DELIVERABLE 2.2.2[1]

CONTRACT N°	**SPC8-GA-2009-233655**
PROJECT N°	**FP7-233655**
ACRONYM	**CITYHUSH**
TITLE	**Acoustically Green Road Vehicles and City Areas**
Work Package WP2	**Noise score rating models and annoyance**
2.2	**Improved noise score model for indoors integrated into noise mapping software**
Written by	**Christian Fend, Markus Petz**
Due submission date	
Actual submission date	

Project Co-Ordinator
Partners

Acoustic Control	ACL	SE
Accon	ACC	DE
Alfa Products & Technologies	APT	BE
Goodyear	GOOD	LU
Head Acoustics	HAC	DE
Royal Institute of Technology	KTH	SE
NCC Roads	NCC	SE
Stockholm Environmental & Health Administration	SEP	SE
Netherlands Organisation for Applied Scientific Research	TNO	NL
Trafikkontoret Göteborg	TRAF	SE
TT&E Consultants	TTE	GR
University of Cambridge	UCAM	UK
Promotion of Operational Links with Integrated Services	POLIS	BE

Project start date	**January 1, 2010**
Duration of the project	**12 months**

Project funded by the European Commission within the Seventh Framework program

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

1 see List of Deliverables, DoW – Annex I to the contract, p.32
(document 233655_CITYHUSH_AnnexI_DoW_2010-01-31_Corrections.pdf - available on the ftp-server)

TABLE OF CONTENTS

0. EXECUTIVE SUMMARY

0.1 OBJECTIVE OF THE DELIVERABLE

The objective is to integrate a refined noise score rating model for indoors in noise mapping software.

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

The refined noise score rating model for indoors [1] was integrated in noise mapping software. A procedure was developed using CadnaA [2]. It is described step by step to be followed without the need of expert software knowledge.

0.3 MAIN RESULTS ACHIEVED SO FAR

The refined noise score rating model for indoors was integrated in noise mapping software. A procedure was developed using CadnaA. It is described step by step to be followed without the need of expert software knowledge.

0.4 EXPECTED FINAL RESULTS

The final results are described in this deliverable.

0.5 POTENTIAL IMPACT AND USE[2]

In the context of the EU Environmental Noise Directive, it is important to adequately assess the impact of environmental noise on residents. So far, the assessment of the impact of noise on residents is based solely on facade levels of dwellings as obtained from the noise maps. Therefore, measures directed towards a more quiet outdoor situation, in so far as they are not reflected in facade levels, will not show up in health assessment indicators, nor will measures that influence the frequency spectrum, the indoor levels or the rate of occurrence of individual noise events. Using the refined noise score rating model for residents, the expected effect of environmental noise on residents may be better quantified (see [1]).

The developed procedure allows users to adequately assess the impact of environmental noise on residents without the need of expert software knowledge.

2 *including the socio-economic impact and the wider societal implications of the project so far*

0.6 PARTNERS INVOLVED AND THEIR CONTRIBUTION

The refined noise score rating model was developed by TNO and is described in CityHush Deliverable 2.2.1 [1].

0.7 CONCLUSIONS

The refined noise score rating model for indoors [1] was integrated in noise mapping software. A procedure was developed using CadnaA [2]. The developed procedure allows users to adequately assess the impact of environmental noise on residents without the need of expert software knowledge.

1. INTRODUCTION

The refined rating model for residents is described in CityHush Deliverable 2.2.1, dated June 29, 2011 [1]. In the model, indicators for equivalent noise level at the facade of the dwelling are combined with information about outdoor noise levels in the vicinity of the dwelling, spectrum characteristics (in conjunction with insulation characteristics) and temporal variations in noise levels. This model may be used to predict the overall annoyance response, i.e. the percentage and number of residents that will be expected to be annoyed by noise in a given area.

In the context of the EU Environmental Noise Directive, it is important to adequately assess the impact of environmental noise on residents. So far, the assessment of the impact of noise on residents is based solely on facade levels of dwellings as obtained from the noise maps. Therefore, measures directed towards a quieter outdoor situation, in so far as they are not reflected in facade levels, will not show up in health assessment indicators, nor will measures that influence the frequency spectrum, the indoor levels or the rate of occurrence of individual noise events.

Using the refined noise score rating model for residents, the expected effect of environmental noise on residents may be better quantified.

For an application of the refined rating model within the CityHush project it was necessary, to implement a calculation methodology into the noise mapping software CadnaA [2], which allows to consider the expected effects on large scale areas or test sites.

2. GLOSSARY

Building	CadnaA object for buildings
Building Evaluation	CadnaA object used to calculate the sound levels along facades of buildings
Building Noise Map	shows the noise level distribution at specified stories along the facade of a building
CadnaA	a Noise prediction software [2]
Calc_S01.cna	example CadnaA file name (extension: *cna*)
Embedded Park	Park within a Q-Zone
Facade Points	receiver points for noise calculation along the facades of a building (part of the object *Building Evaluation*)
L_{den}	day-evening-night noise indicator (A-weighted long-term average sound level), shall mean the noise indicator for overall annoyance (Directive 2002/49/EC)
L_{den}'	modified day-evening-night noise indicator for usage in the refined noise score rating model
LP1	CadnaA evaluation parameter (LP1—LP4), here: LP1 = L_{den}
Memo-Window	containing text or variables corresponding to a CadnaA object
Noise Map	a grid of calculated receiver points with defined spacing and height
Q-Zone	Quiet zone; inner city zone where only quiet low emission vehicles are tolerated

3. CALCULATION METHODOLOGY

3.1. CALCULATION FORMULAS

The calculation formulas used in this report are taken from the CityHush Deliverable 2.2.1 [1]. They are summarized below.

$L_{den}' = L_{den} + \Delta L_I + \Delta L_Q + \Delta L_A$	Annoyance at home
$\Delta L_I = a\,(I - I_{av})\,L_{den} + b\,(I - I_{av})$ For easy explanation the following values for the parameters will be used in the instruction $a = -0.0222$ $\quad I = 30$ (Example City) $b = 1$ $\quad I_{av} = 28$	Facade insulation Influence of the facade insulation of a building I → Facade insulation Values from Norwegian facade insulation study
$\Delta L_Q = a\,(Q - Q_{av})\,L_{den} + b\,(Q - Q_{av})$ For easy explanation the following values for the parameters will be used in the instruction $a = -0.0156$ $\quad Q = L_{max} - L_{min}$ $b = 0.7$ $\quad Q_{av} = 10$	Quiet facade Influence of the Difference between the most exposed and quietest facade of a building Q → maximum and minimum Levels (L_{den}) Values from various studies (Gothenburg, TNO)
$\Delta L_A = a\,(A - A_{av})\,L_{den} + b\,(A - A_{av})$ For easy explanation the following values for the parameters will be used in the instruction $a = -0.0039$ $\quad A = 25$ Percentile $b = 0.175$ $\quad A_{av} = 50$ Percentile (av Average)	Ambient noise Influence of the ambient noise in a radius of 200 m around a building 25 / 50 Percentile → defines the area with ambient noise below that level Values from various studies (Gothenburg, TNO, Gent)

3.2. GENERAL EXPLANATION

The noise prediction software CadnaA shows objects as buildings and roads like a city map. You can double click on these objects to get attributes of them such as height of the building, number of residents, maximum speed of the road, average daily traffic density etc. Each object provides a so-called *Memo-Window* in which information like arbitrary text string or user-defined string variables with the related numerical value can be written.

