Sounding Brighton, exploring practical approaches towards better soundscapes

Soundscape and urban morphology

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Outline

Explores relations between urban morphology and soundscape design, *considering various urban structures and cultures*.

- Relationships between urban sound environment and social-economic factors;
- Noise resistance of different urban structures;
- From noise maps, to sound maps, to soundscape maps, taking perception and cultural factors into account;
- Urban morphology and soundscape masking

Relationships between urban sound environment and social-economic factors

- **A case study in London**
- **2 acoustic indices**

  L_{ave} average traffic noise level
  L_{10} spatial intrusive traffic noise level

- **41 social-economic factors at neighbourhood level**

  deprivation (factor A1~A8), demography (factor A9~A10), religion (factor A11~A18), health (factor A19~25), employment (factor A26~A35), environment (factor A36~A41)

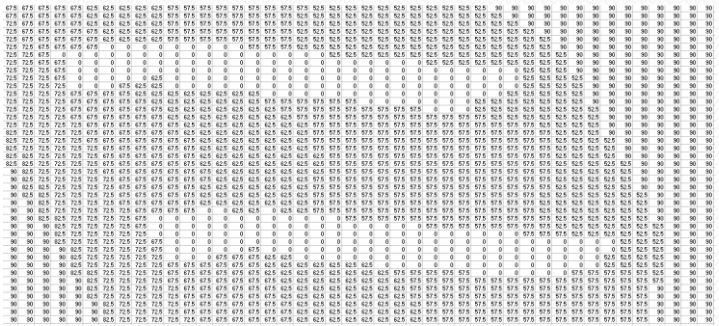
- **37 social-economic factors at borough level**

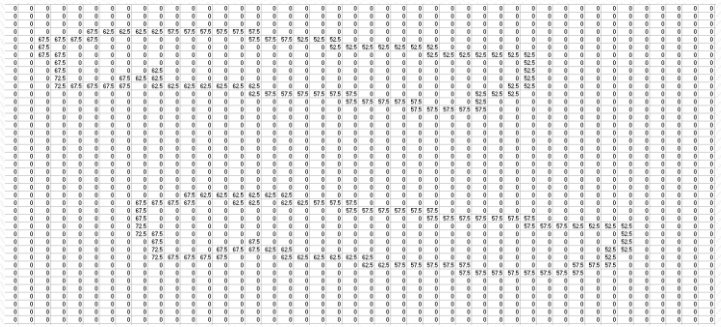
  education (factor B1~B4), age (factor B5~B13), demography (factor B14~B20), employment (factor B21~B28) and income (factor B29~B37)

- **3 geographic types**

  Postcode (329)
  Lower Super Output Areas/ Neighbourhood (272)
  London Borough (21)

Processing of Noise Map Data





Neighbourhood level

The rank of total deprivation has a significant negative correlation with the neighbourhood noise level ($p<0.05$ for both Lave and L10). In other words, the neighbourhood with higher noise level tends to be more deprived in England.

	Total deprivation	Income deprivation	Employment deprivation	Health deprivation	Education deprivation	Barriers to housing & services deprivation	Crime deprivation	Living environment deprivation
L_{ave}	-0.139(*)	-0.054	-0.091	-0.150(*)	-0.073	-0.188(**)	-0.058	-0.276(**)
L_{10}	-0.105(*)	-0.023	-0.051	-0.127(*)	-0.064	-0.190(**)	-0.014	-0.289(**)

** indicates $p<0.01$ and * indicate $p<0.05$.

Neighbourhood level

No significant correlation has been found between the neighbourhood noise levels and the percentages of various religious communities

	Christian	Buddhist	Hindu	Jewish	Muslim	Sikh	Others	No religion
L_{ave}	0.009	0.088	-0.117	0.056	0.113	0.082	-0.097	0.033
L_{10}	0.021	0.107	-0.118	0.044	0.075	0.032	-0.069	0.096

Borough level

Significant correlations are generally found between borough noise levels and median income levels and the correlation coefficients are rather high. That means people's income is generally higher in nosier borough. A possible reason is that more working-age people are living in nosier areas.

