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NOISE CONTROL FOR A BETTER ENVIRONMENT

METHODOLOGY FOR DEVELOPING AND PRIORITIZING PROPOSED STRATEGIES AND ACTIONS IN NOISE ACTION PLAN OF ROADS

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ABSTRACT

A noise action plan for a road network must give the answer to certain relevant questions, such as: where, when and how to tackle noise pollution? Which are the criteria to choose the location to start? This article presents an action prioritizing method based on a multi-criteria analysis of the following variables: the amount of affected people, the acoustic level of the affection, the landscaping, the efficacy and the ease of implementation of the measure, as well as the cost-benefit analysis. This has been applied to more than three thousand kilometres of Spanish roads.

Key words: Plant Noise Control, Noise Action Plan, Environmental Noise.
I-INCE Classification of Subject Number: 55 Outdoor plant noise control (design and construction)

1. INTRODUCTION

The Noise Action Plan for a network of major roads must aim to:

- Comply with the legislation which sets the obligation to elaborate it through strategic noise maps [1].
- Identify the areas where the population is most exposed to acoustic levels beyond the authorized limits.
- Put forward measures to minimize harmful effects on the people concerned.
- Set out actions which are as efficient as possible.
- Establish an economic investment, as well as its scheduling.

To achieve these goals, it is necessary to design a methodological procedure which determines, develops and sequences each one of the duties that the technical team in charge of the action plan must undertake.

2. DECISION MAKING SYSTEM

The hotspots identified through the strategic noise mapping can help obtain a rough approximation of the areas where the actions are to be implemented. Spanish Acoustic Quality Goals are not fulfilled at those hotspots. Therefore, it may seem evident that those are the areas subject to measures against noise.

However, hotspots do not quantify the number of people affected so, in order to determine the areas in which action must be taken first, it is necessary to use additional criteria.

The technical staff responsible for the definition of noise action plans must rely on a decision making procedure which gives a systematic answer to certain basic questions concerning

“where and how to act against noise”

and also

“when and why there first”.

It is difficult to answer to those questions if we take into account dozens or hundreds of areas where legal limits are exceeded.

That is when doubts arise: What is more pressing: many people exposed to a slightly excessive noise or few people exposed to a highly excessive noise? Before answering to this question, it is essential to know the level of affection on people and to compute its concentration and location.

Whatever the case, Directive 2002/49/EC urges the competent administrative bodies to adopt action plans, so that problems are assessed and prioritized and measures sequenced and scheduled. There is no doubt that the administration must preserve environmental acoustic quality for every citizen. Nevertheless, it is essential to start taking action where it is most urgent, i. e., where exposure levels may affect human health and where the largest amount of people can benefit from it. That is why the noise level and the extension of the affection to a vast amount of citizens must be taken into account to select the locations and areas where the acoustic intervention is most needed.

The decision making system is based on certain calculation algorithms and procedural duties and measures. In general terms, the system consists of three activities:

- Hotspots detection and hierarchical organization
- Definition, design and viability of improvement measures for the area’s acoustics
- Multi-criteria analysis to prioritize actions

The following sections develop the various procedures included in the decision making system.

2.1. Hotspots detection and hierarchical organization

The identification of hotspots is done through a Geographic Information System (GIS) and certain space-related procedures [2] [3]. The following images show an example of the sequenced procedure, taking the map of the façade exposure in a residential area as a starting point.

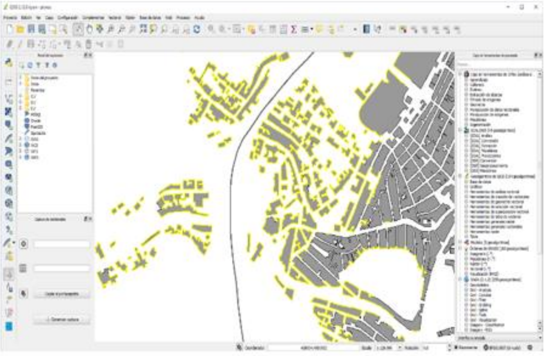

Figure 1. Selection of façades exposed to levels exceeding the Spanish Acoustic Quality Goals

