DELIVERABLE 3.3.2

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PROJECT N°	**FP7-233655**		
ACRONYM	**CITYHUSH**		
TITLE	**Acoustically Green Road Vehicles and City Areas**		
Work Package 3	**Noise and vibration control at source**		
3.3	**Creating a low noise road surface for inner city use**		
	Cost/benefit analysis of low noise road surface		
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Dissemination Level

PU	Public	✓
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restrictec to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for the members of the consortium (including the Commission Services)	

Nature of Deliverable

R	Report	✓
P	Prototype	
D	Demonstrator	
O	Other	

SEVENTH FRAMEWORK PROGRAMME

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0 EXECUTIVE SUMMARY

0.1 OBJECTIVE OF THE DELIVERABLE

To develop and evaluate methodologies for Cost Benefit Analysis for the comparison of action plans of Low Noise Road Pavement.

Low noise road pavements are often more expensive, not because their initial cost but mostly due to higher maintenance: the top layer has to be refurbished more often.

On the other hand (benefit), there is a certain "Willingness to Pay" for a reduced noise annoyance.

The efficiency of one action plan compared to a second, then can be evaluated not only on a cost versus dB factor but also on a quantifiable monetary value.

Further, hot spot identification methods are evaluated to prioritising the application of the low noise pavements.

The methodology will be tested on both a larger region and a smaller agglomeration.

0.2 DESCRIPTION OF THE WORK PERFORMED SINCE THE BEGINNING OF THE PROJECT

The study has been carried out according to plan and is terminated. This is the final report.

0.3 MAIN RESULTS ACHIEVED SO FAR

Study is terminated. See §0.4.

0.4 FINAL RESULTS

For benefit analysis, a monetarisation method based on noise dose effect relations (as proposed by Heatco) has been retained as very valuable.

It has been indicated that for larger regions, simple low noise road pavements such as standard porous asphalt give very positive results. More sophisticated low noise road pavements give a higher noise reduction, but are much more difficult to recommend based on cost benefit analysis.

For agglomerations, low noise road pavements alone are not sufficient to reduce the noise annoyance sufficient.

0.5 POTENTIAL IMPACT AND USE

The methods set forward can be used by noise action planners to evaluate in more detail the effect of low noise pavements as action plans.

It is illustrated that at least simple low noise road pavements should be applied: the cost benefit analysis showed that the return on investment is very high. The "Willingness to Pay" for such measures exceeds the additional costs for implementation.

The use of hot spot identification methods has been demonstrated and shown to give additional information on the prioritising of refurbishment of road pavements.

0.6 PARTNERS INVOLVED AND THEIR CONTRIBUTION

Akron

0.7 CONCLUSIONS

The study has been carried out according to plan.

The report given hereafter summarizes the study.

The results of the study have been presented and disseminated on the Polis Conference in Perugia (November 2012) and the City Hush workshop in Stockholm (December 2012).

1 INTRODUCTION

In almost all regions in Europe, the use of low noise road pavements is selected as an action plan within the requirements of the European Directive of Strategic Noise Mapping and Action Planning.

However, the real realisation on the field is sometimes limited by financial implications: the cost is thought to be too high.

In this study, it is sought to develop a Cost Benefit Analysis (CBA) procedure to better estimate the real cost, but also to better valuate the benefits of low noise road pavements. By this approach, it is hoped to find additional arguments to implement more and/or faster additional low noise road pavements.

Different approaches for both the estimation of costs, and of benefits will be proposed. Further, they will be evaluated for application in both, a larger region and an agglomeration.

In addition to this, automated calculation and visualisation methods of hot spot identification of noise problems are evaluated as a method for optimisation of the application of low noise pavements: prioritising of road segments for renovation or refurbishing based on the number of people annoyed. Those methods will be applied to the same examples as used for the cost benefit analysis above.

2 COST BENEFIT ANALYSIS

Cost-benefit analysis (CBA) provides a means for systematically comparing the value of outcomes with the value of resources achieving the outcomes required. It measures the economic efficiency of the proposed approach. When all else is equal more efficient approaches should be chosen over less efficient ones. When there are many options to consider during a decision-making task, it is useful to evaluate the options with a common metric. Cost-benefit analysis refers to any type of structured method for evaluating decision options.

CBA has become widely accepted among business and governmental organisations. Although CBA has definite limitations, especially in the non-standard way that the payoff function is derived and calculated, its potential for making decisions more rational is comforting to those who must make the decisions. The presentation of a cost-benefit analysis is the preferred way to demonstrate the reasoning behind investments.

The CBA of measures against noise pollution comprise consequently:

- the costs of the measures;
- the reduction of the costs for public health;
- the willingness to pay: how much are people prepared to pay for a less noisier environment?

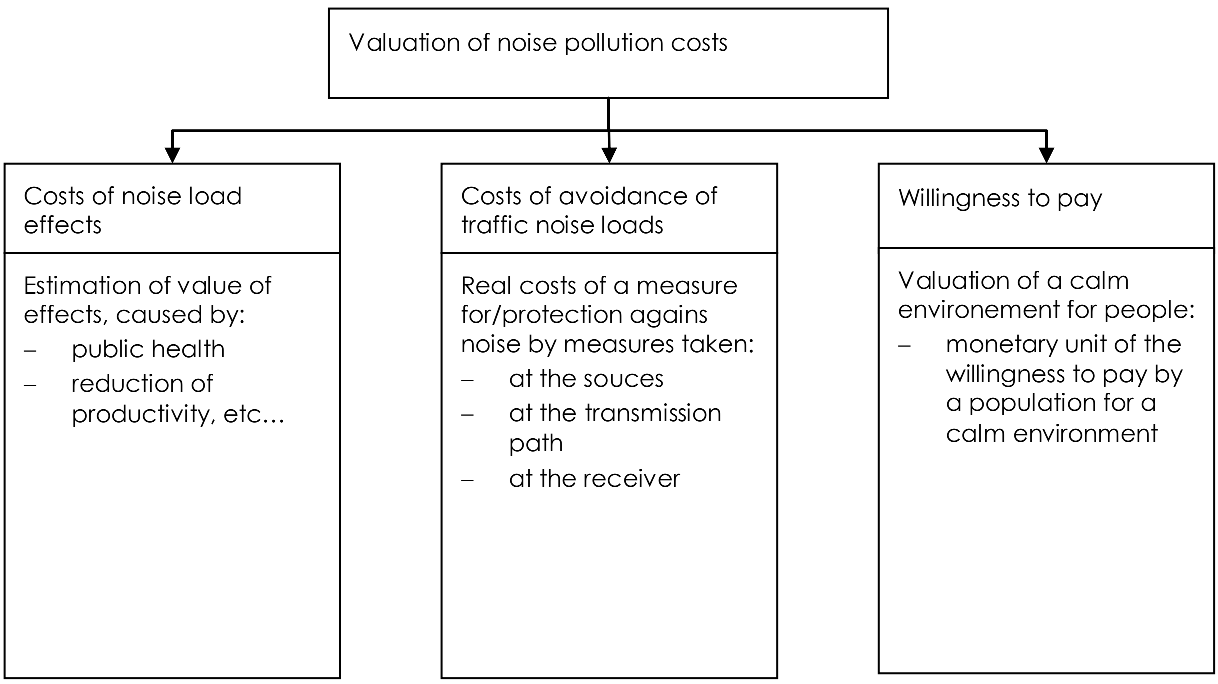


Figure 2.1.0 Evaluation of macro economical noise costs

For the evaluation of road pavements, this general approach can be applied,with omission of effects such as time savings and productivity reduction and costs at the transmission paths and at the receiver.

2.1 Benefits

Different methods for evaluation in reliable economic terms or even better, economic valuation have been proposed over the last 10 years. Three of these methods are given underneath.

2.1.1 WHSAE

Starting point and guideline was "Position Paper" of the European Work Group for health and socio-economic aspects, WHSEA, 2003 (ref. 2). This document proposes an approximate method to calculate the benefits, but also recognises the need for further research and study.

In this document and in general, distinction is made between:

- direct noise experience: effects such as low noise living areas and improved conversation are positive experiences that are immediately perceptible.
- health effects: effects on middle long or long term that are not immediately felt or experienced.

2.1.1.1 Direct noise experience

The benefits of noise reduction and more specifically of direct noise experiences have been studied extensively in the EU, of which the most noted are published by prof. Navrud (ref. 5).

Here also, different analyses are known:

- Stated Preference (SP) or contingent perception method: people are directly asked how much they are willing to pay for an improved noise environment.
- Hedonic Pricing (HP) or hedonistic perception method: a hedonistic evaluation that mainly takes into account a value reduction (rental value/purchase price) of buildings and plots in noise exposed areas. A number of studies on this subject have been executed in Switzerland, ref. 3 and recently in the United Kingdom, ref. 4.

With the evaluation, the WHSEA has chosen a price per living unit. The SP method (willingness to pay) was considered to be the most reliable method to obtain the benefit.

The retained willingness to pay was determined to be 25 €/household/decibel/year; or, based on 2.3 persons per household: 11 €/person/decibel/year, where noise pollution is expressed as L_{den} and is situated between 50 and 75 dB. This monetary value has a wide margin (the above willingness to pay of 25 € per household was deducted from different studies, in which the lowest estimation was 2 € per household and the highest 99 € per household).

2.1.1.2 Health effects

The WHSEA noted that also implicit health costs needed to be included, but more information or numbers were not given.

This information can however be found in other studies, where the study of the VITO, ref. 53, gives the specific numbers for Flanders. This study concerns the quantification of health risks based on DALYs and external health costs.

This study calculated that for Flanders, the global external health cost, due to noise, was 268 million €, mainly caused by perceived impacts (which are serious noise pollution and serious sleep disturbance: 232 million €). Preventing hospitalisation and death and their contribution in the health costs is much smaller: 36 million €.

This means that the above benefits for the direct noise experiences must be multiplied by a factor 1.15 to calculate the total benefits.

This means a benefit of 12.5€/person/decibel/year.

2.1.1.3 Conclusions

For comparison with other valuation methods, a correction for inflation has to be made (2002 -> 2010 : 3%/year – 28%).

Globally this means a benefit of 16 €/person/decibel/year.

2.1.2 HeatCo

A more detailed approach for carrying out CBA can be the HEATCO methodology [5].

HEATCO's primary objective was the development of global and harmonised guidelines for project assessment at an EU level, principally on transportation related projects and for differing country methodologies. This included the provision of a consistent framework for monetary valuation with transport costing.

This method is also used in Delivery 2.3.1 for the evaluation of Q-zones and is not repeated hereafter.

The HEATCO team identified certain elements for a consistent framework for project appraisal on an EU-level. For road traffic, that framework included:

- Value of time and congestion (incl. business passenger traffic, non-work passenger traffic etc), and most importantly;
- Environmental costs (incl. air pollution, noise and global warming).

The suggested impact indicator, which should be reported alongside the monetary results, is the number of persons highly annoyed. All values include health effects and annoyance and central values comprise the WTP (Willingness to Pay) for reducing annoyance, based on stated preference studies (see Working group on health and socio-economic aspects, 2003).

- Annoyance was based on dose-response functions;
- Monetary values were taken from the HEATCO surveys (see Navrud et al. 2006.

Elsewhere, studies carried out by the World Health Organisation (WHO - Burden of disease from environmental noise, 2011) have considered the extent to which exposure to noise results in a reduction in life expectancy, which is expressed as **D**isability **A**djusted **L**ife **Y**ears (DALYs). Whilst the study is useful in understanding the effects of exposure to high levels of noise, it does not provide any additional information in respect of the costs of noise exposure. Therefor, different to the first method, indirect (health) cost were not taken into account in the “Heatco” method.

2.1.2.1 Willingness to Pay (Navrud)

Within Heatco, updated studies were carried out by Navrud and co. (ref 6), to evaluate the WTP (Willingness to Pay) for noise annoyance. For both road and rail noise, it was found that:

- for extreme, high and “regular” annoyance, the WTP was identical;
- for lower annoyance levels, the WTP decreased accordingly.

	Road	Rail
Highly annoyed	85 €	59 €
Annoyed	85 €	59 €
Little annoyed	37 €	38 €
Not annoyed	0 €	0 €

Table 2.1.1 Recommended values for annoyance categorys for road (2005-€ per annoyed person per year) – according to Navrud (ref 6)

Therefore, a new monetarisation table can be established, with an increase of WTP for the higher noise values (column 1 of table 2.1.2): ±13 € below 70 dB(A); ±22 € above 70 dB(A).

2.1.2.2 Noise-Dose Relations (Heatco)

According to Heatco studies, the valuation should be corrected by noise-dose relationships. The suggested impact indicator, which should be reported alongside with the monetary results, is the number of persons highly annoyed. (The monetary values are corrected, based on a default inter-temporal elasticity to GDP per capita growth of 3%.)

