Institute of Noise Control Engineering, 2009. INTER-NOISE 2009 - Innovations in pratical noise control.

18. *Portuguese Real Estate Taxation, Land Use and Noise.* **Rocha, C. and Carvalho, A.** Shanghai, China : I-INCE, International Institute of Noise Control Engineering, 2008. INTER-NOISE 2008 - From silence to harmony. p. 18.

19. **Walls, J. and Smith, M.** *Life-Cycle Cost Analysis in Pavement Design – In Search of Better Investment Decisions;.* [Pavement Division Interim Technical Bulletin] Washington : Federal Highway Administration; US. Department of Transportation, 1998. Publication No. FHWA-SA-98-079.

20. **Carvalho, A. e Rocha, C.** *Manual Técnico para a elaboração de Planos Municipais de Redução de Ruído.* Lisboa : APA - Agência Portuguesa do Ambiente, 2008.

21. **Costa, H.** *Análise de Custos de Ciclo de Vida Relativa a Pavimentos Rodoviários Flexíveis.* [MSc Thesis] Lisboa : Instituto Superior Técnico - Universidade Técnica de Lisboa, 2008.

22. **IA, Instituto do Ambiente, et al.** *Exposição da População a Ruído Ambiente (Exposed Population to Environmental Noise).* [Situation Report] Amadora : IA - Instituto do Ambiente, 2006.

23. **Maroco, J.** *Análise estatística : com utilização do SPSS.* 3rd Edition. Lisboa : Edições Sílabo, 2007. p. 824 p. ISBN: 9789726184522.

24. **Branco, J.A.** *Uma introdução à análise de clusters.* Évora : Sociedade Portuguesa de Estatística, 2004. ISBN: 972-98619-9-4.

25. **Bickel, P. and Friedrich, R.** *Estimating Environmental Costs using the Impact Pathway Approach.* Stuttgart : UNITE - UNIfication of accounts and marginal costs for Transport Efficiency, 2001. Project funded by the European Commission. http://www.its.leeds.ac.uk/projects/unite/paris/bickel.pdf.

26. **M. Maibach, C. Schreyer, D. Sutter (INFRAS), et al.** *Handbook on estimation of external costs in the transport sector.* Delft : Delft, CE, 2008. Produced within the study Internalisation Measures and Policies for All external Cost of Transport (IMPACT): Version 1.1. CE publications available from www.ce.nl. Publication number: 07.4288.52.

27. **Bickel, P.; (IER), S. Schmid; Tervonen, J.; Hämekoski, K.; Otterström, T; (EKONO), Peter Anton; Enei, Riccardo; Leone, G. (ISIS); Donselaar, P.van; Carmigchelt, H. (NEI).** *Deliverable 11: Environmental Marginal Cost Case Studies.* Stuttgart : IER, University of Stuttgart, 2003. UNITE (UNIfication of accounts and marginal costs for Transport Efficiency): Version No: 2.0. Working Funded by 5th Framework RTD Programme.

28. **L.C. (Eelco) den Boer, A. (Arno) Schroten.** *Traffic noise reduction in Europe.* [Report] Delft : CE Delft, 2007. Commissioned by: T&E Brussels. Publication code: 07.4451.27.

29. **Miedema, H.M.E. e Oudshoorn, C.G.M.** Annoyance from Transportation Noise: Relationships with Exposure Metrics DNL and DENL and Their Confidence Intervals. *Environmental Health Perspectives.* 2001, Vol. 109, 4, pp. 409-416.

30. **Miedema, H.M.E., Passchier-Vermeer, W. e Vos, H.** *Elements for a position paper on night-time transportation noise and sleep disturbance.* [Report] Delft : TNO Netherlands Organisation for Applied Scientific Research: Department of Environment and Health, 2003. TNO Inro report 2002-59.

31. **WGHSA, Working Group on Health and Socio-Economic Aspects.** *Position Paper on Dose-effect relationships for night time noise.* s.l. : European Commission Working Group on Health and Socio-Economic Aspects, 2004.

32. **EC, EUROPEAN COMMISSION (WG2 - Dose/Effect).** *Position paper on dose response relationships between transportation noise and annoyance.* [Position Paper] Luxembourg : Office for Official Publications of the European Communities, 2002. ISBN 92-894-3894-0.