	Males				Females				All people median
	Median	10% earned less than median	25% earned less than	25% earned more than	Median	10% earned less than	25% earned less than	25% earned more than	
L_{ave}	0.417	0.391	0.334	0.421	0.606(**)	0.626(**)	0.652(**)	0.420	0.497(*)
L_{10}	0.486(*)	0.418	0.476(*)	0.544(*)	0.723(**)	0.663(**)	0.776(**)	0.582(*)	0.580(**)

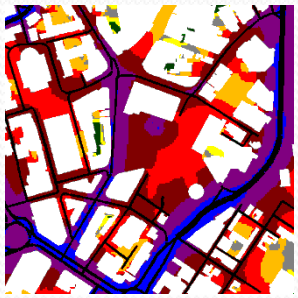
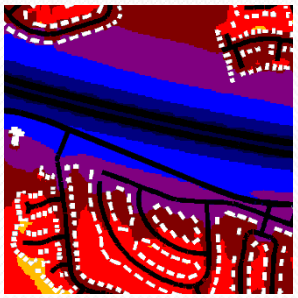
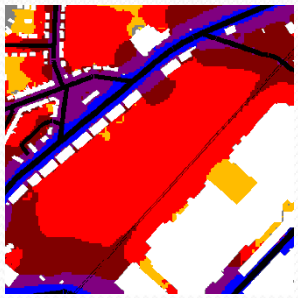
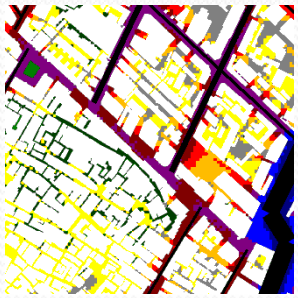
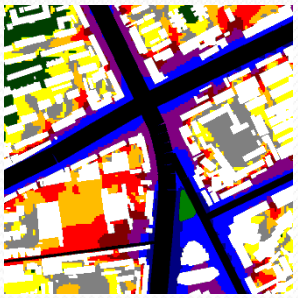
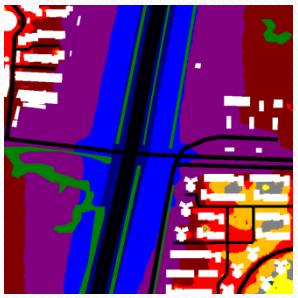
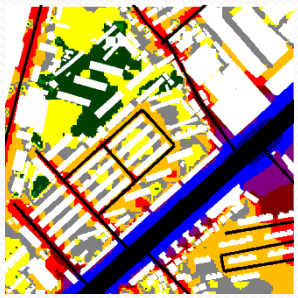
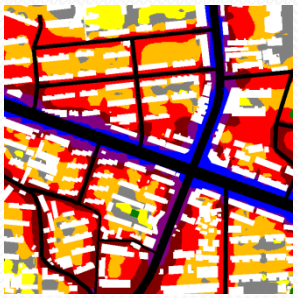
** indicates $p<0.01$ and * indicate $p<0.05$.

Noise resistance of different urban structures

Comparison between two typical cities, Sheffield in the UK and Wuhan in China.

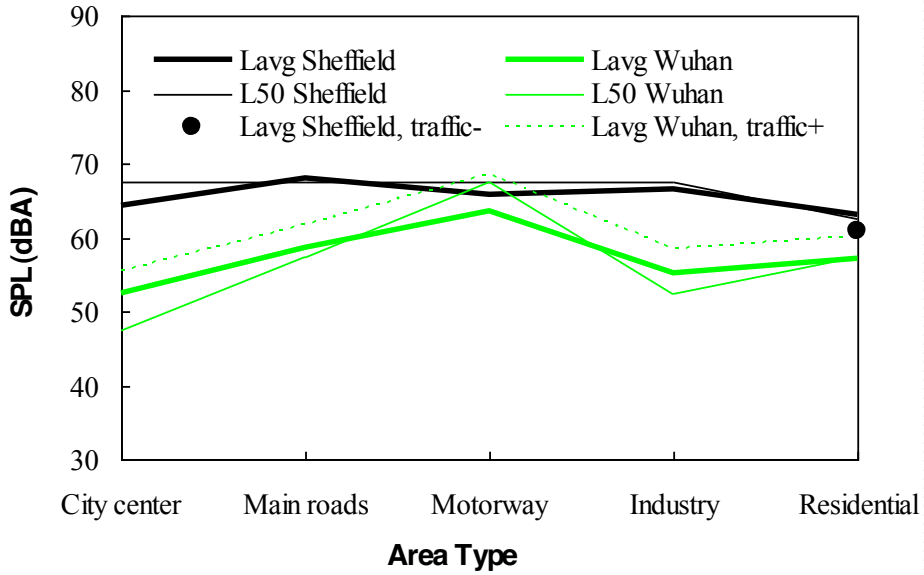
- In the sampling process the urban morphological characteristics, the classification of road traffic and the noise source types have all been all taken into account.
- Each sampled area is 500*500m.
- Considering traffic noise sources only, including roads, trams and light rails. The volume of traffic flow is based on site survey of some typical roads.