L_{den} dB(A)	WWT €	Dose Relation 80%	Cost factors €
≥51	14	3.3	0.5
≥52	26	3.7	1.0
≥53	40	4.2	1.7
≥54	53	4.6	2.5
≥55	66	5.1	3.4
≥56	80	5.6	4.5
≥57	93	6.2	5.8
≥58	106	6.8	7.3
≥59	120	7.5	9.0
≥60	133	8.3	11.0
≥61	146	9.0	13.2
≥62	159	9.9	15.8
≥63	173	10.8	18.7
≥64	185	11.9	22.0
≥65	199	12.9	25.8
≥66	213	14.1	30.0
≥67	226	15.4	34.7
≥68	239	16.8	40.0
≥69	252	18.2	46.0
≥70	265	19.8	52.5

L_{den} dB(A)	WWT €	Dose Relation 80%	Cost factors €
≥71	353	21.5	75.7
≥72	375	23.3	87.1
≥73	397	25.2	99.8
≥74	419	27.2	114.0
≥75	442	29.4	129.7
≥76	463	31.7	146.7
≥77	486	34.1	165.6
≥78	508	36.7	186.4
≥79	530	39.4	208.9
≥80	552	42.3	233.6

Table 2.1.2. Valuation of benefit according to Heatco

Column 2 values comprise the WTP for reducing annoyance, based on stated preference studies (monetary values were taken from the HEATCO surveys (see Navrud et al. 2006)).

Column 4 values are based on dose-response functions; monetary values were taken from the HEATCO surveys.

2.2 Cost

2.2.1 Road Surface Type

Underneath a list of the most important road surfaces in Europe is given.
An evaluation is made for each road surface concerning acoustical performance and lifetime. Further, also a cost estimate will be carried out.

Hot Rolled Asphalt AB AB: Reference situation in this study. Asphalt with concrete parts. The emission is partly function of the size of the concrete inserts. Still used at lower speeds in many cities (with smaller size inserts). Expected lifetime: 15y.	
Split Mastic Asphalt SMA (picture: type SMA-C) Different types as function of grain type. A special type is SMA-D: smaller size; less noisy 1 dB, also can be used as thin layer (TL). SMA-C: acoustic same noise level as AB. Lifetime: 15y (SMA-D: 12y).	
Porous Asphalt: ZOA The absorption characteristics of the top layer can contribute to the reduction of the air-pumping and a partial absorption of the engine noise. A high absorption level requires at least 20% of openings. Reduction of rolling noise on porous asphalt is at least 3 dB(A); but is partially reduced by obturation by dirt, especially on ordinary roads. This has been taken into account. Lifetime: 8y - Acoustical value : -1.5 dB. Dual layer ZOA: small grain top layer; increased absorption (-2.5 dB) but shorter life-time (6y).	
Cement Concrete (CC) Since a few years, road surfaces are systematically treated with the procedure of chemical washing. The rolling noise for chemically washed cement concrete (0/20) is however still about 2 to 3 dB(A) higher than the reference surface. Two layered chemically washed concrete of which the top layer has a smaller grain size (0/6.3) corresponds acoustically with the reference surface. Life time: 30 years. CC (0/20): +4 dB CC (0/6.3): +3 dB BCC: +4 dB	

2.2.2 Cost Calculation

Costs of road surfaces are function of three parameters:

- type of road surface and the number of km of the type;
- width of the road;
- load of the road.

Width of the road

For the calculation of the width of the road, following scheme can be is used:

speed regime [km/h]	width per direction [m]
90 – 120	13
70	6
50	3.5

Table 2.2.1

Load of the road

Following relation is the construction (type and thickness of the sublayer and top layer), the speed and the building class of the road.

speed [km/u]	building class	total thickness (asphalt)
90-120	B1	22 cm
70	B3	20 cm
50	B5	17 cm

Table 2.2.2

Calculation of costs for refurbishment

The cost price calculations are made over a period of 30 years. After 30 years, both for asphalt and concrete, the total road including the sub-layer must be replaced. For asphalt, thin layers and others, the top layer needs additionally to be replaced once or more during the 30-year period (see §2.2.1).

Based on this, a price per running meter for each road type and building class can determined.

	SMA	TL	AB	ZOA	2-ZOA	CC	2-CC	BCC	ZOA-comp	SMA-comp	TL-comp
B1	611	955	611	858	1241	513	546	552	1001	757	1098
B3	216	372	216	327	510	210	225	228	435	322	480
B5	115	206	115	180	287	122	131	122	254	188	280

Table 2.2.3 Cost per km [€]

2.3 METHODOLOGY

2.3.1 Method 1: Standard Approach based on Noise mapping

Traffic noise pollution is quantified by following known methods:

- calculation of facade values, based on the European indicator L_{den};
- determination of the number of exposed persons – deducted from the facade values and the known number of persons per building.

All over Europe, these data are already available for all traffic sources from phase 1 of the strategic noise mapping according the European Directive.

After implementation of a measure of package of measures, the facade values are adapted (in accordance with the parametric estimation of the expected effect of the measure) and the number of exposed is recalculated.

This way, it can be shown how big (or small) the effect of the expected noise reduction is on the number of exposed.

The method includes eight individual steps.

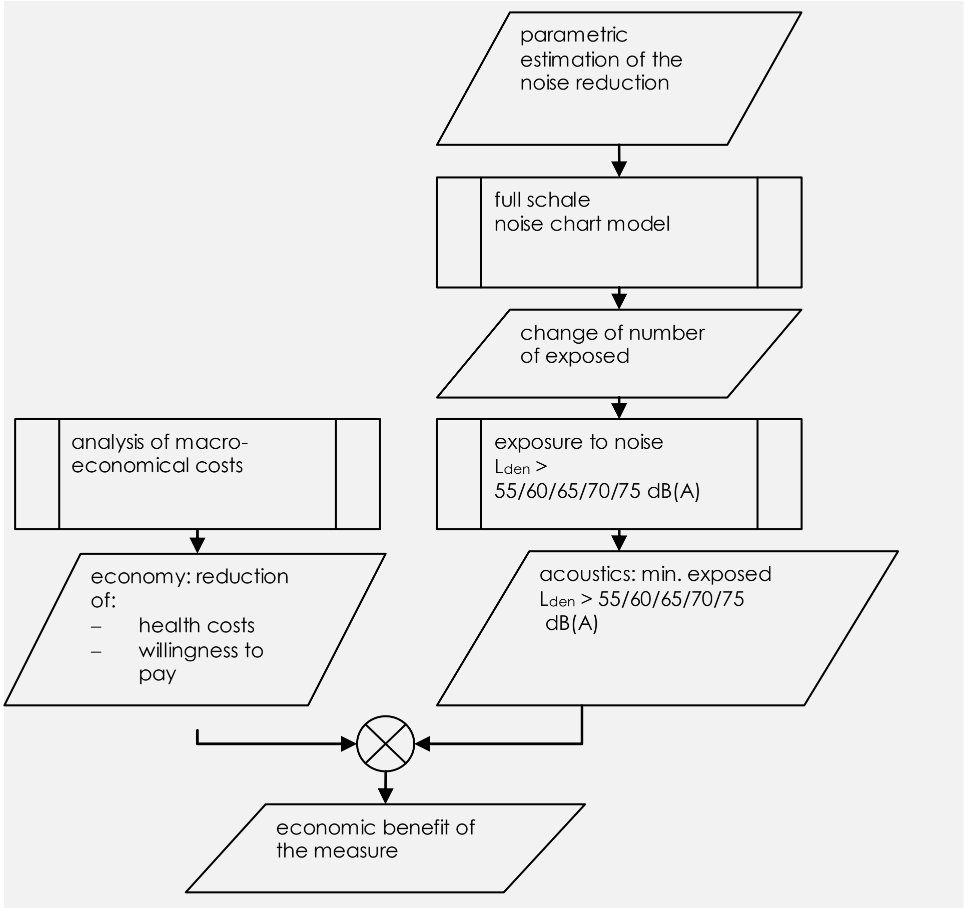


Figure 2.3.1

In full details, the benefits of a reduced exposure to traffic noise are calculated as follows (per ambition level):

- we start from the exposures after taking measures at the sources;
- per exposure interval we define the difference between the number of exposed in the reference situation and in the ambition level;
- per class, we multiply the number of persons by:
  - the difference between the considered class and the reference group: 5 dB for class 55-60, 10 dB for class 60-65, etc…
  - 16 € (the benefit per dB per habitant per year).

2.3.2 Method 2: Parametric evaluation

A more simplified method also can be used, avoiding the necessity of recalculating all facade levels. The method is based on the road types and speeds.

This can be done following the scheme underneath:

1. Identification of existing road surface pavements out of the road traffic model (EU noise-mapping).
2. Determination of noise reduction on basis of following assumptions:
   2.1 speed >= 90 km/h: considered to be primary roads;
   2.2 speed < 90 km/h: considered to be secondary roads;
   2.3 replace road pavements by proposed alternatives.
3. Determination of parametric noise reduction for each road type.
4. For each type of road pavement: calculation of noise reduction, weighted in function of the total length of that type of road.
5. Calculation of the average noise reduction for each region or agglomeration or other.

Then, the benefit can be calculated using the method above.

This method of course, can only be used for linear benefits.

2.3.3 Intermediate conclusions

All four different methods for valuation of low noise pavement will be calculated and evaluated on two test regions (see chapter 4):

- one typical European region, without major cities;
- one agglomeration: city of Antwerp.

3 HOT SPOT IDENTIFICATION

3.1 INTRODUCTION

Hot spot identification is an automated calculation and visualisation method for areas with important noise loads. For the application of low noise pavements, these methods can be very useful for prioritising of road segments for renovation or refurbishing based on the number of people annoyed. Those methods will be applied to the same examples as used for the cost benefit analysis above.

3.2 LITERATURE SURVEY

Generally, three methods can be distinguished to determine hot spots:

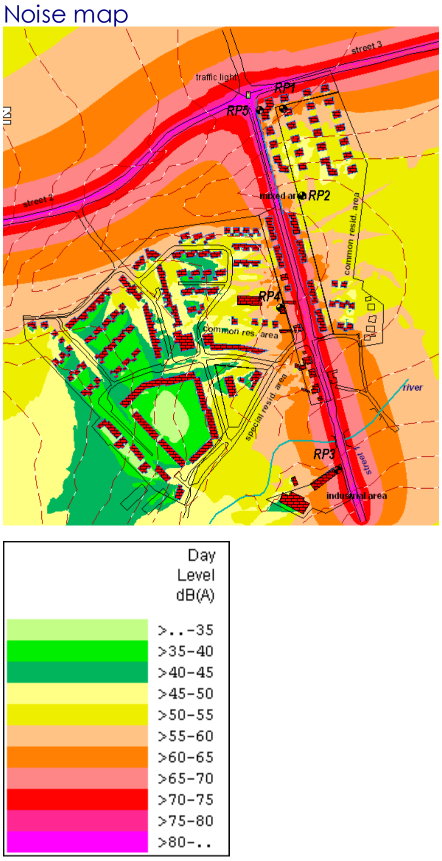
– type 1: a simple calculation of the exceedence of a ruling relevant limit or reference value;
– type 2: a coupling of calculated noise levels or of exceedences with the locally involved persons;
– type 3: a calculation of indicators for annoyance (L_{den}) and sleep disturbance, based on dose/effect relations, L_{den}/L_{night} and number of annoyed.

The calculation of hot spots (type 1) is simple (differentiation maps). The calculation of types 2 and 3 is new and was only recently introduced in commercial software. The currently available methods belong to types 2 and 3 and are described below.

3.2.1 Exceedance Maps

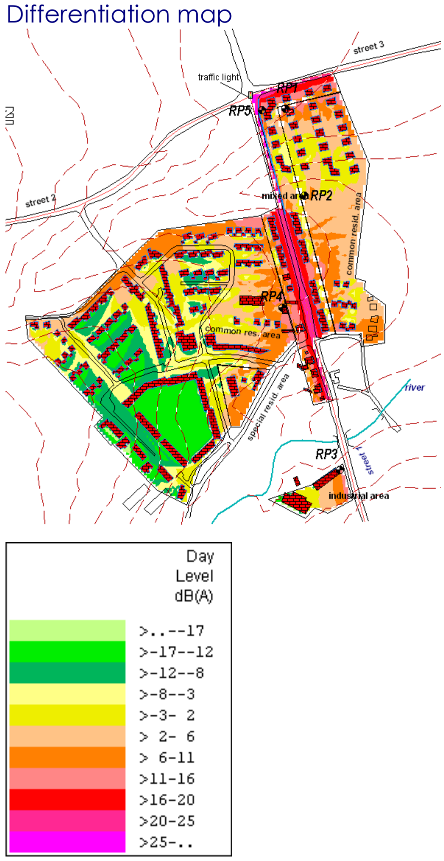
name	type	formula	IMMI	used where?
Exceedence map	1	L_{den} – reference value L_{night} - reference value	Yes	Annex 4 of the European guide line; frequently in Germany
Description	The simplest method consists in visualising the exceedences by drawing a differentiation map between the actual and wanted noise level. These can be legally imposed levels, but for Flanders as well general, local of differentiated environmental quality norms. In most software packages, this function is standard. An example is given below.			