We will use two tools of CadnaA for this Calculation Methodology.

1. Modify Objects

Click with the right mouse button into the white area of the screen and select the command *Modify Objects* from the context menu displayed

This command enables to address various actions, like *Modify Attribute*, to several objects. By the action *Modify Attribute*, attributes of objects can be altered globally. Formulas can be used to calculate new values for the selected attributes.

2. Object-Scan

Click in the menu bar at the item *Grid* and select the item *Object-Scan* from the context menu.

For the selected object type the value of any object attribute can be summed up with the possibility of mathematical conversions.

3.3. START SITUATION

A CadnaA file is required that includes

- the *Noise Map* with calculated values L_{den} ,
- the *Building Noise Map* with calculated values L_{den} ,
- the objects *Building* with number of residents and
- the objects *Building Evaluation*.

Open a calculated CadnaA file which includes a *Noise Map*, a *Building Noise Map*, the objects *Building* and *Building Evaluation*; e.g. *Calc_S01.cna*. Save as new CadnaA file, e.g. *Calc_S01_2.cna*.

Remarks:

1. In the following example, the CadnaA Evaluation Parameter LP1 corresponds to L_{den}.
2. The results of the calculations will be written in string variables in the *Memo-Window* of the objects.

3.4. Example: Calculating the refined noise score of a building

3.4.1 Facade Insulation: Correction ΔLI

First, the Objects *Building Evaluation* have to be modified (See Figure 3.4.1):

→ Modify Objects

→ Action: Modify Attribute…

→ Object Types: Building Evaluation

→ OK

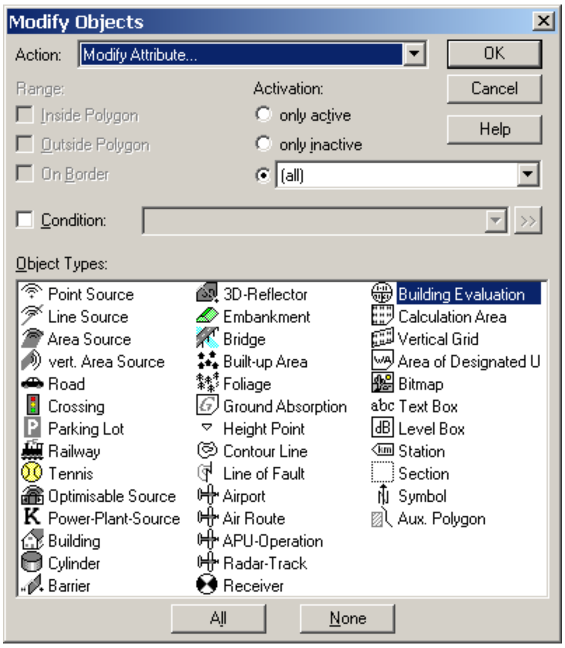

Figure 3.4.1: Facade insulation: define DLI – step 1

Then, a new attribute DLI representing the facade insulation has to be created (see Figure 3.4.2):

→ Attribute: MEMOTXTVAR (String variable)

→ Text Variable: DLI

→ Arithmetic

→ New Value = -0.0444*LP1+2 (Example City)

→ OK

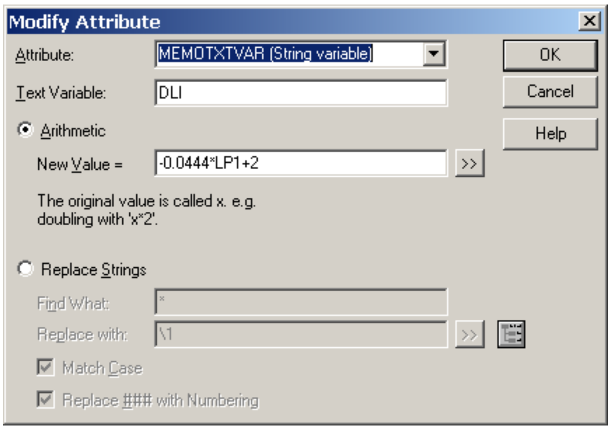

Figure 3.4.2: Facade insulation: define DLI – step 2

The result can be seen in the example in Figure 3.4.3: with LP1 = 56.5 (i.e. the level at the loudest facade) the variable DLI is about -0.5.

Note: if you want to recalculate the example above, you have to use LP1 with more decimals than shown in the figure to get the exact values (LP1 = 56.4779) – even if in practice you would never use more than the first decimal place.

The variable DLI is now stored with the object Building Evaluation for further calculations.