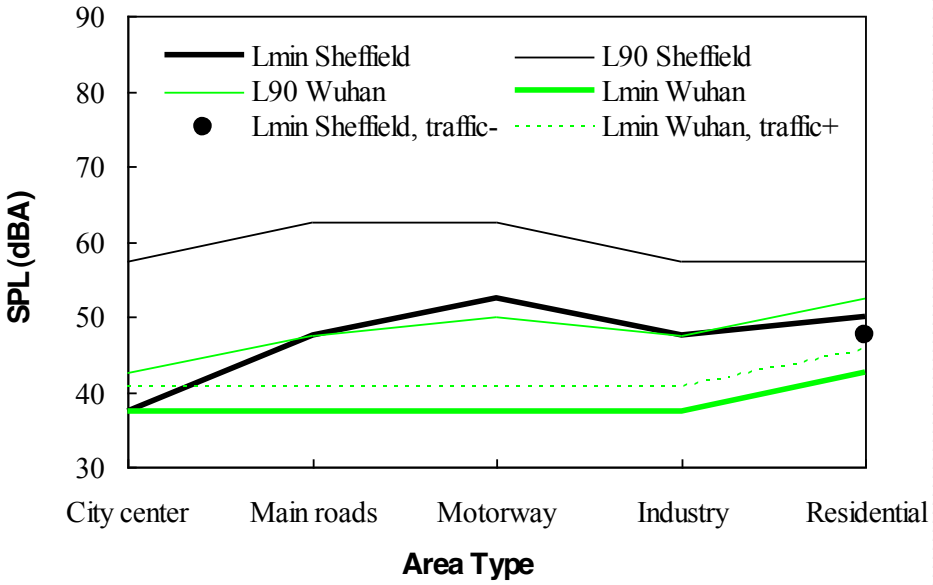
Again, a Matlab program has been developed to obtain a series of indices from the maps such as the noise levels at 1m from façade, road-side noise levels, noise levels in open spaces, spatial (rather than temporal as conventionally defined) statistical sound levels L_{max}, L_{10}, $L_{avg,}$ L_{50}, L_{min}, and L_{90}, as well as some urban morphological indices.

Category	City centre	Main road with tram/light rail	Residential with motorway	Industry area	Residential area
Sheffield	 Peace Gardens	 Brook Hill Road	 Motorway M1	 Meadowhall industrial area	 Crookes
Wuhan	 Jianghan Road	 Jinghan Road light rail	 Airport motorway	 Qingshan industrial area	 Hongshan

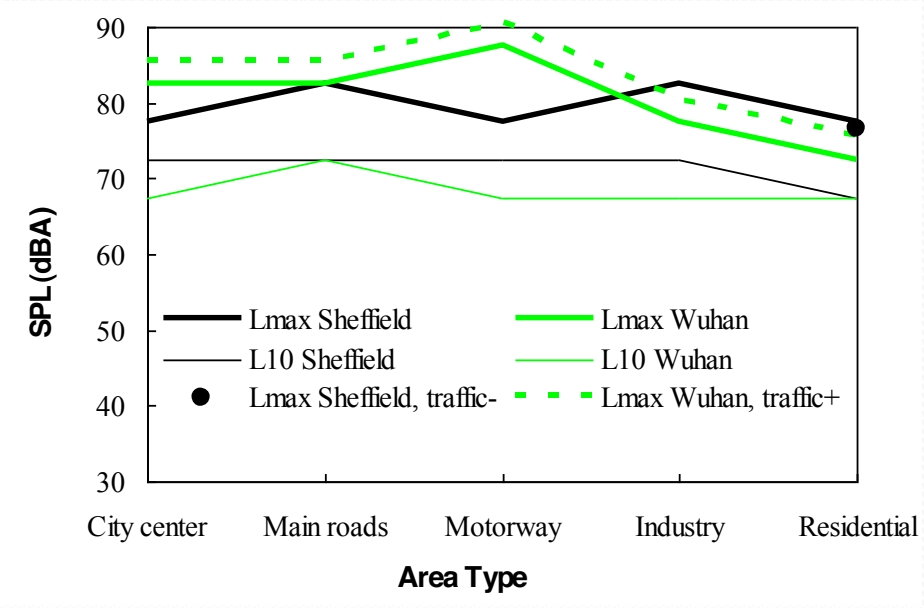
Comparison of the SPL between Sheffield and *Wuhan*

- The average noise levels Lavg in all the sampled areas are 2-11dBA lower than those in Sheffield. For L50 the result is similar to that of Lavg.
- For L90 and Lmin the difference is even greater, up to 15dBA.