Noise map



Zoning

Differentiation map



3.2.2 Percentage of Highly Annoyed (% HA)

<table>
<tr><th>name</th><th>type</th><th>formula</th><th>IMMI</th><th>used where?</th></tr>
<tr><td>%HA</td><td>3</td><td>Road noise level:
$\%HA = 9.868*10-4 (L_{den}-42)3$
$- 1.436*10-2 (L_{den}-42)2$
$+ 0.5118 (L_{den}-42)$</td><td>Yes</td><td>Recommended by workgroup HSEAN of the European Commission</td></tr>
<tr><td colspan="2">Description</td><td colspan="3">This method is mostly used on international level in the EU for annoyance in strategic noise maps. The annoyance indicator agrees with the formulas proposed by the European working group 2 and the HSEA in their recommendations.

It concerns actual annoyance during the day. Specific formulas have been developed on statistical basis, for each of the different sources of traffic noise: road, rail and air. The annoyance is defined at the most exposed facade of the dwelling. Initially, two parameters were defined: %A (Annoyed) and %HA (Highly Annoyed).

Starting point: the result of a calculation at the most exposed facade, with related to the dwelling, the number of exposed.

The procedure consist of following steps:
– calculation of the facade noise load (and known number of habitants per building);
– choice of an evaluation zone (grid, circle, …) e.g. 100 x 100 m;
– choice of the parameter: %A, %HA.

From this, the software calculates:
– the formation of a zone around the considered point;
– gathering of all facade points within this zone;
– adding up of all noise pollution according this parameter in this zone.
– this total noise pollution is related to the considered (central) point.

This results in a grid map with the noise pollution in each point. This map can be compared with the grid map of the residential distribution.</td></tr>
</table>

3.2.3 Percentage of Highly Sleep Disturbed (%HSD)

name	type	formula	IMMI	used where?
%HSD	3	Road Traffic Noise: $\%HSD = 20.8 - 1.05L_{night} + 0.01486(L_{night})$	Yes	Recommended by the work group HSEAN of the European Commission
Description		This method is mostly used on international level in the EU for annoyance in strategic noise maps. The annoyance indicator agrees with the formulas proposed by the European working group 2 and the HSEA in their recommendations. It concerns actual **annoyance during the night**. Specific formulas have been developed on statistical basis, for each of the different sources of traffic noise: road, rail and air. The annoyance is defined at the most exposed facade of the dwelling. Initially, two parameters were defined: %SD (Sleep Disturbed) and %HDS (Highly Sleep Disturbed). Starting point: the result of a calculation at the most exposed facade, with related to the dwelling, the number of habitants. The procedure consist of following steps: – calculation of the facade noise load (and known number of habitants per building); – choice of an evaluation zone (grid, circle, …) e.g. 100 x 100 m; – choice of the parameter: %SD, %HSD. From this, the software calculates: – the formation of a zone around the considered point; – gathering of all facade points within this zone; – adding up of all noise pollution according this parameter in this zone. – This total noise pollution is related to the considered (central) point. This results in a grid map with the noise pollution in each point. This map can be compared with the grid map of the residential distribution.		

3.2.4 LEG – “Lärm-Einwohner-Gleichwerte”

name	type	formula	IMMI	used where?
LEG	2	$LEG = \sum E_i \cdot 2^{(0{,}1\cdot(L_{r,i} - L_{GW}))})$	Yes	Germany
Description	LEG is short for Lärm-Einwohner-Gleichwerte (noise exposed equivalent). It is a quantity without unit. The parameters in the formula are defined as follows: – Ei = the i^th exposed; – Lr,i = i^th evaluation level; – LGW = limit value. Starting point: the result of a calculation at the most exposed facade, with related to the dwelling, the number of habitants. The procedure consist of following steps: – calculation of the facade noise load (and known number of habitants per building); – choice of an evaluation zone (grid, circle, …) e.g. 100 x 100 m; – choice of the parameter: %SD, %HSD. From this, the software calculates: – the formation of a zone around the considered point; – gathering of all facade points within this zone; – adding up of all noise pollution according this parameter in this zone. – This total noise pollution is related to the considered (central) point. This results in a grid map with the noise pollution in each point. This map can be compared with the grid map of the residential distribution.			

3.2.5 LKZ – Lärm-Kenn-Ziffer

name	type	formula	IMMI	used where?
LKZ	2	$LKZ = \sum E_i \cdot (L_{r,i} - L_{GW})$	Yes	Germany
Description	Is a quantity without unit. The parameters in the formula are defined as follows: – Ei = the ith exposed; – Lr,i = ith evaluation level; – LGW = limit value. Starting point: the result of a calculation at the most exposed facade, with related to the dwelling, the number of habitants. The procedure consist of following steps: – calculation of the facade noise load (and known number of habitants per building); – choice of an evaluation zone (grid, circle, …) e.g. 100 x 100 m; – choice of the parameter: %SD, %HSD. From this, the software calculates: – the formation of a zone around the considered point; – gathering of all facade points within this zone; – adding up of all noise pollution according this parameter in this zone. – This total noise pollution is related to the considered (central) point. This results in a grid map with the noise pollution in each point. This map can be compared with the grid map of the residential distribution.			

3.2.6 PB – "Priorisierung Bayern"

name	type	formula	IMMI	used where?
PB	2	$P = \sum E_i \cdot (2^{0,1 \cdot L_{r,i}} - 2^{0,1 \cdot L_{GW}})$	Yes	Bavaria (Germany)
Description	It is a quantity without unit. The parameters in the formula are defined as follows: – Ei = the i[th] exposed; – Lr,i = i[th] evaluation level; – LGW = limit value. Starting point: the result of a calculation at the most exposed facade, with related to the dwelling, the number of habitants. The procedure consist of following steps: – calculation of the facade noise load (and known number of habitants per building); – choice of an evaluation zone (grid, circle, …) e.g. 100 x 100 m; – choice of the parameter: %SD, %HSD. From this, the software calculates: – the formation of a zone around the considered point; – gathering of all facade points within this zone; – adding up of all noise pollution according this parameter in this zone. – This total noise pollution is related to the considered (central) point. This results in a grid map with the noise pollution in each point. This map can be compared with the grid map of the residential distribution.			

3.2.7 UCE_{den}

name	type	formula	IMMI	used where?
UCE_{den}	2	$UCE_{den} = 10 * \log_{10} \sum_{i=1}^{N} 10^{\frac{L_i + L_c}{10}}$	No	Luxemburg (Walloon Region)

Description

UCE_{DEN} can be used for rail as well as for road traffic.

UCE is short for 'Unité Comparative d'Exposition au bruit des transports terrestres' (Comparative unit of exposure to noise from terrestrial transports). A surface or zone is described by the combination of the number of exposed and the L_{den} level of those actually exposed.

LKZ is a quantity without unit. The parameters in the formula are defined as follows:

- ***N*** = number of habitants
- ***Li*** = Average level:
  - 57,5 dB(A) for a reach of "55-60 dB(A)",
  - 62,5 dB(A) for a reach of "60-65 dB(A)",
  - 67,5 dB(A) for a reach of "65-70 dB(A)",

  for L_{den} > 70 dB(A) the real level is used instead of an average
- ***Lc*** = Correction value for:
  schools L_c = + 5 dB(A), and for
  hospitals L_c = + 10 dB(A)

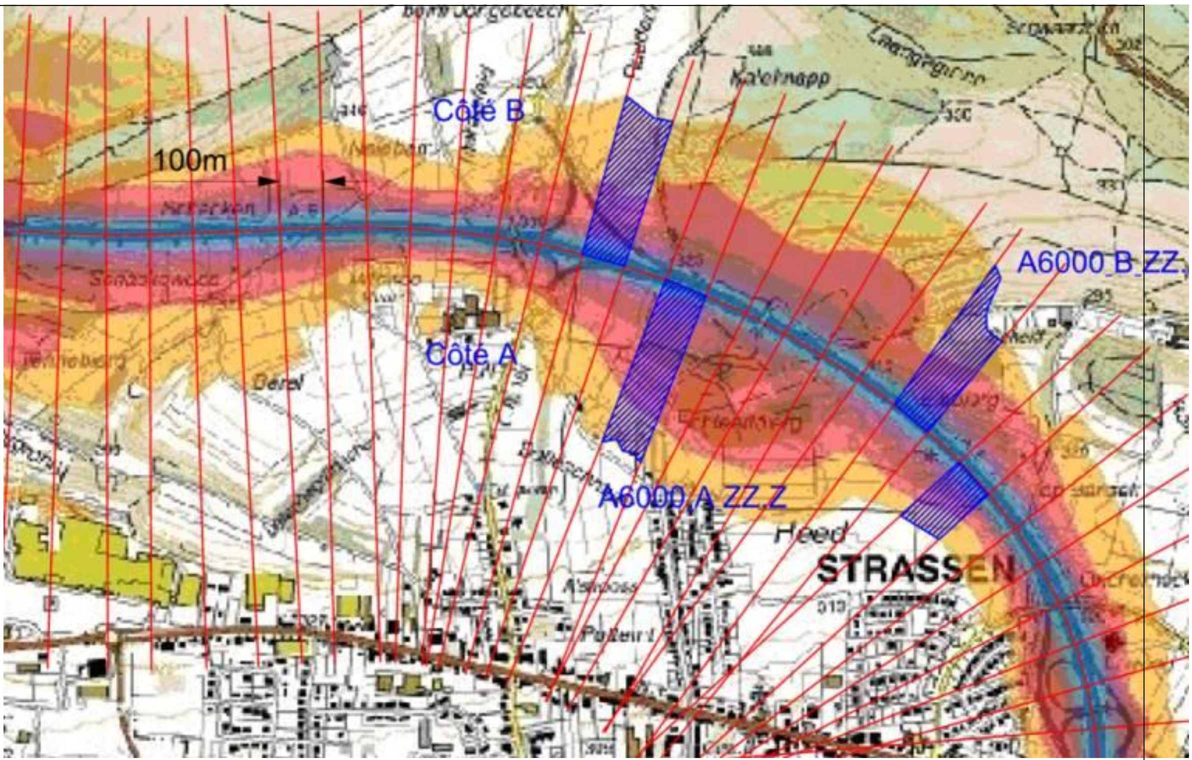
From this is concluded that for all following circumstances, identical UCE_{DEN} are calculated

Number of exposed	L_{den} [dB(A)]	UCE_{den} ----
1	67,5	67,5
3	60 – 65	67,5
10	55 – 60	67,5

The logarithmic addition in the calculation of UCE_{den} gives a much stronger weight to high noise levels than to low ones. UCE_{den} can be used in cases where a correction value of $L_c > 0$ is used.

It is a type 2 indicator: multiplication of an L_{den} with the number of exposed to this L_{den}. It is not possible to compare UCE_{den} with L_{den}.

UCE_{den} is calculated for a reference surface. Each surface has a road segment of 100 m long as centre axle.

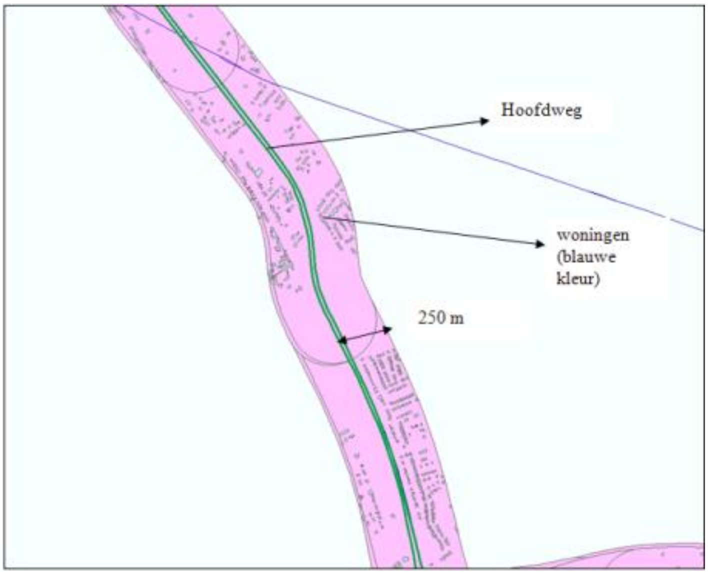


The sides of each zone are normal that run through the endpoint of a straight line segment of 100 m. The maximum distance of this centre axle is limited by the position of the isobar L_{den} = 55 dB(A).