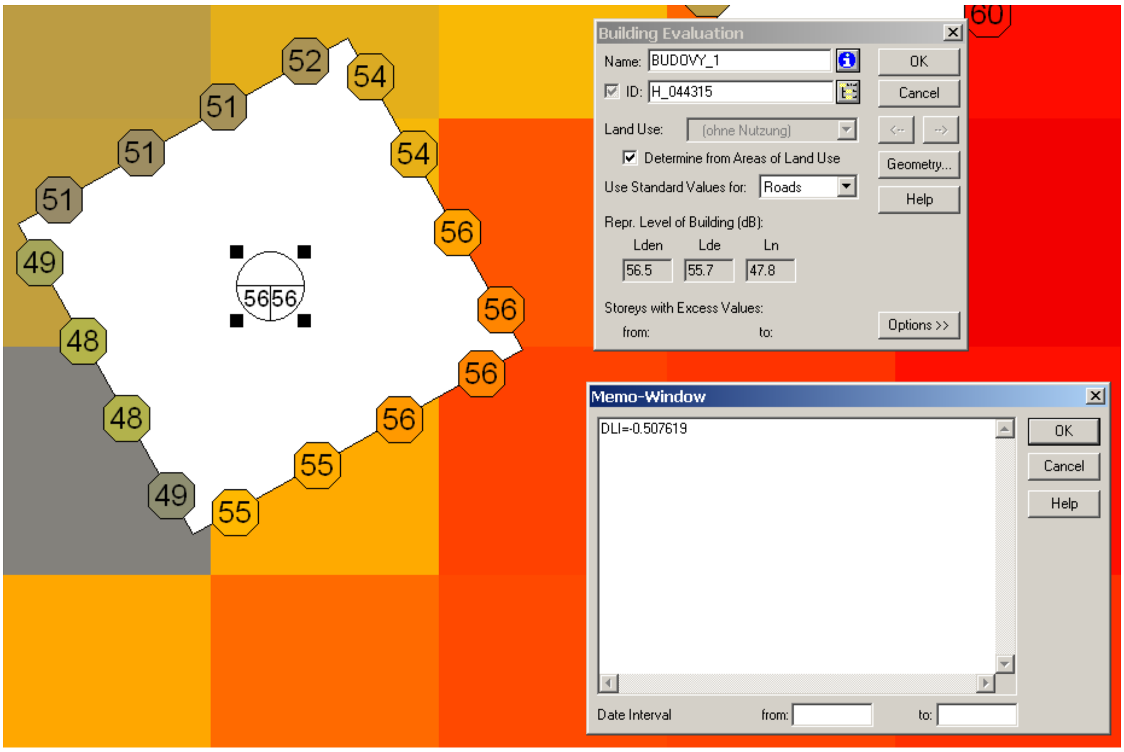

Figure 3.4.3: Facade insulation: example for calculated DLI

3.4.2 Quiet Facade: Correction ΔLQ

First, the loudest and the quietest facade of each building have to be identified. The detected values then have to be written in new attributes *FPmin* and *FPmax* of the objects building evaluation (See Figure 3.4.4):

→ Menu → Grid → Object-Scan…

→ Object Type: Facade Point

→ Action / Sum into: Specified Areas / Polygons

→ Target Object Type: Building Evaluation

→ (1) Attribute: MEMOTXTVAR (String variable) -> Text Variable: FPmin

→ (2) Attribute: MEMOTXTVAR (String variable) -> Text Variable: FPmax

→ (1) Formula for Summation: iif(LP1>-87, LP1, 200)

→ (2) Formula for Summation: LP1

→ (1) Formula for Total: min

→ (2) Formula for Total: max

→ OK

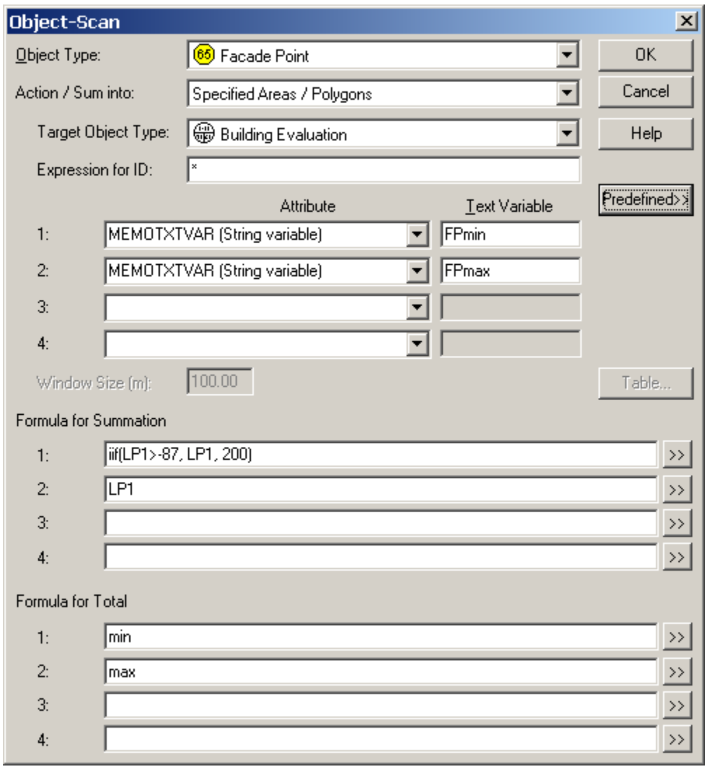

Figure 3.4.4: Quiet facade: define DLQ – step 1

As you can see in Figure 3.4.5 the lowest level appears on the west facade (FPmin = 48.49 dB), the highest on the southeast edge of the building (FPmax = 57.35 dB). These variables are stored with the object Building Evaluation for further calculations.

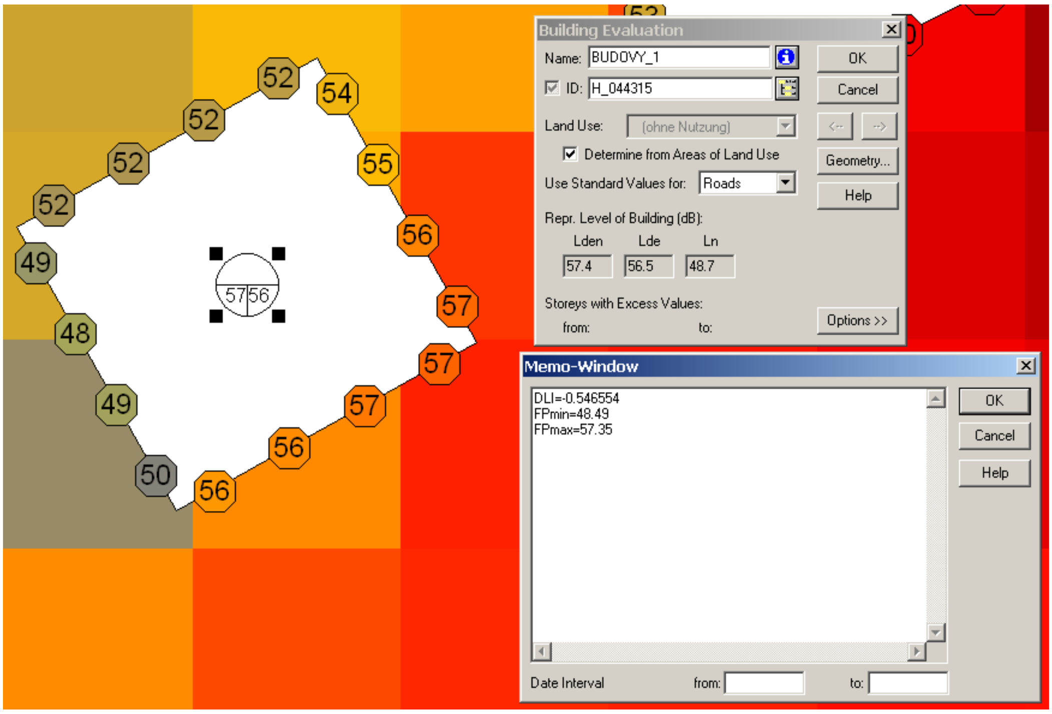

Figure 3.4.5: Example building with calculated levels of loudest and quietest facade