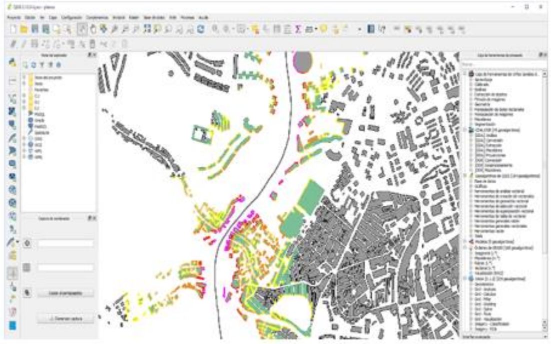

Figure 2. Identification of exposed residential buildings

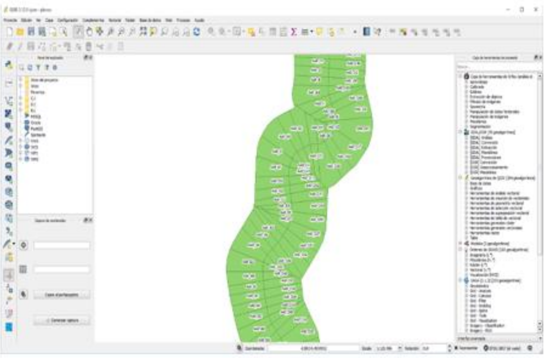

Figure 3. Road sectoring in both margins

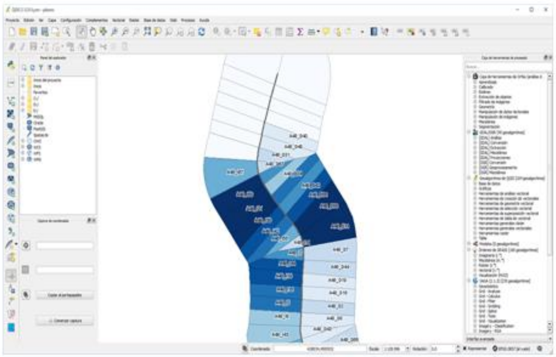

Figure 4. Affection results and classification per sector

Two spatial series (left and right) are therefore created, and they connect the number of exposed citizens in each kilometre point. This data may also be graphically depicted, thus allowing for the rapid detection of the areas with a high (relative) concentration of people undergoing façade exposure. This can be done by observing the peaks in the graph, which represent the priority areas (those which are subject to become hotspots).

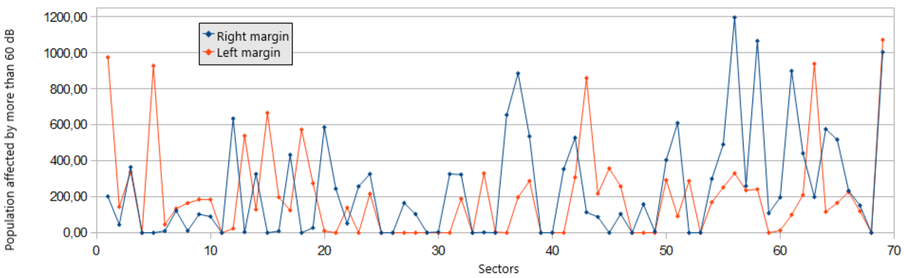

Figure 5. Representation of the population affected in each road sector

This procedure reveals the location of problems, but a different algorithm is necessary to empirically prioritize the affection in each sector. That is why SINCOSUR and the University of Cádiz [4] [5] [6] [7] have developed an algorithm called Environmental Noise Valuation Index (SVRA, as it is referred to in Spanish). It is formulated for day (1) and night (2) as follows:

$$SVRA(day) = \sum_{f=1}^{N} Pob_f \cdot 10^{0,05[Ld,f_f-(65+Fuente+Edi,f+Penaliz)]} \qquad (1)$$

$$SVRA(night) = \sum_{f=1}^{N} Pob_f \cdot 10^{0,084[Ln,f_f-(55+Fuente+Edi,f+Penaliz)]} \qquad (2)$$

Where

SVRA (day/night):	Environmental Noise Valuation Index (day/night)
f:	façades exposed (from no. 1 to N)
Pobf:	"f" façade exposed population
Ln,f and Ld,f:	"f" façade noise indicator
Edi,f:	abatement linked to the "f" façade building
Penaliz:	penalty related to noise characteristics

This will allow us to put the road sectors in order regarding the indicator value:

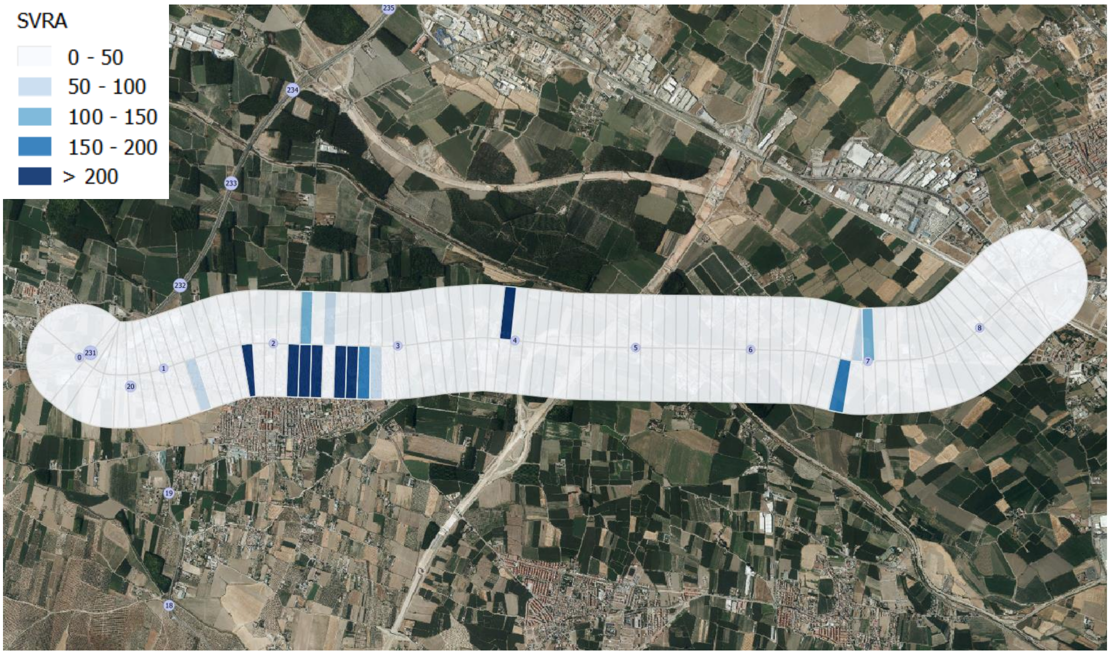

Figure 6. Colour-classified scale-based SVRA level per sector

Once the territory sectors have been classified through the previous procedures, several action scenarios are defined taking into account the following variables:

- Acoustic level in dB(A)
- Amount of people exposed
- SVRA indicator value

Road	Affected population	Starting scenario Ln > 55	Scenario 1 Ln > 55, POB > 25	Scenario 2 Ln > 55, POB > 50	Scenario 1 SVRA night > 100	Scenario 2 SVRA night > 150	Scenario 3 SVRA night > 200
A-92_GR.	2,008	167	26	3	11	3	2
A-92N_GR	130	29	0	0	0	0	0
A-92G	1,308	48	17	7	11	9	8
A-308	0	0	0	0	-	-	-
A-395	516	18	6	5	4	1	0
A-4006	308	3	3	3	2	2	0
A-4027	1	1	0	0	0	0	0
A-4028	23	4	0	0	0	0	0

Table 1. Defined scenarios

2.2. Definition, design and viability of improvement measures for the area's acoustics

In order to define the noise abatement measures on the hotspots exposed to road traffic noise, we will take into consideration the studies carried out by the European projects SILENCE [8] and SMILE [9]. These projects put forward recommendations for abatement measures, specifically in relation to road traffic.

Thanks to these projects, many proposals have been analyzed to tackle noise, particularly concerning road traffic, and its effects have been quantified. The following graphs belong to those documents.