- The Lmax in Sheffield is up to 5-10dBA lower than that in Wuhan some areas.
- For L10, the SPL in Sheffield is only slightly lower than, or the same as, that in Wuhan.



For Sheffield, since there are notable variations in traffic volume, especially in the small roads, a reduced traffic volume is also considered for the residential area, from 1500 to 800 per hour.

For Wuhan, given that the number of vehicles per person is still much lower than that in Sheffield, by >10 times, the SPL is also shown by assuming doubled traffic volume.

Why?

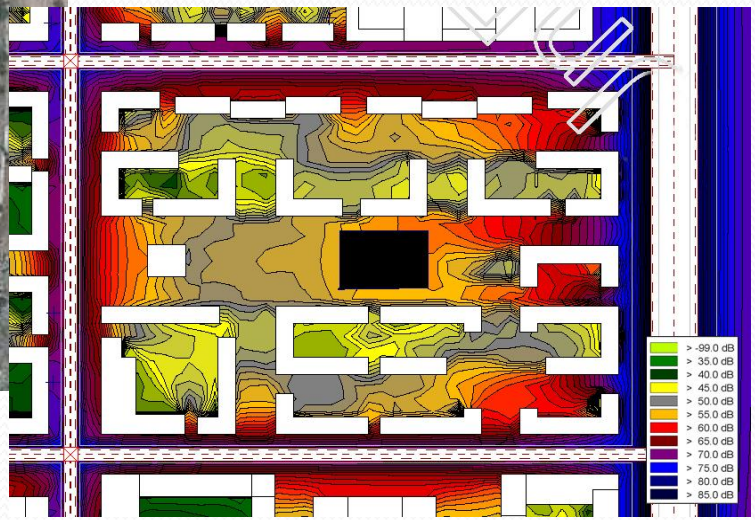
- Roads are evenly distributed in Sheffield whereas heavy traffic make uneven sound distribution in Wuhan, creating large areas of quiet zones, useful for soundscape design.
- High density and high-rise buildings act as effective noise barriers for the residential areas.
- The width of the main roads in Wuhan is generally greater than that in Sheffield.

So...

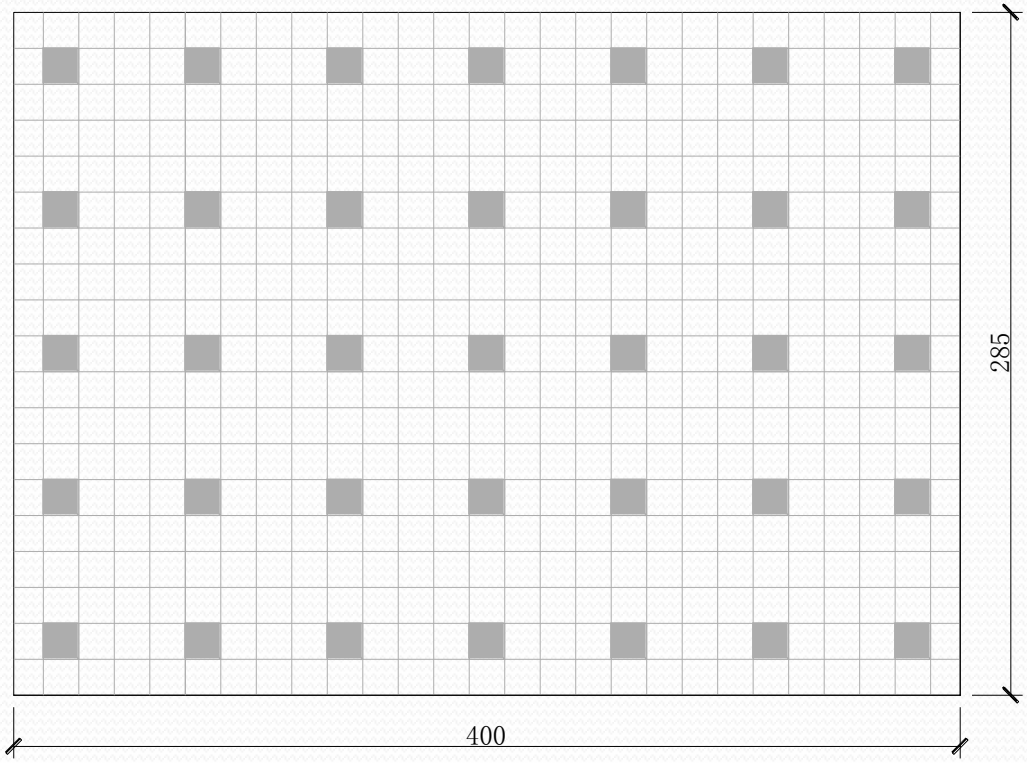
- The comparison clearly demonstrates the effectiveness of urban morphology on the noise distribution.