Then the DLQ has to be calculated for each building. Therefore, the building evaluations have to be modified (See Figure 3.4.6):

→ Modify Objects

→ Action: Modify Attribute…

→ Object Types: Building Evaluation

→ OK

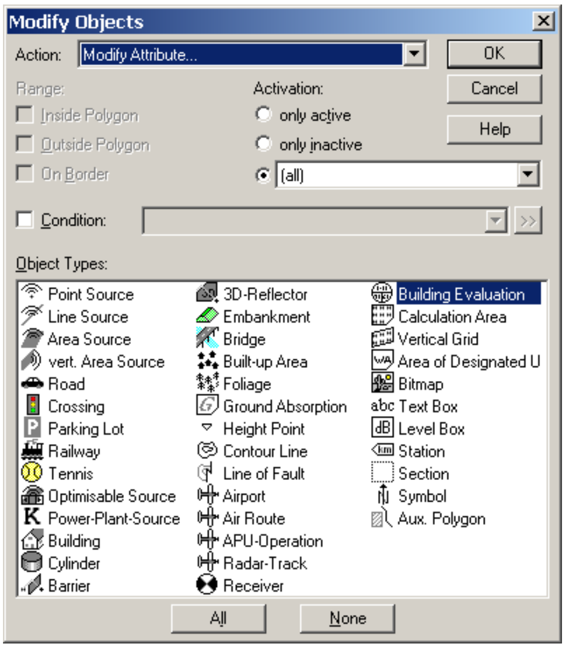

Figure 3.4.6: Quiet facade: define DLQ – step 2

Then, a new attribute DLQ representing the quiet facade has to be created (see Figure 3.4.7):

→ Attribute: MEMOTXTVAR (String variable)

→ Text Variable: "DLQ"

→ Arithmetic

→ New Value = -0.0156*(MEMO_Fpmax-MEMO_Fpmin-10)*LP1
+0.7*(MEMO_Fpmax-MEMO_Fpmin-10)

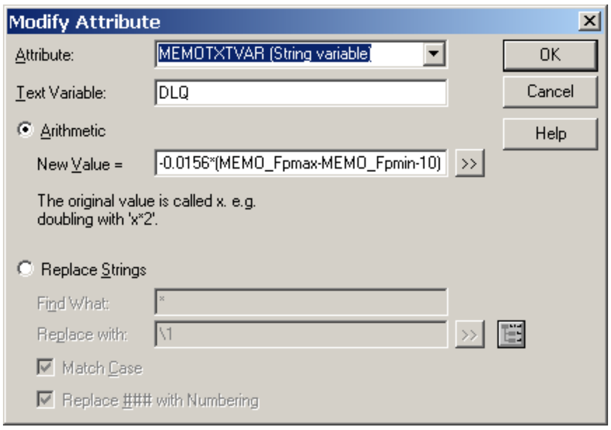

Figure 3.4.7: Quiet facade: define DLQ – step 3

The result can be seen in the example in Figure 3.4.8: with FPmax = 56 dB(A) (i.e. the level at the loudest facade) an FPmin = 48 dB(A) (i.e. the level at the quietest facade) the variable DLQ is about 0.3.

The variable DLQ is now stored with the object Building Evaluation for further calculations.

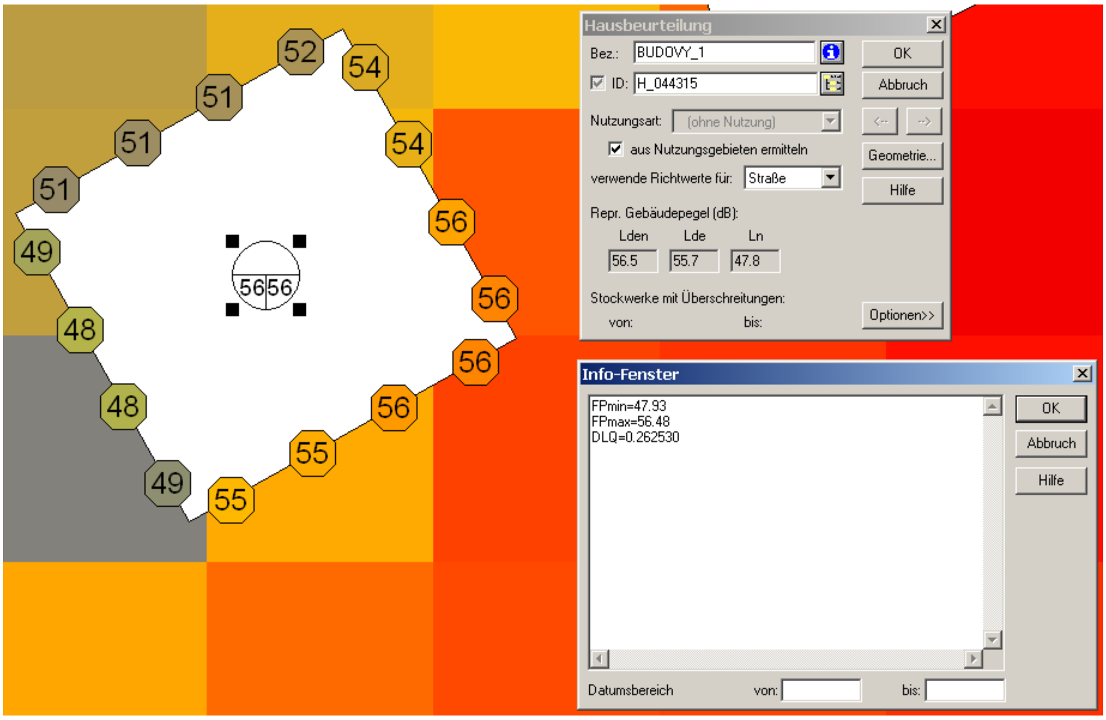

Figure 3.4.8: Quiet facade: Example for calculated DLQ

3.4.3 Ambient Noise: Correction ΔLA

First, the 25- and 50-percentiles of the noise levels within an area of 200 m radius around each object *Building Evaluation* are determined. The values then have to be written in new attributes *perc_25* and *perc_50* (see Figure 3.4.9):