3.2.8 Method of Flemish Government: Priority Map for realisation of Wayside Screening

<table>
<tr><th>name</th><th>type</th><th>formula</th><th>IMMI</th><th>used where?</th></tr>
<tr><td>MOW-Method</td><td>2/3</td><td></td><td>No</td><td>Flemish region</td></tr>
<tr><td colspan="2">Description</td><td colspan="3">

– make priority list
– only main and primary roads
– select dwellings within the 250 m-zone round main and primary road



– mark a buffer zone of 30 m around these dwellings

– add overlapping buffer zones to one zone
– manually add two zones of free standing dwellings to a defined zone if they belong together (see list of zones)
</td></tr>
</table>

– add a score per residential zone based on the known noise level of each dwelling in the residential area: logarithmic addition of noise level or using the MIEDEMA's formula: result is priority list.

3.3 PROPOSED HOT SPOT IDENTIFICATION METHOD FOR ROAD NOISE

As indicated in the previous paragraph, coupling of the acoustic data and habitation is necessary: determination of a dose/effect relation.

It is therefore necessary to work with facade noise loads of the dwellings, rather than with noise load maps. Those values can be coupled directly to the number of habitants of the dwelling. A hot spot defined by this method is based on the combination of a high noise level and an important number of habitants. This combination is best made via a psycho-acoustic relevant dose/effect relation, such as the formula of highly annoyed (%HA) as formulated above.

The spatial visualisation of this relation leads to a visual presentation/localisation of the hot spots.

Where this was already developed in the past for surface sources, it is more interesting for road and rail traffic to develop/visualise this linearly (along the road).

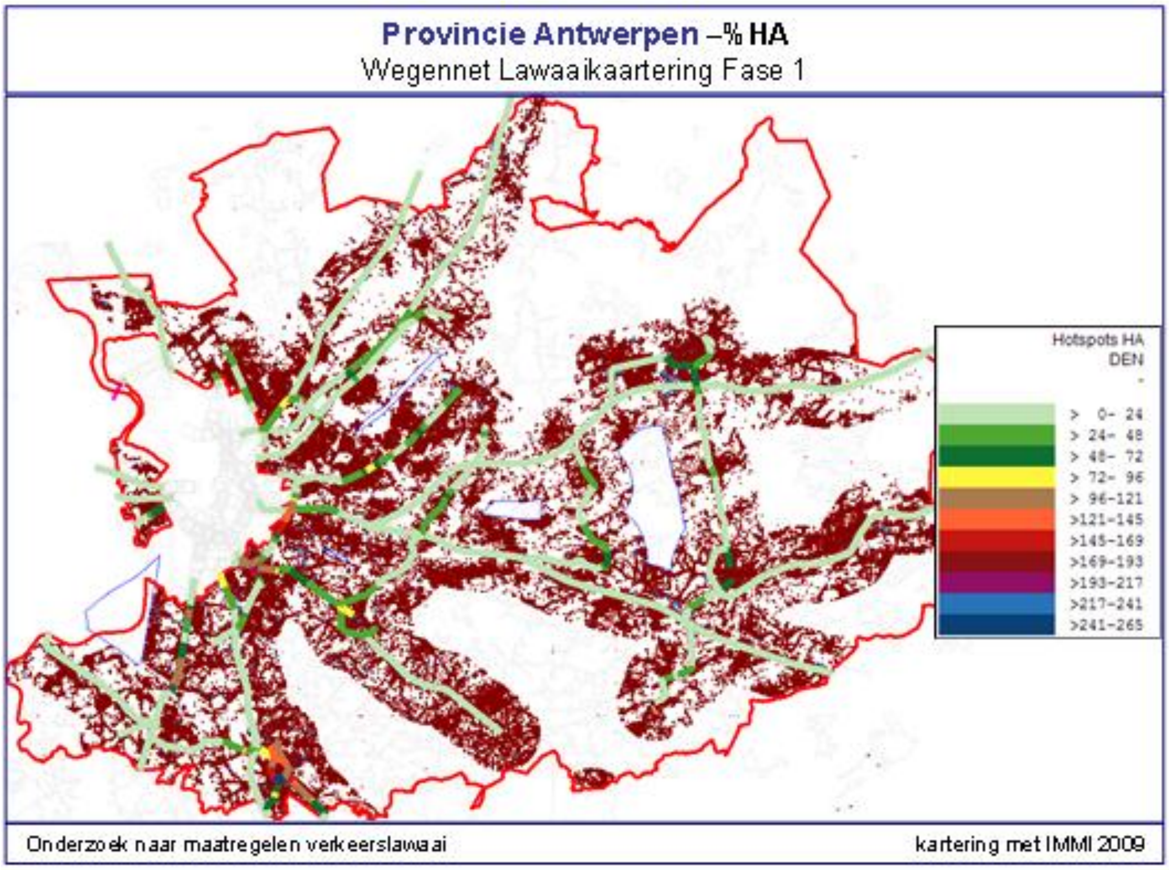
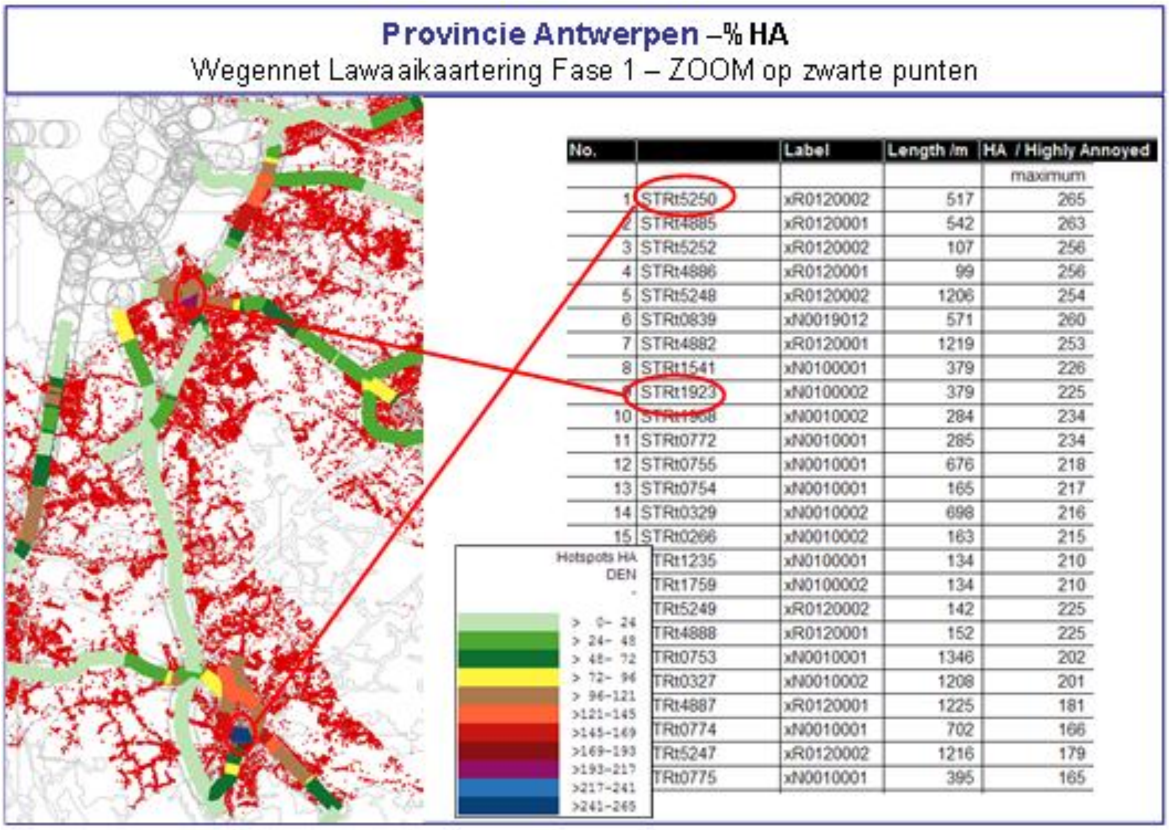


Figure 3.3.1

It is immediately visually clear that this map identifies the hot spots.

In addition, this automatic procedure allows to order a list of hot spots, e.g. per percentage highly annoyed (%HA), per road segment or per length unit (%HA/100m).



No.		Label	Length /m	HA / Highly Annoyed
				maximum
1	STRt5250	xR0120002	517	265
2	STRt4885	xR0120001	542	263
3	STRt5252	xR0120002	107	256
4	STRt4886	xR0120001	99	256
5	STRt5248	xR0120002	1206	254
6	STRt0839	xN0019012	571	260
7	STRt4882	xR0120001	1219	253
8	STRt1541	xN0100001	379	226
[illegible]	STRt1923	xN0100002	379	225
10	[illegible]	xN0010002	284	234
11	STRt0772	xN0010001	285	234
12	STRt0755	xN0010001	676	218
13	STRt0754	xN0010001	165	217
14	STRt0329	xN0010002	698	216
15	STRt0266	xN0010002	163	215
	TRt1235	xN0100001	134	210
	TRt1759	xN0100002	134	210
	TRt5249	xR0120002	142	225
	TRt4888	xR0120001	152	225
	TRt0753	xN0010001	1346	202
	TRt0327	xN0010002	1208	201
	TRt4887	xR0120001	1225	181
	TRt0774	xN0010001	702	166
	TRt5247	xR0120002	1216	179
	TRt0775	xN0010001	395	165

Figure 3.3.2

These maps are clearly a better approach for the identification of hot spots.

3.3.1 Source Identification

However, there is an extra step that will interest the action planner. Which source causes this noise level, or better a high number of annoyed?

Response to this is possible when the noise level is coupled to one defined (facade) point and the number of annoyed. For each point, it is then known which contribution each source element delivers.

This approach allows going further in the search for the cause of these hot spots. It is possible to appoint for each of these hot spots the dominant noise source.

Example

Facade noise load values and habitant information is available in the study of the strategic noise mapping. From this, the number of highly annoyed can be calculated according to the dose/effect relation, proposed by Miedema.

The importance of the annoyance for each of the sources is given in a table, ordered according to the number of highly annoyed (%HA).

No.		Label	Length /m	HA / Highly Annoyed		
				average	minimum	maximum
1	STRt5250	xR0120002	517	243	229	265
2	STRt4885	xR0120001	542	241	229	263
3	STRt5252	xR0120002	107	251	240	256
4	STRt4886	xR0120001	99	251	242	256
5	STRt5248	xR0120002	1206	103	44	254
6	STRt0839	xN0019012	571	228	202	260
7	STRt4882	xR0120001	1219	104	44	253
8	STRt1541	xN0100001	379	215	190	226
9	STRt1923	xN0100002	379	214	191	225
10	STRt1968	xN0010002	284	221	205	234
11	STRt0772	xN0010001	285	221	204	234
12	STRt0755	xN0010001	676	155	79	218
13	STRt0754	xN0010001	165	208	201	217
14	STRt0329	xN0010002	698	150	77	216
15	STRt0266	xN0010002	163	207	200	215
16	STRt1235	xN0100001	134	204	200	210
17	STRt1759	xN0100002	134	204	200	210
18	STRt5249	xR0120002	142	195	171	225
19	STRt4888	xR0120001	152	195	170	225
20	STRt0753	xN0010001	1346	115	40	202
21	STRt0327	xN0010002	1208	124	56	201
22	STRt4887	xR0120001	1225	127	64	181
23	STRt0774	xN0010001	702	123	58	166
24	STRt5247	xR0120002	1216	126	64	179
25	STRt0775	xN0010001	395	132	119	165
26	STRt5260	xR0110002	1011	156	105	182
27	STRt1969	xN0010002	700	122	58	163
28	STRt5279	xR0110001	1011	156	105	182
29	STRt1972	xN0010002	397	132	119	161
30	STRt1967	xN0010002	298	177	126	203
31	STRt0771	xN0010001	305	173	122	203
32	STRt1396	xN0100001	1260	125	102	192
33	STRt5302	xR0110001	952	119	45	192
34	STRt5269	xR0110002	952	119	45	192

Table 3.3.1

Not only shows this table the number of annoyed, but also a link to the dominant source (STRtxxxx). Source characteristics of this source element can be checked (road surface, number of vehicles, speed, …). A further analysis is possible either in a GIS environment or in a simple excel file. An example of such an excel file is given below.