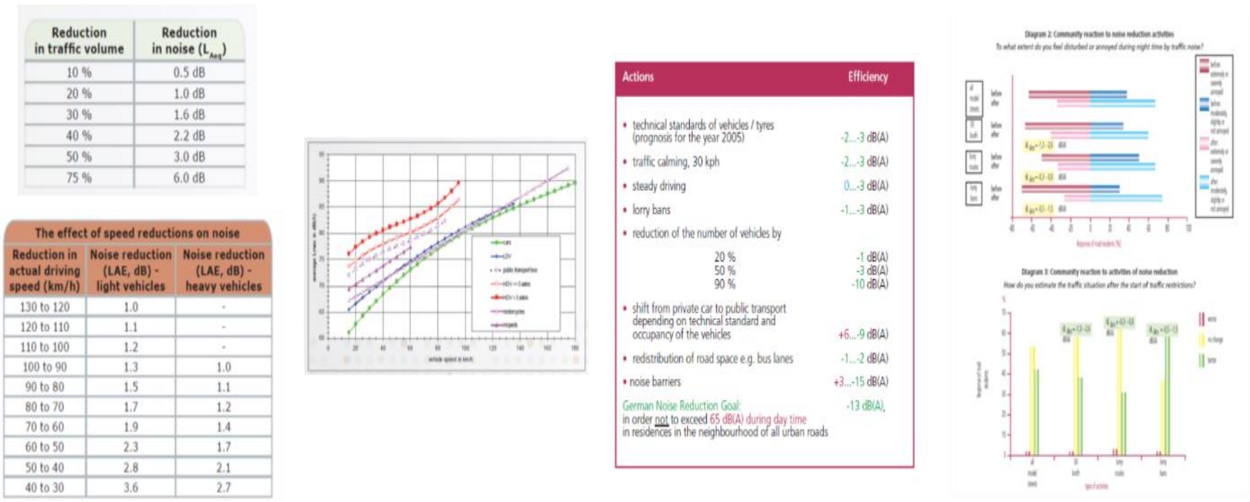

Figure 7. Abatement measures effectiveness assessment

On the basis of these studies plus the territory analysis, the measures will be proposed, always taking into account the special features of each area. This will be done by a viability assessment of the measure implementation. For example, the analysis for a noise barrier would apply the following process:

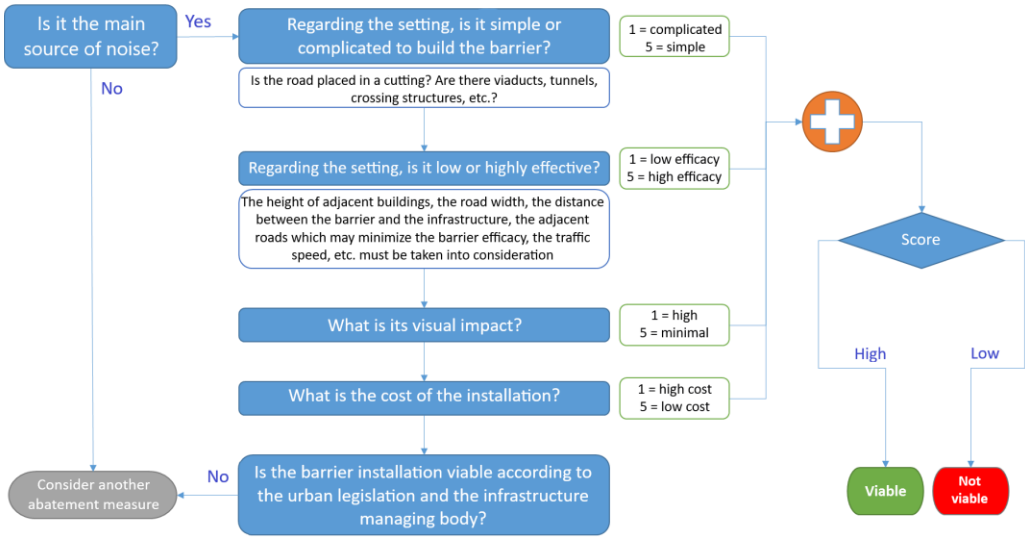

Figure 8. Noise barrier implementation viability

Once the viability of the proposed abatement measure has been verified, we estimate its cost, as well as the number of people who will no longer have to endure acoustic levels exceeding the legal limits, that is to say, we calculate the ratio between the cost and the person who benefits from the measure.

2. 3. - Multi-criteria analysis to prioritize actions

Through indicators and weights, the multi-criteria analysis assesses the results of the proposed measures which are difficult to quantify. The aim of this assessment is to synthesize the information necessary to choose, among all measures, the most suitable ones, taking into account their most relevant aspects and prioritizing them. The assessment criteria for this analysis include:

- the level of priority/urgency of the measure
- the affection acoustic level
- the complexity to install/build the abatement measure
- its visual impact
- its efficacy
- its efficiency

The methodology consists of seven stages:

Figure 9. Multi-criteria analysis methodology

The assessment criteria are the dimensions or factors to be used when weighing the options. More specifically:

- The level of priority/urgency of the measure for hotspots in residential areas matches the SVRA (environmental noise valuation) indicator.
- The acoustic level of the affection for vulnerable buildings is determined as the dB(A) value which the building undergoes.
- The installation/building of the measure means the ease or complexity to build, implement or install it, taking into account how traffic is affected.
- The visual impact is the level of visual perception of the measure by the affected population, taking also into consideration the loss of visibility.
- Efficacy is defined as the percentage of population that no longer has to undergo levels exceeding the Acoustic Quality Goals set by the current legislation.
- Efficiency is the cost, in euro, of decreasing a person exposure level to noise in dB(A).