→ Menu -> Grid -> Object-Scan…

→ Object Type: Building Evaluation

→ Action / Sum into: Specified Areas / Polygones

→Target Object Type: Building Evaluation

→ (1) Attribute: MEMOTXTVAR (String variable) -> Text Variable: perc25

→ (2) Attribute: MEMOTXTVAR (String variable) -> Text Variable: perc50

→ (1) Formula for Summation: GRD_PERC(x, y, 200, 25)

→ (2) Formula for Summation: GRD_PERC(x, y, 200, 50)

→ (1) Formula for Total: [empty]

→ (2) Formula for Total: [empty]

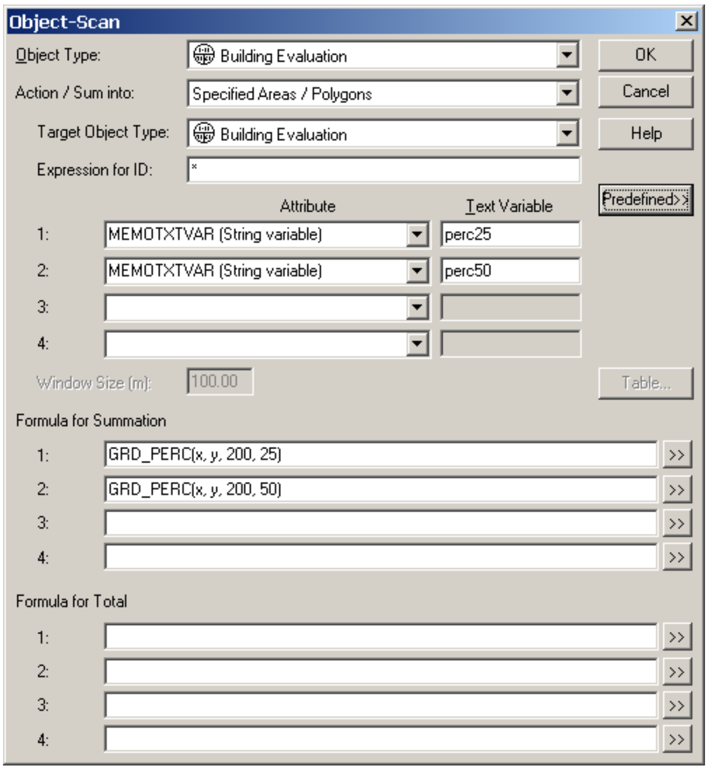

Figure 3.4.9: Ambient noise: define DLA – step 1

Then, the objects *Building Evaluation* have to be modified (see Figure 3.4.10):

→ Modify Objects

→ Action: Modify Attribute…

→ Object Types: Building Evaluation

→ OK

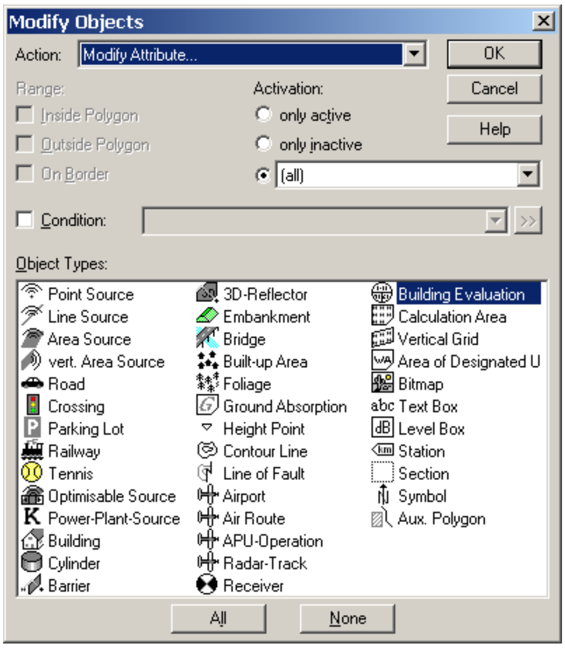

Figure 3.4.10: Ambient noise: define DLA – step 2

At last, a new attribute DLA representing the ambient noise has to be created (see Figure 3.4.11):

→ Attribute: MEMOTXTVAR (String variable)

→ Text Variable: DLA

→ Arithmetic

→ New Value = -0.0039*(MEMO_perc25-MEMO_perc50)*LP1
+0.175*(MEMO_perc25-MEMO_perc50)

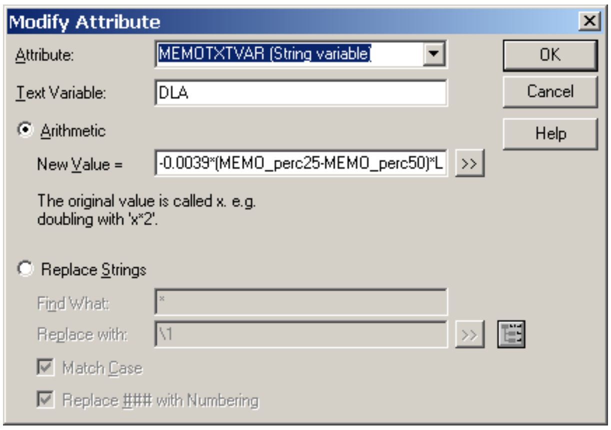

Figure 3.4.11: Ambient noise: define DLA – step 3

The result can be seen in the example in Figure 3.4.12: with perc25 = 57 dB(A) and perc50 = 51 dB(A) the variable DLA is about 0.3.

Note: if you want to recalculate the example above, you have to use LP1 with more decimals than shown in the figure to get the exact values (LP1 = 56.4779) – even if in practice you would never use more than the first decimal place.

The variable DLA is now stored with the object Building Evaluation for further calculations.