No.		Label	Length /m	HA / Highly Annoyed				lichte		middelzware		zware		wegdek	wegcategorie
				average	minimum	maximum		aantal	snelheid	aantal	snelheid	aantal	snelheid		
1	STRt5250	xR0120002	517	243	229	265		417,3	50	21,7	50	83,2	50	201	Overigeweger
2	STRt4885	xR0120001	542	241	229	263		968,0	120	47,6	100	280,5	90	201	Hoofdwegen
3	STRt5252	xR0120002	107	251	240	256		429,0	50	22,3	50	85,5	50	201	Primairewege
4	STRt4886	xR0120001	99	251	242	256		2617,8	120	271,3	100	2067,6	90	207	Hoofdwegen
5	STRt5248	xR0120002	1206	103	44	254		429,0	50	22,3	50	85,5	50	201	Primairewege
6	STRt0839	xN0019012	571	228	202	260		682,5	60	55,7	60	53,9	60	203	Primairewege
7	STRt4882	xR0120001	1219	104	44	253		2434,6	120	292,2	100	749,7	90	201	Hoofdwegen
8	STRt1541	xN0100001	379	215	190	226		416,1	50	49,4	50	80,6	50	202	Overigeweger
9	STRt1923	xN0100002	379	214	191	225		560,8	50	33,7	50	40,5	50	203	Overigeweger
10	STRt1968	xN0010002	284	221	205	234		494,2	50	26,3	50	10,5	50	210	Overigeweger
11	STRt0772	xN0010001	285	221	204	234		585,5	50	30,6	50	37,9	50	202	Overigeweger
12	STRt0755	xN0010001	676	155	79	218		656,2	90	88,6	90	60,2	80	203	Primairewege
13	STRt0754	xN0010001	165	208	201	217		656,2	90	88,6	90	60,2	80	203	Primairewege
14	STRt0329	xN0010002	698	150	77	216		1556,5	120	92,9	100	391,9	90	201	Hoofdwegen
15	STRt0266	xN0010002	163	207	200	215		1008,8	90	59,2	90	108,1	80	207	Primairewege
16	STRt1235	xN0100001	134	204	200	210		598,1	70	37,3	70	40,9	70	201	Primairewege
17	STRt1759	xN0100002	134	204	200	210		740,4	90	87,3	90	33,9	80	201	Primairewege
18	STRt5249	xR0120002	142	195	171	225		865,7	70	44,9	70	172,6	70	202	Primairewege
19	STRt4888	xR0120001	152	195	170	225		372,0	120	50,8	100	202,3	90	207	Hoofdwegen
20	STRt0753	xN0010001	1346	115	40	202		1132,5	70	56,9	70	73,3	70	202	Overigeweger
21	STRt0327	xN0010002	1208	124	56	201		1324,7	120	41,6	100	199,4	90	201	Primairewege
22	STRt4887	xR0120001	1225	127	64	181		374,9	120	22,4	100	283,5	90	204	Hoofdwegen
23	STRt0774	xN0010001	702	123	58	166		662,2	70	27,8	70	57,4	70	202	Overigeweger
24	STRt5247	xR0120002	1216	126	64	179		435,6	50	22,6	50	86,8	50	202	Primairewege
25	STRt0775	xN0010001	395	132	119	165		570,1	70	24,2	70	33,1	70	208	Overigeweger
26	STRt5260	xR0110002	1011	156	105	182		862,3	70	44,7	70	171,9	70	203	Primairewege

Table 3.3.2

This information can be processed statistically. For instance, the number of road segments (or road length) for a certain road type; or the presence of a certain road surface.

wegcategorien			
categorie	Hoofdwegen	Primairewegen	Overigewegen
aantal	6	12	8
lengte	3935,0	6733,0	4287,0

wegdek database			
wegdek			
identificatie	naam	aantal	lengte
211	keien	0	0,0
205	dwarsgegroefd beton	0	0,0
206	langsgegroefd beton	0	0,0
210	betonstraatstenen	1	221,0
208	gebezemd beton	0	0,0
207	chemisch uitgewassen beton	1	251,0
202	AB type 2	2	436,0
209	gefreesd/afgeslepen beton	0	0,0
204	ZOA	0	0,0
201	DAB - SMA	5	942,0
203	SMA D	2	442,0

Table 3.3.3

The left table gives information on the total length of the roads.
The right one gives the same information, but evaluated to the kind of road surface.

3.3.2 Intermediate Conclusion

The method above will be evaluated for the examples studied in the CBA (Cost benefit analysis) – chapter 4.

4 EVALUATION

Evaluation of the different methodologies has been carried out using the strategic noise mapping which has been made in the past for the Flanders Region.

A first evaluation and valuation of noise reduction by low noise pavements has been carried out by the authors on a research project for the Flemish Government: "*Onderzoek naar Maatregelen Omgevingslawaai*", ref 11.

Those data are now used to study the different methodology set forward here above.

4.1 METHODOLOGY: LOW NOISE PAVEMENT

Following different options were asked to be evaluated for the refurbishment of roads in the Flanders region. Compared to the reference situation, two alternatives of increased ambition were studied.

Reference

The actual approach followed by the government is to use split mastic asphalt on the existing asphaltic surfaces and to replace all types existing concrete by chemical washed concrete.

Actual	Max. speed [km/h]	Future
Asphalt	90-120	SMA-C (or SMA-D)
	70	SMA-C (or SMA-D)
	50	AB-4C (or AB-4D)
Concrete	90-120	CC (0/20)
	70	CC (0/20) (or broomed)
	50	Broomed CC

Ambition Level 1 (AL1)

Ambition Level 1 is to use porous asphalt (ZOA) on all major roads with speed limits above 90 km/h, both on existing asphalt or concrete surfaces.

Actual	Max. Speed [km/u]	Future
Asphalt	90-120	ZOA
	70	SMA-D
	50	50% TL and 50% AB-4C (or AB-4D)
Concrete	90-120	ZOA-C (on concrete) (composite)
	70	SMA-D (on concrete) (composite)
	50	CC (0/20)

Ambition Level 2 (AL2)

A more ambitious action plan is mainly based on double layered porous asphalt (2-ZOA) on existing asphalt and regular porous asphalt on existing concrete (composition road surfaces).

Actual	Max. speed [km/h]	Future
Asphalt	120	2-ZOA
	90	2-ZOA
	70	SMA
	50	SMA
Concrete	120	ZOA (on concrete)
	90	TL (on concrete)
	70	TL (on concrete)
	50	CC

Actual Situation of Road Surfaces

The actual situation can be summarized as underneath: road surface types that emerge from the calculation models for the strategic noise maps (only main roads – phase 1).

road surface id.	road surface name	[dB]	length [m]	length [%]	length [%]	potential [dB]
205	(older) concrete	6,0	103 015	5.9	5.9	> 5 dB
208	broomed concrete	4,5	324 665	9,7	16.4	>= 3 dB en <= 5 dB
207	chemically washed concrete	3,0	176 558	6,7		
202	AB-2C	2,0	799 442	21,8	21,8	< 3 dB
201	DAB - SMA	0,0	1 500 453	40,3	40,3	road reference surface
203	SMA D	-1,0	307 141	8,3	20,4	better than road reference surface
204	ZOA	-1,5	448 951	12,1		

4.2 APPLICATION 1 : REGION (LIMBURG)

The first application concerns a typical Flemish Region without major cities.

The region contains ±441 km of important roads: 93.5% are asphalt, 6.5% are with concrete. At 51% of the roads, the speed limit is above 100 km/h.

4.2.1 Acoustical Evaluation

The acoustical situation of the 3 scenarios (reference, AL1 & AL2) can be summarized as follows:

Region Limburg – reference situation							
Category	sum	>55-60 dB	>60-65 dB	>65-70 dB	>70-75 dB	>75-80 dB	>80 dB
Exposed	575 979	21 360	9 325	9 442	10 913	1 115	24
Total Exposed above L_{den} > 65 dB(A)				21 494			
Total Exposed above L_{den} > 70 dB(A)					11 990		
Total Exposed above L_{den} > 75 dB(A)						1 139	
Region Limburg: Ambition Level 1							
Category	sum	>55-60 dB	>60-65 dB	>65-70 dB	>70-75 dB	>75-80 dB	>80 dB
Exposed	575 979	16 133	7 839	11 108	6 841	580	0
Total Exposed above L_{den} > 65 dB(A)							
Total Exposed above L_{den} > 70 dB(A)					7 415		
Total Exposed above L_{den} > 75 dB(A)							
Region Limburg: Ambition Level 2							
Category	sum	>55-60 dB	>60-65 dB	>65-70 dB	>70-75 dB	>75-80 dB	>80 dB
Exposed	575 979	11 847	7 590	11 920	2 897	49	15
Total Exposed above L_{den} > 65 dB(A)				14 881			
Total Exposed above L_{den} > 70 dB(A)					2961		
Total Exposed above L_{den} > 75 dB(A)						64	

Table 4.2.1 Number of Exposed

Situation	no. HA
Reference	8 607
Ambition level 1	6 862
Ambition level 2	5 222

Table 4.2.2 Number of Highly Annoyed (HA)

Situation	dB
Reference	-
Ambition level 1	-2.4
Ambition level 2	-3.9

Table 4.2.3 Parametric evaluation

4.2.2 Cost (refurbishing)

Following costs are calculated:

Situation	x 1000 €			difference
	total	total/year	difference/year	%
Reference	190 714	6 357	-	-
Ambition level 1	228 278	7 609	1 252	19.7
Ambition level 2	316 681	10 556	4 199	66.0

Table 4.2.4 Refurbishing costs

4.2.3 Monetarisation - Standard Method

Ambition level 1

exposure class [dB]	ref	AL1	reduction	monetarisation	cost/year [€]
>55-60	21 360	16 133	5 227	80	418 160
>60-65	9 325	7 839	1 486	**160**	237 760
>65-70	9 442	11 108	-1 666	240	-399 840
>70-75	10 913	6 841	4 072	320	1303 040
>75-80	1 115	580	535	400	214 000
>80	24	20		480	0
				total benefit	1 773 120
				add. cost	1 252 000

Table 4.2.5 WHSEA method

exposure class [dB]	ref	AL1	reduction	monetarisation	cost/year [€]
>55-60	21 360	16 133	5 227	93	486 111
>60-65	9 325	7 839	1 486	**159**	236 274
>65-70	9 442	11 108	-1 666	226	-376 516
>70-75	10 913	6 841	4 072	375	1 527 000
>75-80	1 115	580	535	486	260 010
>80	24	20		597	0
				total benefit	2 132 879
				add. cost	1 252 000

Table 4.2.6 Navrud method

exposure class [dB]	ref	AL1	reduction	monetarisation	cost/year [€]
>55-60	21 360	16 133	5 227	6	30 317
>60-65	9 325	7 839	1 486	**16**	23 479
>65-70	9 442	11 108	-1 666	35	-57 810
>70-75	10 913	6 841	4 072	87	354 671
>75-80	1 115	580	535	166	88 596
>80	24	20		403	0
				total benefit	439 252
				add. cost	1 252 000

Table 4.2.7 Heatco method

Ambition level 2

exposure class [dB]	ref	AL1	reduction	monetarisation	cost/year [€]
>55-60	21 360	11 847	9 513	80	761 040
>60-65	9 325	7 590	1 735	**160**	277 600
>65-70	9 442	11 920	-2 478	240	-594 720
>70-75	10 913	2 897	8 016	320	2 565 120
>75-80	1 115	49	1 066	400	426 400
>80	24	15		480	0
				total benefit	3 435 440
				add. cost	4 199 000

Table 4.2.8 WHSEA method

exposure class [dB]	ref	AL1	reduction	monetarisation	cost/year [€]
>55-60	21 360	11 847	9 513	93	884 709
>60-65	9 325	7 590	1 735	**159**	275 865
>65-70	9 442	11 920	-2 478	226	-560 028
>70-75	10 913	2 897	8 016	375	3 006 000
>75-80	1 115	49	1 066	486	518 076
>80	24	15		597	0
				total benefit	4 124 622
				add. cost	4 199 000

Table 4.2.9 Navrud method

exposure class [dB]	ref	AL1	reduction	monetarisation	cost/year [€]
>55-60	21 360	11 847	9 513	6	55 175
>60-65	9 325	7 590	1 735	**16**	27 413
>65-70	9 442	11 920	-2 478	35	-85 987
>70-75	10 913	2 897	8 016	87	698 194
>75-80	1 115	49	1 066	166	176 530
>80	24	15		403	0
				total benefit	871 325
				add. cost	4 199 000