Each criterion must have an assessment scale which formulation is based on an "indicator", as this will allow us to measure or estimate the performance of each alternative with regard to that specific criterion.

In this case, we set a homogenous scale from 0 to 10 for each indicator, where:

- 0 = the indicator has no value,
- 10 = the indicator has the maximum value,

and with the following indication:

- Level of priority/urgency of the measure: the level and the indicating value are directly proportional.
- Acoustic level of the affection: the level and the indicating value are directly proportional.
- Installation/building: the ease to install or build and the indicating value are directly proportional.
- Visual impact: the impact and the indicating value are inversely proportional.
- Efficacy: the percentage of people living below the Acoustic Quality Goals and the indicating value are directly proportional.
- Efficiency: the cost per person and dB(A) and the indicating value are inversely proportional.

Once the weighing scales and the values have been established, we will apply the following formula to compute the final score of the measures implementation on hotspots.

$$Scoring_M = \sum_{K=1}^{7} W_K \bullet V_{K,M} \qquad (3)$$

Where
$Scoring_M$ is the score obtained by hotspot "M"

W_K is the weight of criterion K in the decision (value function)

$V_{K,M}$ is a number between 0 and 10 which depends on the measurement scale of criterion K, assessed for hotspot M (assessment scale).

The measure which obtains the highest value will be the priority.

3. RESULTS OBTAINED FROM THREE THOUSAND KILOMETRES OF ROAD INFRASTRUCTURES

3. 1. Road Action Plan by the Regional Government of Canarias (year 2014)

All major roads with a traffic flow exceeding 3,000,000 vehicles per year were analyzed. The road sections meeting this condition accounted for a total amount of 950.77 km, distributed through the islands as follows:

ISLAND	Total amount of km estimated
Tenerife	401.43
La Palma	36.31
Gran Canaria	264.97
Lanzarote	103.40
Fuerteventura	144.66
TOTAL	**950.77**

Table 2. Major roads

After the application of the hotspots selection procedure, we defined a scenario with the following ones, also distributed through the islands:

Island	Number of hotspots NAP 2013 - 2017
Tenerife	33
Gran Canaria	31
Fuerteventura	0
La Palma	0
Lanzarote	2
TOTAL	66

Table 3. Hotspots

The prioritization established for those hotspots on the basis of the viability indicators resulted in the order shown in the following table, which presents the 10 hotspots with the highest priority.

Road	Hotspot number	Kilometre point	Length (m)	SVRA (day)	SVRA (night)
GC001	35	0+500 to 1+900	1,400	4,980.4	13,539.0

Road	Hotspot number	Kilometre point	Length (m)	SVRA (day)	SVRA (night)
GC001	34	0+000 to 0+500	500	5,198.0	11,046.7
TF005	10	1+000 to 2+800	1800	3,927.8	9,414.1
TF002	8	2+800 to 3+600	800	1,382.2	7,487.5
GC001	36	2+200 to 3+600	1,400	3,801.2	7,427.7
TF005	17	9+700 to 10+400	700	2,792.3	7,377.2
GC001	43	19+700 to 20+800	1,100	2,738.2	7,047.7
GC001	38	3+900 to 4+900	1,000	2,980.4	6,335.2
TF005	16	8+900 to 9+700	800	1639.3	4,271.4
TF005	14	6+000 to 7+100	1,100	1,444.9	3,263.3

Table 4. First ten hotspots prioritization

3. 2. Road Action Plan by the Regional Government of Galicia (year 2018)

The subject analyzed for the Action Plan by the Regional Government of Galicia consists of a two-staged noise mapping (with one stage in 2006; and the second one, in 2012) of the major roads in the region of Galicia.