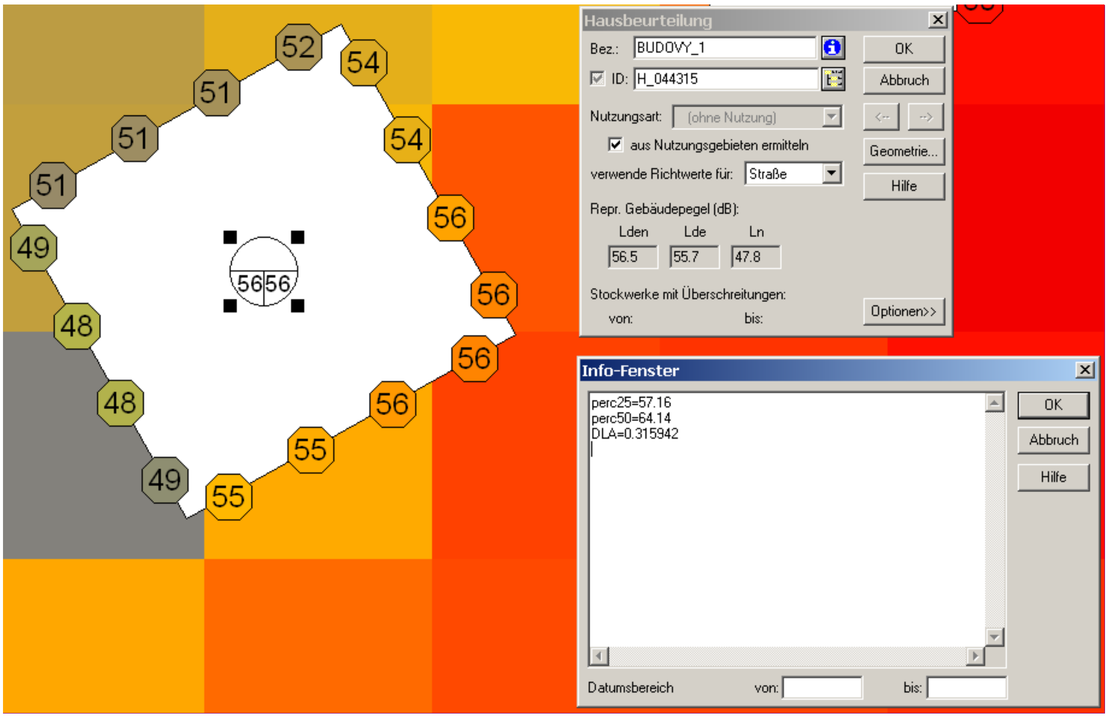

Figure 3.4.12: Ambient noise: example for calculated DLA

3.4.4 Calculating L_{den}'

First, the Objects *Building Evaluation* have to be modified (see Figure 3.4.13):

→ Modify Objects

→ Action: Modify Attribute…

→ Object Types: Building Evaluation

→ OK

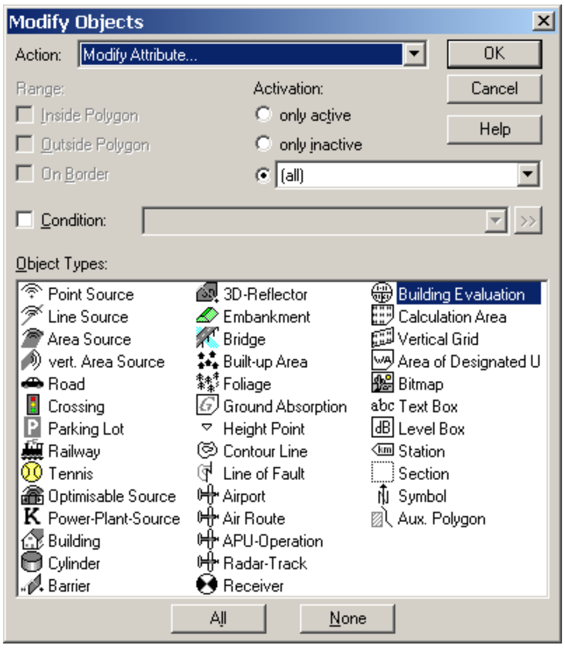

Figure 3.4.13: Define Lden2 – step 1

Then, a new attribute *Lden2* representing the noise level L_{den}' has to be created (see Figure 3.4.14):

→ Attribute: MEMOTXTVAR (String variable)

→ Text Variable: *Lden2*

→ Arithmetic

→ New Value = LP1+MEMO_DLI+MEMO_DLQ+MEMO_DLA

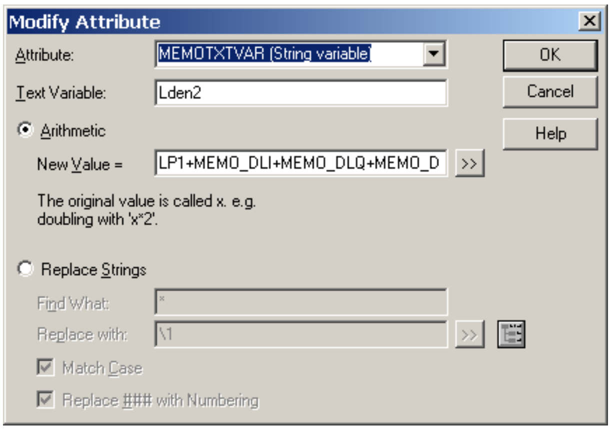

Figure 3.4.14: Define Lden2 – step 2

At last, the new attribute L_{den2} representing the noise level L_{den}' has to be copied from the object *Building Evaluation* to the object *Building* (see Figure 3.4.15):

→ Menu -> Grid -> Object-Scan...

→ Object Type: Building Evaluation

→ Action / Sum into: Specified Areas / Polygones

→ Target Object Type: Building

→ (1) Attribute: MEMOTXTVAR (String variable) -> Text Variable: "Lden2"

→ (1) Formula for Summation: MEMO_Lden2

→ (1) Formula for Total: sum

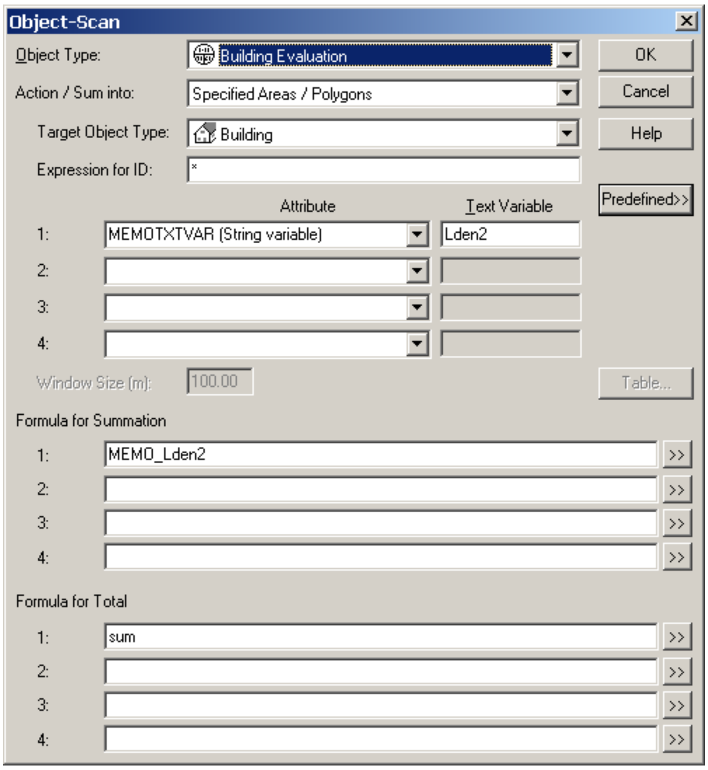

Figure 3.4.15: Define Lden2 – step 3

The result can be seen in the example in Figure 3.4.16: with L_{den} = 56.5 dB(A) (see 3.4.1), ΔLI = -0.5 dB (see 3.4.1), ΔLQ = 0.3 dB (see 3.4.2) and ΔLA = 0.3 dB (see 3.4.3) the result is L_{den}' = 56.5.