Table 4.2.10 Heatco method

Parametric evaluation

	Ambition Level 1	Ambition Level 2
total no of exposed	52 179	52 179
average noise reduction	2.4 dB	3.9 dB
gain/dB(A)/person	16	16
total benefit (year)	2 003 673	3 255 969
add cost (year)	1 252 000	4 199 000

Table 4.2.11 Parametric Evaluation

4.2.4 Hot Spot Identification

Standard hot spot identification for the Limburg region looks as follows:

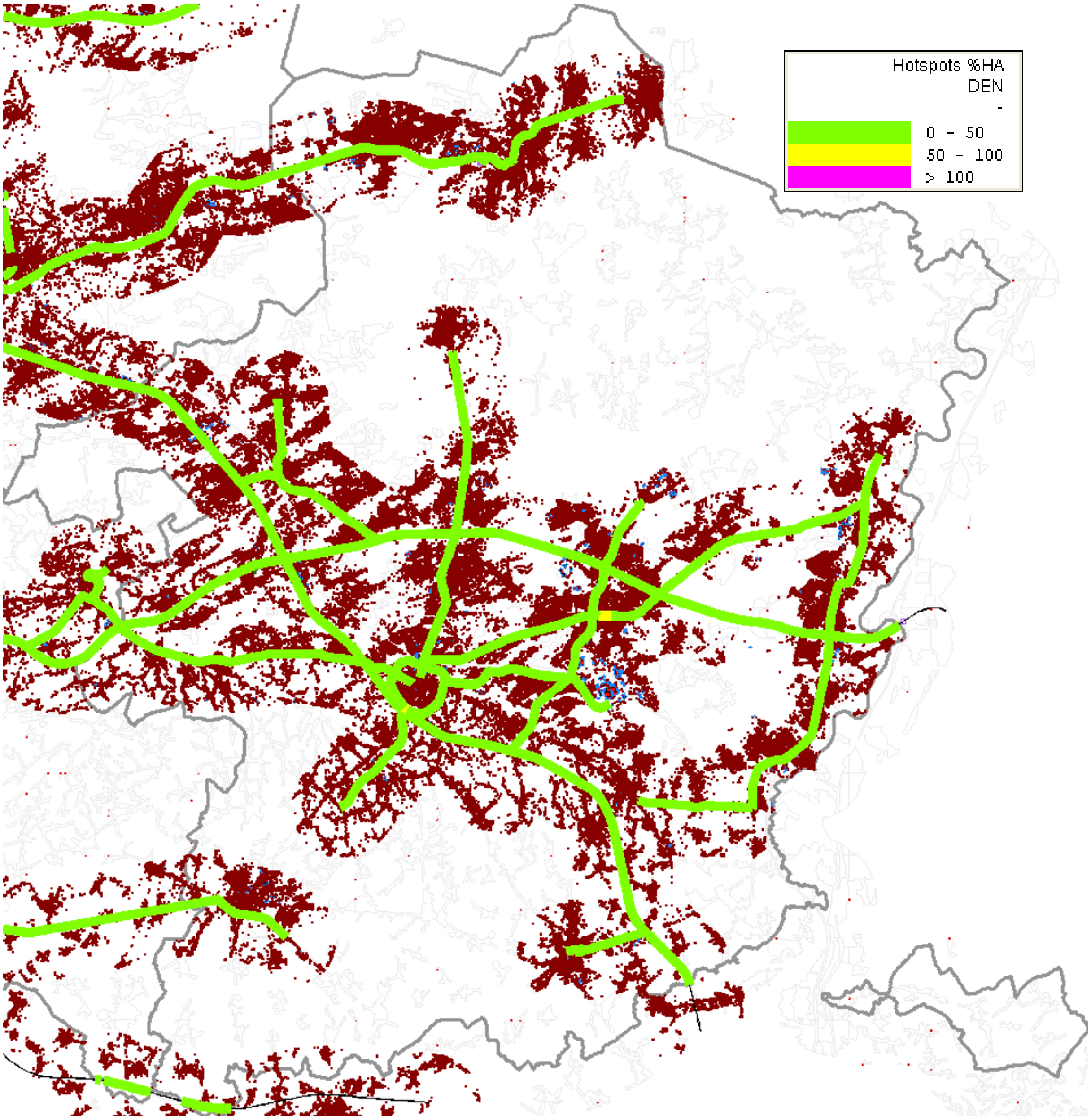


Figure 4.2.1

Province Limburg – %HA - Road network noise - mapping phase 1 – Reference

Figure 4.2.1 does not indicate much "colour" visual evaluation. This can be understood by the table underneath (4.2.12). No road segment with HA/100 above 100; only 11 segments above 50.

Region Limburg			
	REF	AL1	AL2
road segments			
>=100	0	0	0
>=50	11	2	2
<50	1802	1811	1811
0	734	786	830
all	1813	1813	1813

Provincie Limburg - Referentie					Provincie Limburg - Ambitieniveau 1					Provincie Limburg - Ambitieniveau 2				
No.		Label	Sect	%HA / HA maximum	No.		Label	Sect	%HA / HA maximum	No.		Label	Sect	%HA / HA maximum
6803	STRt3203	xN0750001	2	99	6803	STRt3203	xN0750001	2	66	6803	STRt3203	xN0750001	2	53
7307	STRt3496	xN0750002	2	98	7307	STRt3496	xN0750002	2	66	7307	STRt3496	xN0750002	2	53
6802	STRt3203	xN0750001	1	75	6802	STRt3203	xN0750001	1	49	6802	STRt3203	xN0750001	1	39
7306	STRt3496	xN0750002	1	72	7306	STRt3496	xN0750002	1	47	7306	STRt3496	xN0750002	1	38
7308	STRt3496	xN0750002	3	57	7308	STRt3496	xN0750002	3	38	7308	STRt3496	xN0750002	3	31
10654	STRt5355	xR0710001	1	54	8790	STRt4376	xR0710002	1	36	10654	STRt5355	xR0710001	1	30
5717	STRt2609	xN0800001	1	53	10654	STRt5355	xR0710001	1	36	5717	STRt2609	xN0800001	1	29
7693	STRt3724	xN0800002	1	53	5717	STRt2609	xN0800001	1	35	7693	STRt3724	xN0800002	1	29
8790	STRt4376	xR0710002	1	53	7693	STRt3724	xN0800002	1	35	8790	STRt4376	xR0710002	1	29
6899	STRt3255	xN0780002	2	50	6448	STRt3016	xN0780001	1	33	4390	STRt1808	xN0780001	1	26
7058	STRt3346	xN0780001	2	50	4390	STRt1808	xN0780001	1	32	6448	STRt3016	xN0780001	1	26

Table 4.2.12

Therefore, an adapted visualisation with another colour scale, seems needed. See underneath.