PROVINCE	Km
1ST STAGE	
A CORUÑA	51.11
PONTEVEDRA	31.06
2ND STAGE	
A CORUÑA	224.79
LUGO	7.11
OURENSE	32.78
PONTEVEDRA	246.8
KM (TOTAL)	**593.65**

Table 5. Major roads per province

After the application of the hotspots selection procedure, we defined a scenario with 39 of them:

Hotspot Number	Road	Assessed Km	ROAD SECTION ID
PC-2	AC - 162	4,39	0 - 0+400

Hotspot Number	Road	Assessed Km	ROAD SECTION ID
PC-4	AC-211	3,51	0+000 – 0+500
PC-8	AC –305	7,28	32+600 -33+200
PC-9			35+300 -34+200
PC-10			38+400 -39+600
PC-11	AC - 415	5,07	0+000 – 0+100
PC-12	AC - 543	1,24	6+500 - 7+280

Table 6. Hotspots (only the top 12)

The prioritization established for those hotspots on the basis of the viability indicators resulted in the order shown in the following table, which presents the 10 hotspots with the highest priority.

	1	2	3	4	5	6	7	8	9	10
HOTSPOT	**PC-10**	**PC-12**	**PC-9**	**PC-8**	**PC-14**	**PC-44**	**PC-13**	**PC-22**	**PC-1**	**PC-23**
SCORE	**760**	**725**	**520**	**515**	**505**	**415**	**415**	**355**	**297.5**	**200**

Table 7. Hotspots prioritization

3. 3. Road Action Plan by the Regional Government of Andalusia (year 2018)

The major roads from the Andalusian road network with a traffic flow exceeding 3,000,000 vehicles per year account for 1,333.239 km. They are distributed throughout the provinces as follows:

- ALMERÍA: 11 Strategic Map Units, with a total length of 185.035 km.
- CÁDIZ: 11 Strategic Map Units, with a total length of 219.124 km.
- CÓRDOBA: 4 Strategic Map Units, with a total length of 21.680 km.
- GRANADA: 8 Strategic Map Units, with a total length of 253.780 km.
- JAÉN: 2 Strategic Map Units, with a total length of 43.470 km.
- HUELVA: 11 Strategic Map Units, with a total length of 110.020 km.
- MÁLAGA: 16 Strategic Map Units, with a total length of 192.095 km.
- SEVILLE: 33 Strategic Map Units, with a total length of 308.035 km.

After the application of the hotspots selection procedure, we defined a scenario with 52 of them:

PROVINCE	HOTSPOTS
Almería	5
Cádiz	2
Córdoba	3
Granada	4
Huelva	1
Jaén	0
Málaga	10
Seville	27
TOTAL	**52**

Table 8. Hotspots per province

The prioritization established for those hotspots on the basis of the viability indicators resulted in the order shown in the following table, which presents the 10 hotspots with the highest priority.

PRIORITY	ROAD	LOCATION	SVRA	Highest population
1	A-92_SE	(SE-30) - LIM. PROV. MÁLAGA:	3,286	601
2	A-431	CÓRDOBA - VILLARUBIA (CO-3314)	1,490	777
3	A-368	BENALMÁDENA (A-7) - TORREMOLINOS	1331	745
4	A-376	SEVILLE (SE-30) - UTRERA (A-362)	1,232	560
5	A-92G	SANTA FE (A-92) - GRANADA (N-432)	1,171	205
6	A-392	DOS HERMANAS -ALCALÁ DE GUADAÍRA	804	331
7	A-8058	SEVILLE (SE-30) - LA PUEBLA DEL RÍO	610	226
8	A-8002	SAN JOSÉ DE LA RINCONADA (A-8004)	553	150
9	A-7282	ENTRANCE TO ANTEQUERA (A-7283 - A-343)	527	273
10	A-7057	CÁRTAMA (A-7059)	418	131

Table 8. Hotspots prioritization

4. CONCLUSIONS

The decision making system hereby presented has been applied to a network consisting of more than three thousand kilometres of major roads, it has located their hotspots and prioritized the actions proposed for them. This has allowed for the design of an action plan, in order for the competent authorities to undertake the economic investments necessary for the most urgent measures.

The system has proved to be suitable after action plans from stages 1 and 2 have been compared with the application of the same methodology and the priority areas have coincided.

It represents a tool which will provide action plans designers with a systematized procedure to identify hotspots and prioritize action, taking into account the number of people affected, the affection acoustic level, the measure landscaping, its ease of installation, its efficacy and its cost-benefit analysis.

5. ACKNOWLEDGEMENTS

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