Note: if you want to recalculate the example above, you have to use values with more decimals than above to get the exact values: L_{den} = 56.4779 dB(A), ΔLI = -0,507619 dB, ΔLQ = 0.262530 dB, ΔLA = 0.315942 dB, L_{den}' = 56,5488. That makes a difference of +0.0709 dB – even if in practice you would never use more than the first decimal place.

The variable Lden2 is now stored with the object *Building Evaluation* for further calculations.

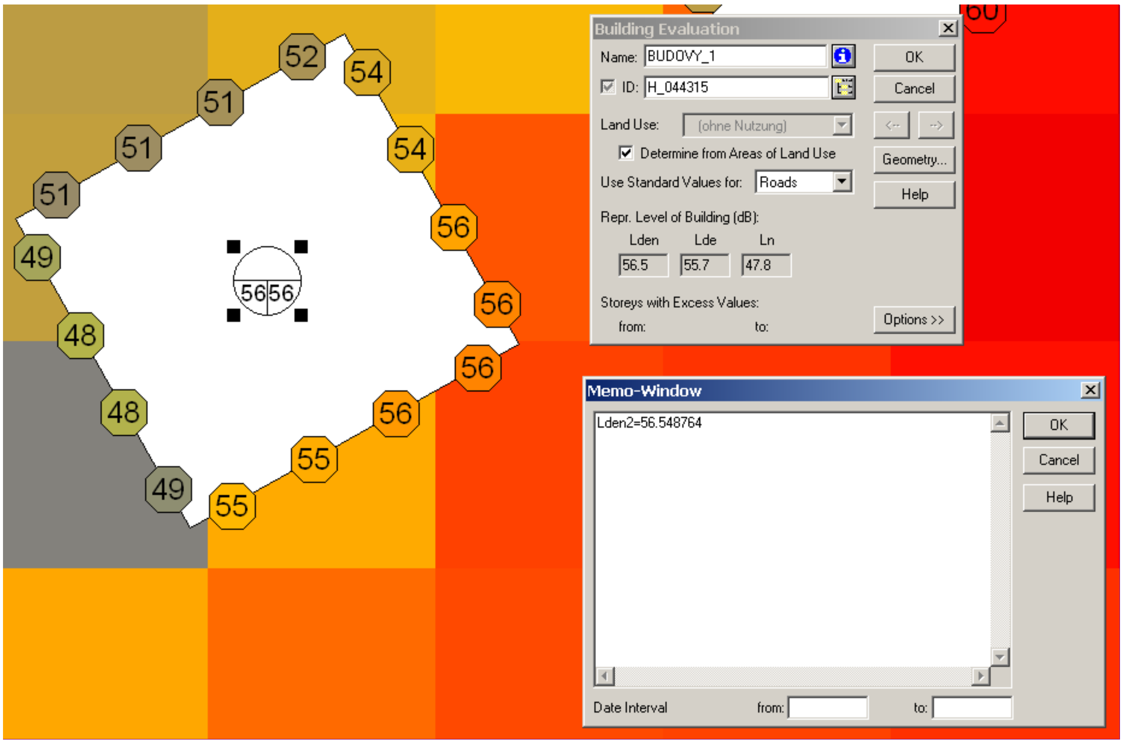

Figure 3.4.16: Example: calculated Lden2 representing the noise level L_{den}'

3.5. EXAMPLE: CALCULATED REFINED NOISE SCORE OF AN AREA

Figure 3.5.1 shows the test site Bratislava. The calculation area, the Q-Zone and the embedded park are encircled.

Figure 3.5.1: Example Map 1 – City of Bratislava: aerial view with borderline of the areas

A noise map of the small quiet zone is shown in Figure 3.5.2.

Figure 3.5.2: Example Map 2 – City of Bratislava:
Noise Map and Building Noise Map in the small quiet zone

To see more details a zoomed area ist shown in Figure 3.5.3. The values written inside the buildings represent the noise levels L_{den} of the loudest facade are converted to the noise levels L_{den}' in the next step.

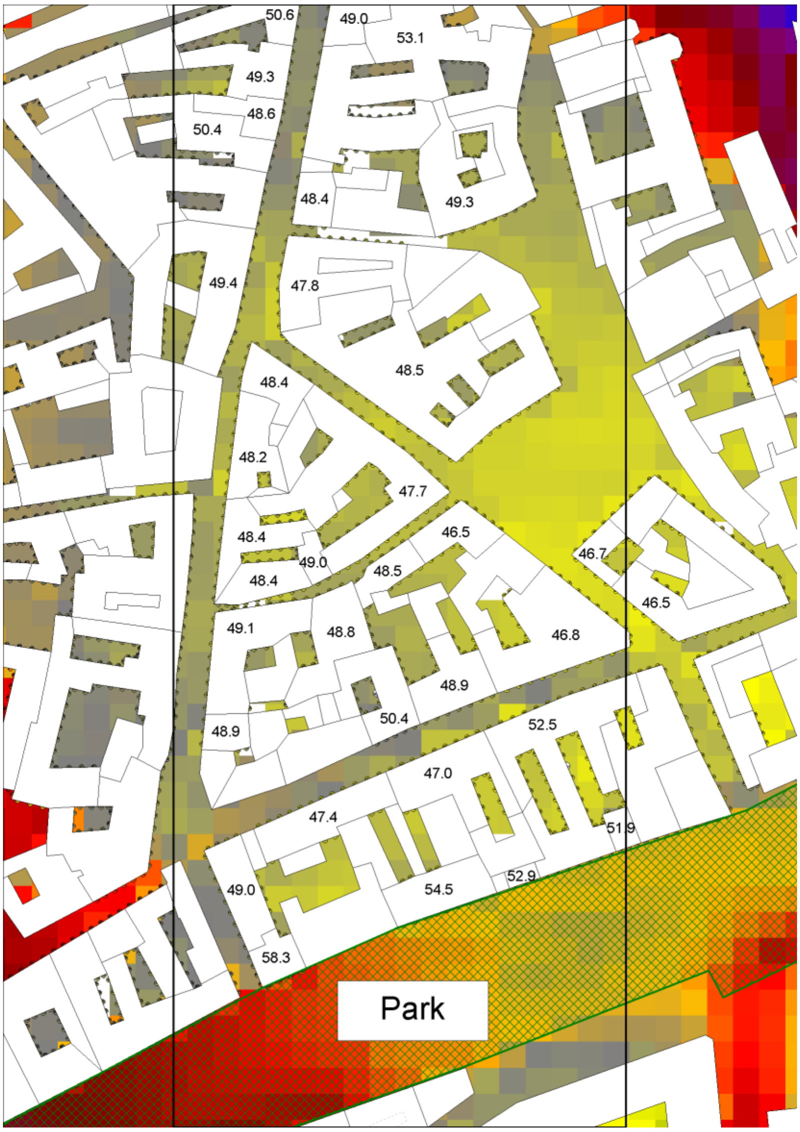

Figure 3.5.3: Example Map 3 – City of Bratislava:
Building Noise Map with numerical values L_{den} inside the buildings within the zoom area