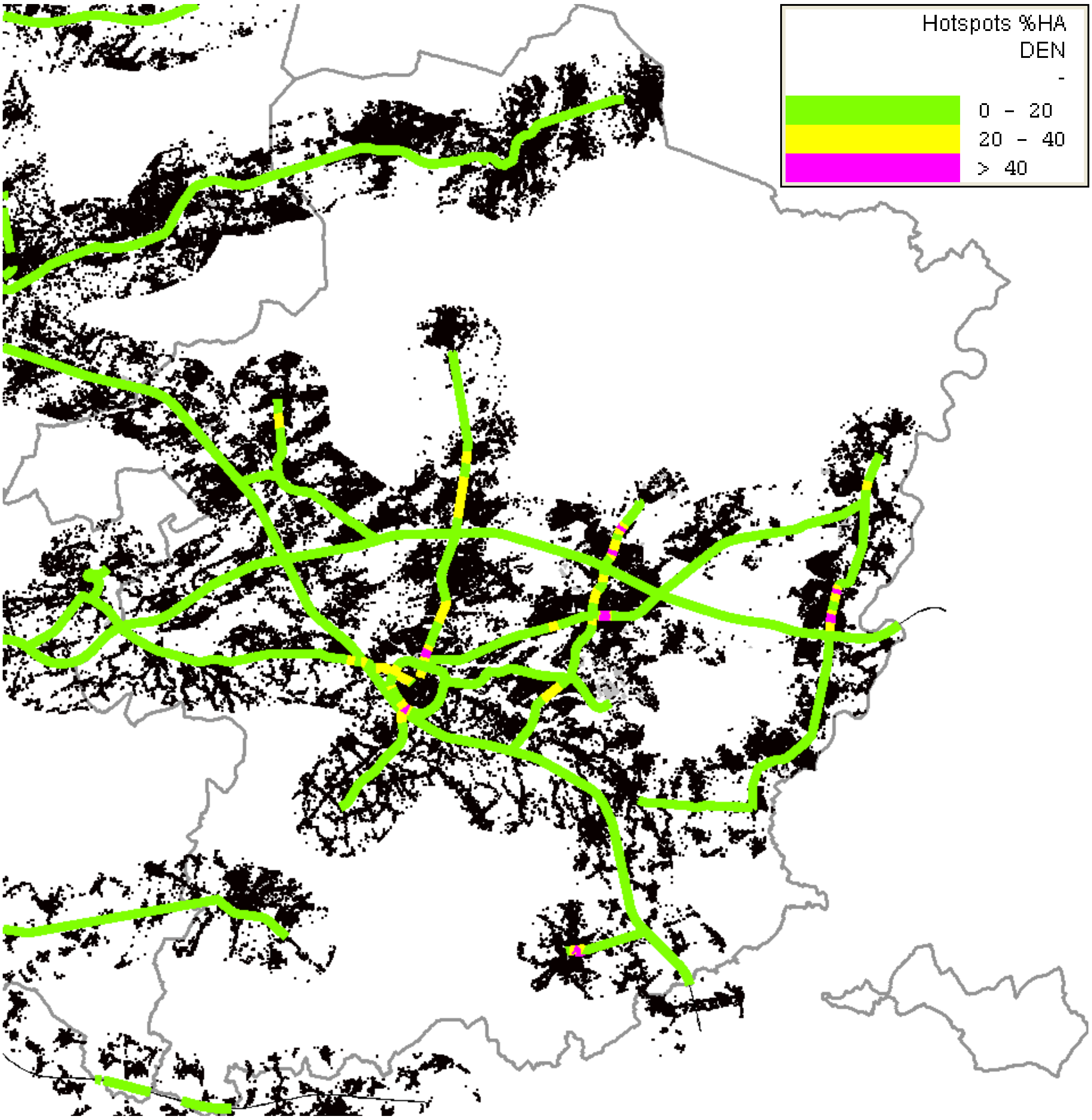


Figure 4.2.2
Region Limburg - %HA/100m – Reference situation 0/20/40

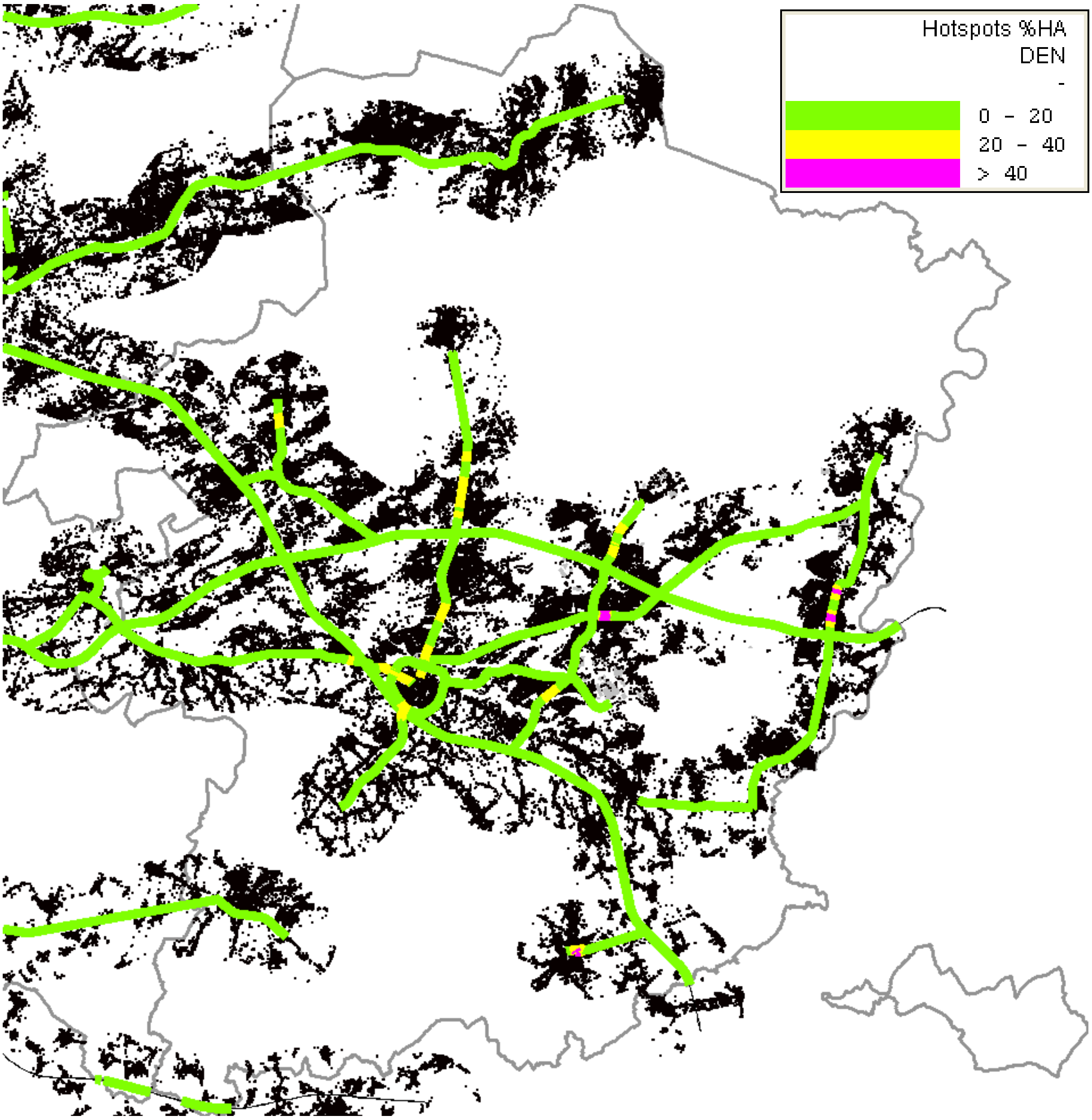


Figure 4.2.3

Region Limburg - %HA – Ambition Level 1 – 0/20/40

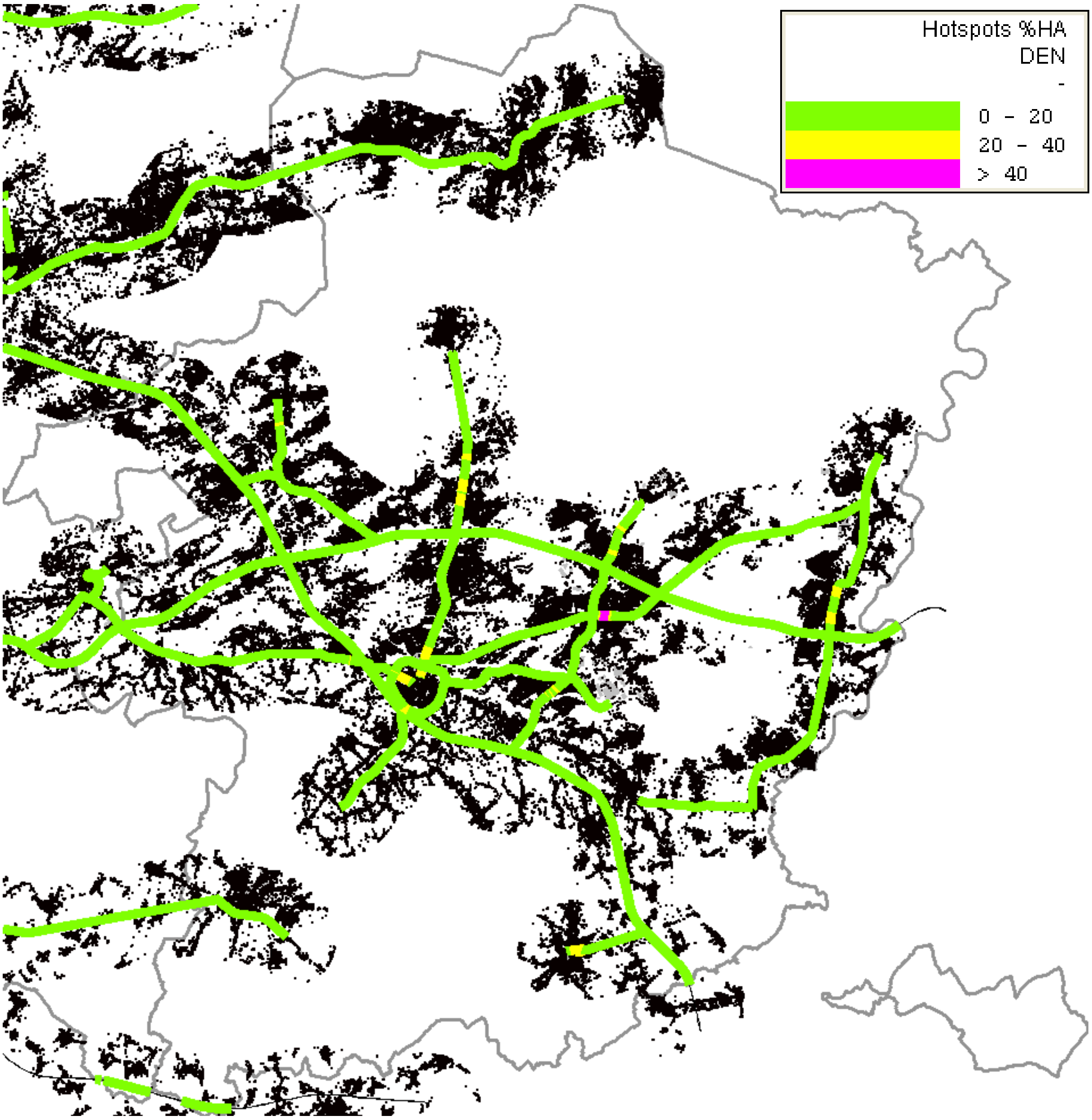


Figure 4.2.4

Region Limbourg – Ambition Level 2 – 0/20/40 map

4.3 Application 2: agglomeration (Antwerp)

The Antwerp city agglomeration is an area with dense population and a dense road network of ±330 km.

The methodology for evaluation is identical to the one for the Limburg region.

4.3.1 Acoustical Calculations

Agglomeration Antwerp – Reference: phase 1 road traffic							
Category	sum	>55-60 dB	>60-65 dB	>65-70 dB	>70-75 dB	>75-80 dB	>80 dB
Inhabitants	441 929	35 813	22 983	27 232	32 380	12 209	0
Inhabitants exposed to L_{den} > 65 dB(A)				71 821			
Inhabitants exposed to L_{den} > 70 dB(A)					44 291		
Inhabitants exposed to L_{den} > 75 dB(A)						12 209	
Agglomeration Antwerp - Ambition level 1: road traffic							
Method 2002/49/EG: most exposed facade							
Category	suom	>55-60 dB	>60-65 dB	>65-70 dB	>70-75 dB	>75-80 dB	>80 dB
Inhabitants	441 929	26 555	21 852	31 055	22 263	5 938	0
Inhabitants exposed to L_{den} > 65 dB(A)				59 245			
Inhabitants exposed to L_{den} > 70 dB(A)					28 190		
Inhabitants exposed to L_{den} > 75 dB(A)						5 938	
Agglomeration Antwerp - Ambition level 2: road traffic							
Method 2002/49/EG: most exposed facade							
Category	sum	>55-60 dB	>60-65 dB	>65-70 dB	>70-75 dB	>75-80 dB	>80 dB
Inhabitants	441 929	24 275	24 679	33 186	11 448	5 407	0
Inhabitants exposed to L_{den} > 65 dB(A)				50 041			
Inhabitants exposed to L_{den} > 70 dB(A)					16 855		
Inhabitants exposed to L_{den} > 75 dB(A)						5 407	

Table 4.3.1 Number of Exposed

	number HA
Reference	120 690
Ambition level 1	97 804
Ambition level 2	78 133

Table 4.3.2 Number of Highly Annoyed (HA)

Situation	dB
Reference	-
Ambition level 1	-2.2
Ambition level 2	-3.7

Table 4.3.3 Parametric evaluation

4.3.2 Cost (refurbishing)

Following costs are considered:

Situation	x 1000 € total	total/year	difference/year	difference %
Reference	128 236	4 274	-	-
Ambition level 1	155 437	5 181	907	21
Ambition level 2	214 026	7 134	2 860	70

Table 4.3.4 Refurbishing costs

4.3.3 Monitarisation – standard method

Ambition level 1

exposure class [dB]	ref	AL1	reduction	monetarisation	cost/year [€]
>55-60	35 813	26 555	9 258	80	740 640
>60-65	22 983	21 852	1 131	**160**	180 960
>65-70	27 232	31 055	-3 823	240	-917 520
>70-75	32 380	22 263	10 117	320	3 237 440
>75-80	12 209	5 938	6 271	400	2 508 400
>80	0	0	0	480	0
				total benefit	5 749 920
				total cost	906 204

Table 4.3.5 WHSEA cost

exposure class [dB]	ref	AL1	reduction	monetarisation	cost/year [€]
>55-60	35 813	26 555	9 258	93	860 994
>60-65	22 983	21 852	1 131	**159**	179 829
>65-70	27 232	31 055	-3 823	226	-863 998
>70-75	32 380	22 263	10 117	375	3 793 875
>75-80	12 209	5 938	6 271	486	3 047 706
>80	0	0	0	597	0
				total benefit	7 018 406
				total cost	906 204

Table 4.3.6 Navrud cost

exposure class [dB]	ref	AL1	reduction	monetarisation	cost/year [€]
>55-60	35 813	26 555	9 258	6	53 696
>60-65	22 983	21 852	1 131	**16**	17 870
>65-70	27 232	31 055	-3 823	35	-132 658
>70-75	32 380	22 263	10 117	87	881 191
>75-80	12 209	5 938	6 271	166	1 038 478
>80	0	0	0	403	0
				total benefit	1 858 576
				total cost	906 204

Table 4.3.7 Heatco cost

Ambition level 2

exposure class [dB]	ref	AL1	reduction	monetarisation	cost/year [€]
>55-60	35 813	24 275	11 538	80	923 040
>60-65	22 983	24 679	-1 696	**160**	-271 360
>65-70	27 232	33 186	-5 954	240	-1 428 960
>70-75	32 380	11 448	20 932	320	6 698 240
>75-80	12 209	5 407	6 802	400	2 720 800
>80	0	0	0	480	0
				total benefit	8 641 760
				total cost	2 859 679

Table 4.3.8 WHSEA cost

exposure class [dB]	ref	AL1	reduction	monetarisation	cost/year [€]
>55-60	35 813	24 275	11 538	93	1 073 034
>60-65	22 983	24 679	-1 696	**159**	-269 664
>65-70	27 232	33 186	-5 954	226	-1 345 604
>70-75	32 380	11 448	20 932	375	7 849 500
>75-80	12 209	5 407	6 802	486	3 305 772
>80	0	0	0	597	0
				total benefit	10 613 038
				total cost	2 859 679

Table 4.3.9 Navrud cost

exposure class [dB]	ref	AL1	reduction	monetarisation	cost/year [€]
>55-60	35 813	24 275	11 538	6	66 920
>60-65	22 983	24 679	-1 696	**16**	-26 797
>65-70	27 232	33 186	-5 954	35	-206 604
>70-75	32 380	11 448	20 932	87	1 823 177
>75-80	12 209	5 407	6 802	166	1 126 411
>80	0	0	0	403	0
				total benefit	2 783 108
				total cost	2 859 679

Table 4.3.10 HeatCo cost

Parametric evaluation

	Ambition Level 1	Ambition Level 2
total no of exposed	130 617	130 617
average noise reduction	-2.2	-3.7
gain/dB(A)/person	16	16
total benefit	4 597 718	7 732 526
add cost	906 204	2 859 679

Table 4.3.11 Parametric evaluation

4.3.4 Hot Spot Identification

A summary of the hot spot identification is given hereafter.

It can be seen that a visualisation on a 0/50/100 scale will be more appropriate than a 0/20/40 scale. The number of road segments below 100 and below 50 changes significantly from one scenario to another; but remains important below 50. Road Segments with HA-levels above 50 and 100 decrease to values below 50 but still above 40 or 20.

Agglomeration Antwerpen			
	REF	AMB 1	AMB 2
road segments			
>=100	111	42	31
>=50	256	184	126
<50	656	728	786
0	400	411	415
all	912	912	912

Table 4.3.12

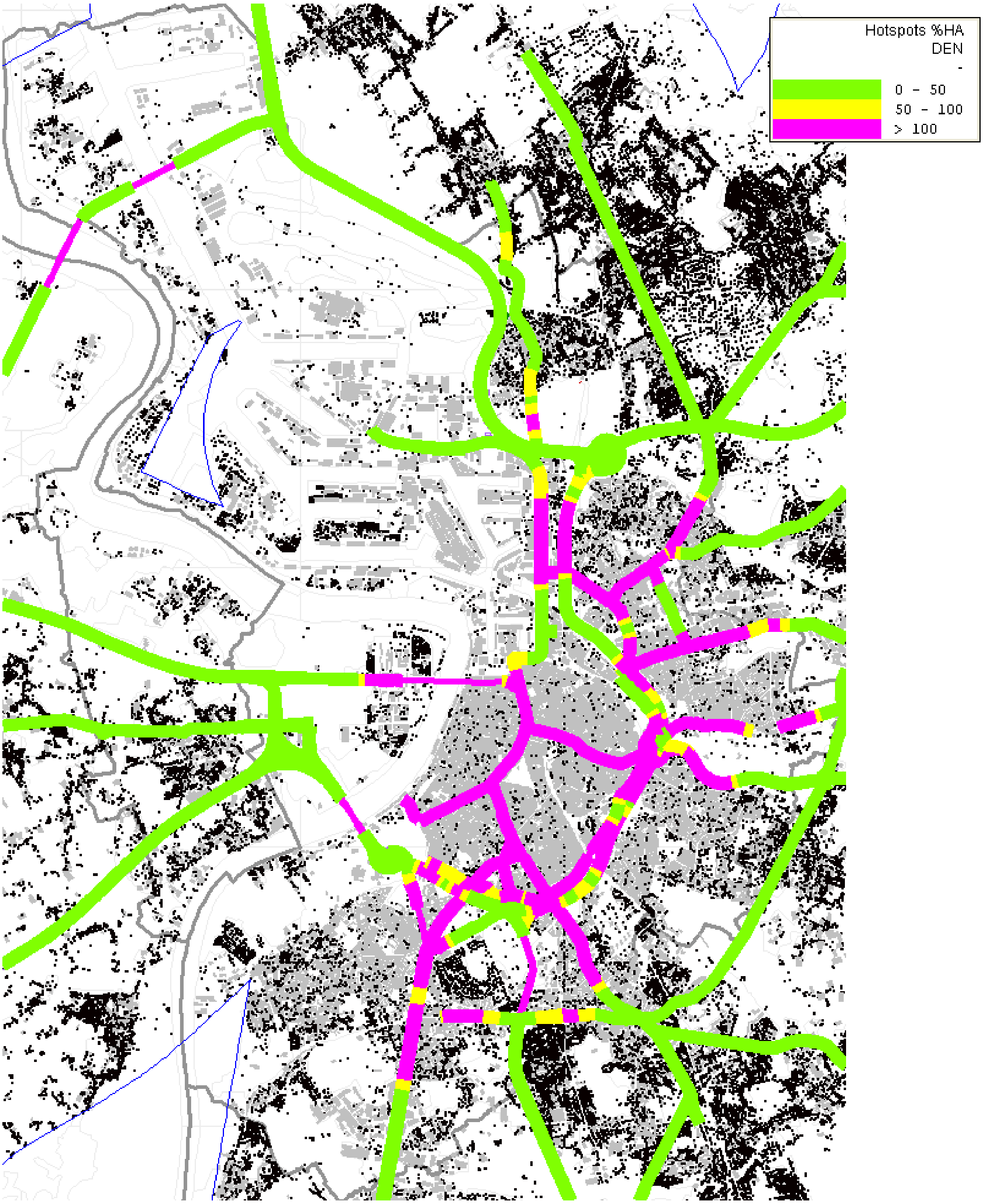


Figure 4.3.1

Agglomeration Antwerp – %HA - Road network - noise mapping - phase 1 - Reference

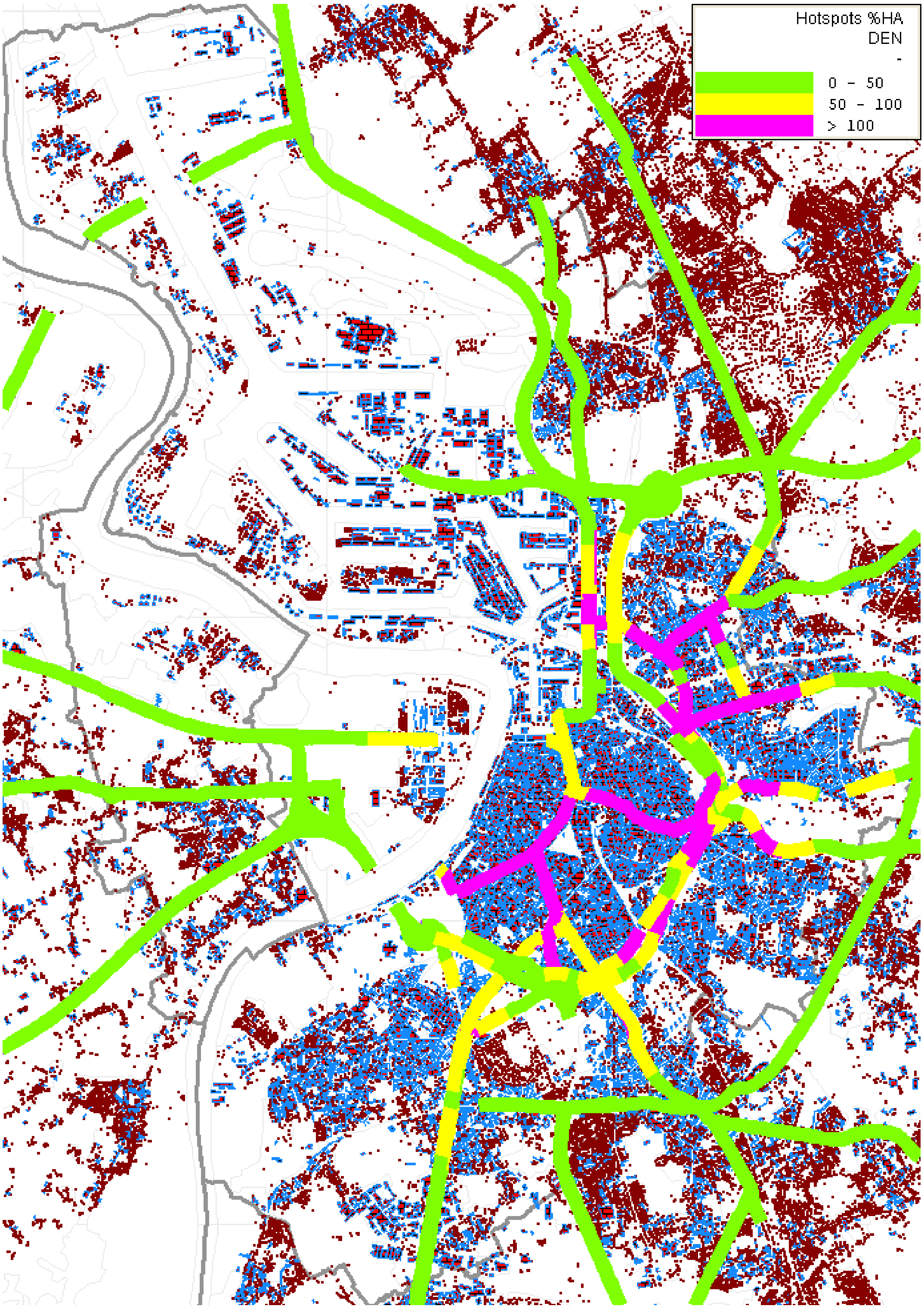


Figure 4.3.2

Agglomeration Antwerp – %HA - Road network - noise mapping - phase 1 – AL1

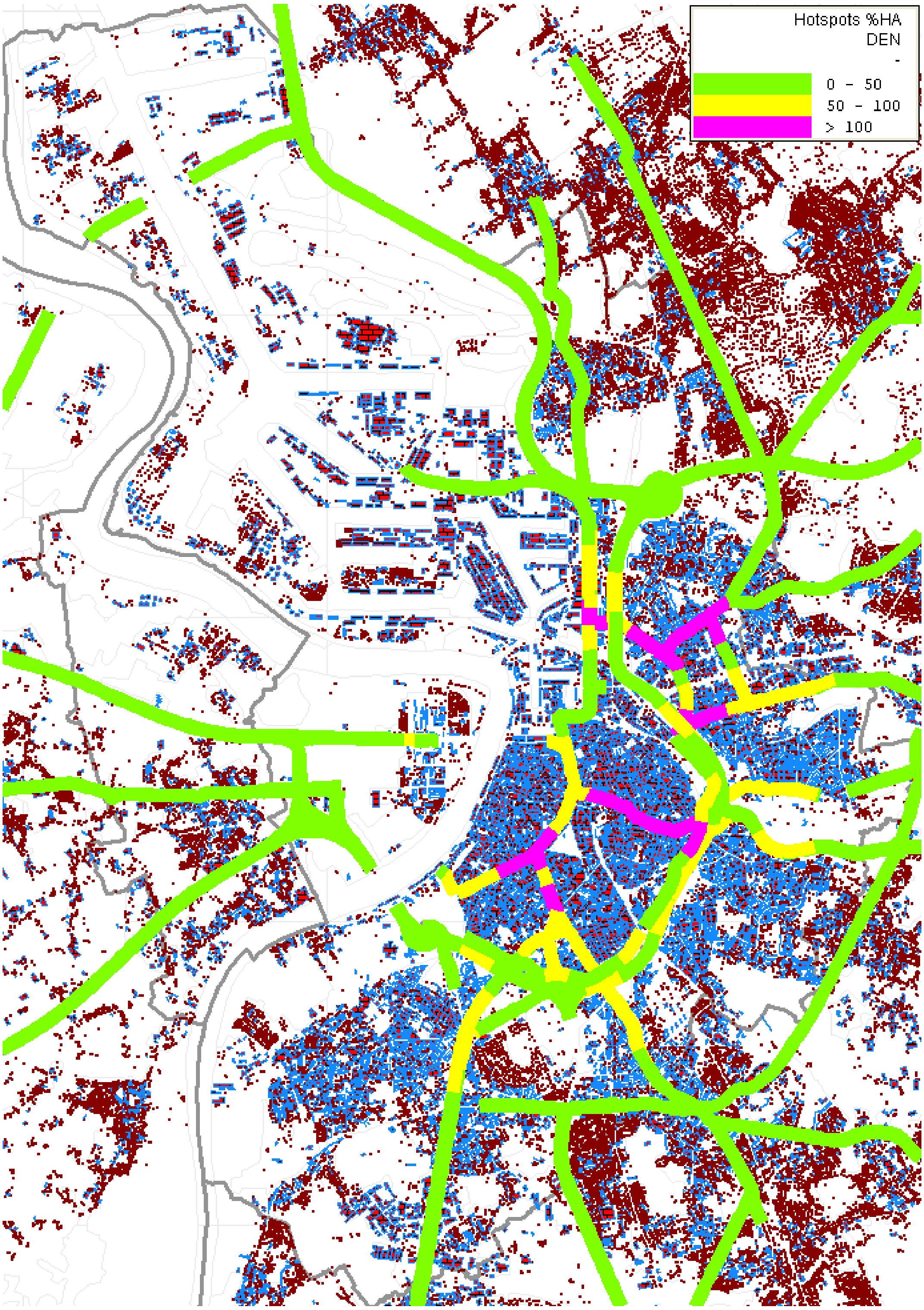


Figure 4.3.3

Agglomeration Antwerp – %HA - Road network - noise mapping - phase 1 – AL2

4.4 CONCLUSIONS

New methods for valuation of the noise reduction when using low noise pavements are discussed. According to literature, the HeatCo method is considered to be the most appropriate method for valuation of noise benefits. This method is also by far the most conservative method, yielding the lowest benefit values.

Although the values of the benefit analyses vary significantly, applying these methods to both more open regions (without major cities) or to a typical agglomeration permit similar conclusions.

For a city area, applying low noise pavements is always beneficiary: for a moderate ambition level based on standard porous asphalt the cost/benefit ratio is even ½. For more sophisticated methods based on double layer porous asphalt and thin layer surfaces on concrete, the cost benefit ratio is 1/1.

For an open area, the use of low noise pavements cannot be justified by the Heatco method; cost/benefit ratio is 4/1. But using other evaluation methods (such as the parametric evaluation) a positive ratio is obtained.

It should be stated that these conclusions are only valid for the regions studied. For other regions, similar calculations of costs and benefits have to be carried out according to the procedures discussed above.

Second, the hot spot identification maps and tables were made for the above situations. The clear visualisation using the linear colour maps show their use. Also the tables with the individual road segments and the corresponding no.HA/100m values give the stakeholders immediately full detail about the road surface situation and the possibilities of improvement. It is also shown that different colour scales should be used between city areas and more open areas.

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