Figure 3.5.4 shows the noise levels L_{den}' written inside the buildings.

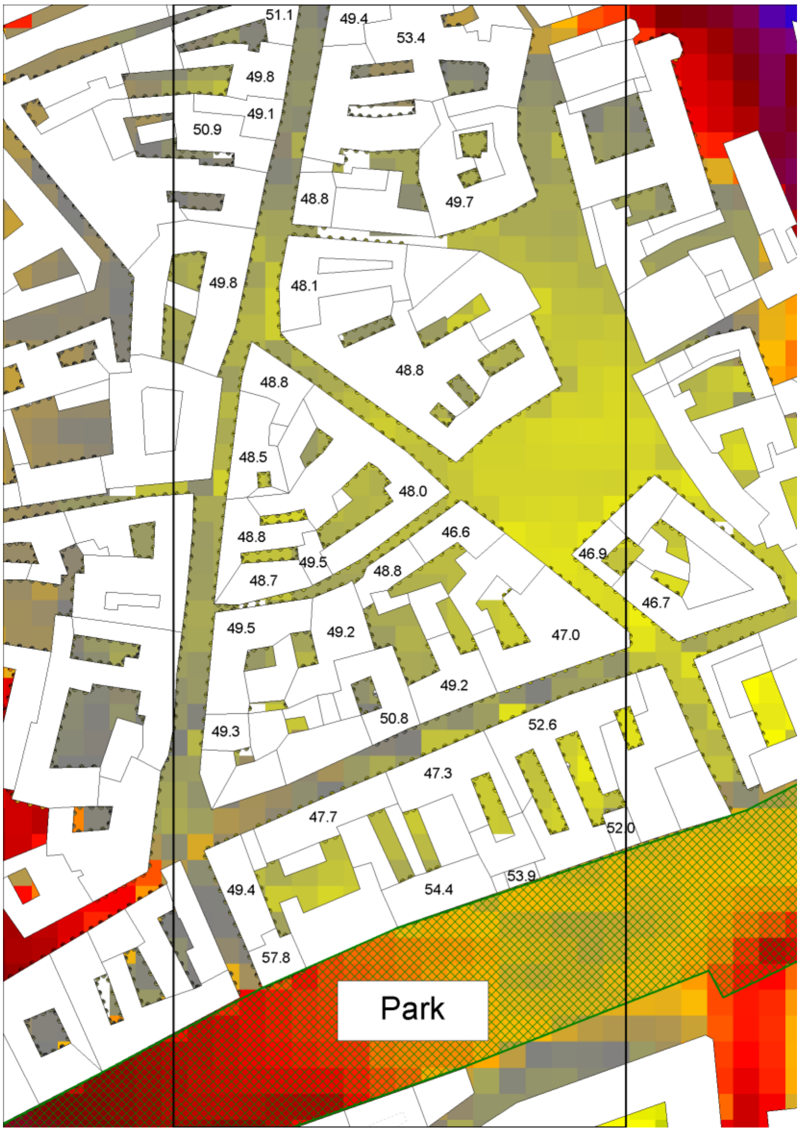

Figure 3.5.4: Example Map 4 – City of Bratislava:
Building Noise Map with numerical values L_{den}' inside the buildings within the zoom area

Table 3.5.1 shows the evaluation of the number of residents and the number of highly annoyed people within the noise level ranges of both L_{den} and L_{den}'.

Table 3.5.1: Example: difference of highly annoyed people based on L_{den} and L_{den}' in the small quiet zone

Level Range		Residents		Factor	Highly Annoyed People		
from	to	Lden	Lden'	Road	Lden	Lden'	Difference
[dB(A)]	[dB(A)]			[%]			
45	46	0	0	1,4	0	0	0
46	47	134	71	1,9	3	1	-1
47	48	93	130	2,3	2	3	1
48	49	173	101	2,8	5	3	-2
49	50	259	304	3,2	8	10	1
50	51	81	111	3,7	3	4	1
51	52	219	135	4,2	9	6	-3
52	53	75	150	4,7	4	7	4
53	54	21	96	5,2	1	5	4
54	55	68	10	5,8	4	1	-3
55	56	60	17	6,4	4	1	-3
56	57	81	144	7,1	6	10	4
57	58	114	334	7,8	9	26	17
58	59	308	322	8,6	26	28	1
59	60	239	276	9,4	22	26	3
60	61	174	482	10,3	18	50	32
61	62	354	161	11,3	40	18	-22
62	63	285	637	12,4	35	79	44
63	64	203	304	13,6	28	41	14
64	65	147	0	14,8	22	0	-22
65	66	75	182	16,2	12	29	17
66	67	541	110	17,7	96	19	-76
67	68	0	134	19,2	0	26	26
68	69	159	75	20,9	33	16	-18
69	70	175	15	22,8	40	3	-36
70	71	93	5	24,7	23	1	-22
71	72	11	15	26,8	3	4	1
72	73	10	0	29,1	3	0	-3
73	74	10	0	31,5	3	0	-3
74	75	79	0	34,0	27	0	-27
75		180	100	36,7	66	37	-29
Sum		**4.421**	**4.421**		**554**	**454**	**-100**

4. CONCLUSION

The refined noise score rating model for indoors [1] was integrated in noise mapping software. A procedure was developed using CadnaA [2]. The developed procedure allows users to adequately assess the impact of environmental noise on residents without the need of expert software knowledge.

5. REFERENCES

[1] Salomons, Erik M. , Janssen, Sabine A.: *Refined noise score rating model for residents*, CityHush Deliverable 2.2.1, 2011-06-29

[2] *CadnaA*, software for calculation, presentation, assessment and prediction of environmental noise, Datakustik GmbH, Greifenberg, Germany