Optimisation:

Effects of building arrangements in a given urban area based on genetic algorithms



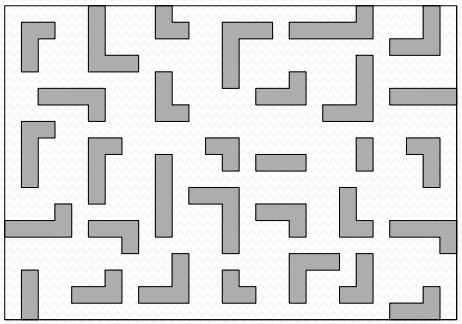
Computing the best sound environmental layout form by applying Genetic Algorithm under the control of sunshine and plot ratio

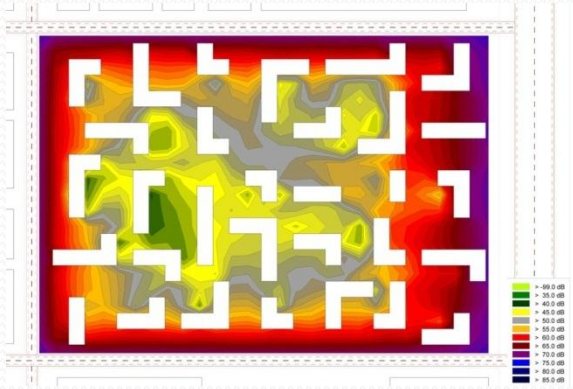


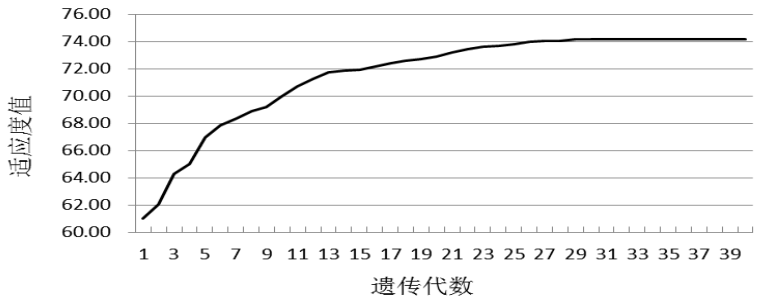
1.初始种群大小： 40
2.遗传代数： 40
3.选择概率： 0.5
4.交叉概率： 0.5
5.变异概率： 0.05
6.存活率： 0.8

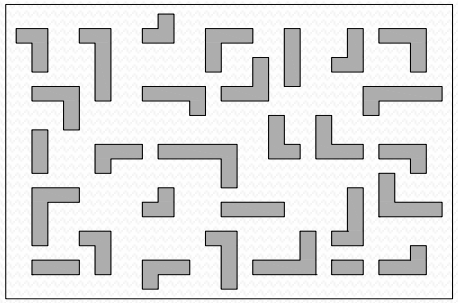
约束条件主要有以下两种：
1. 容积率为1.56
2. 住宅建筑日照标准

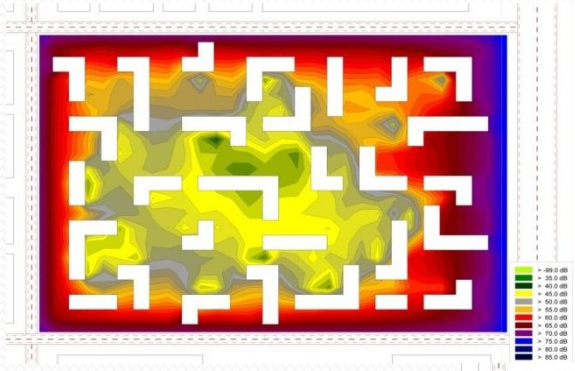
1st generation (60.02)





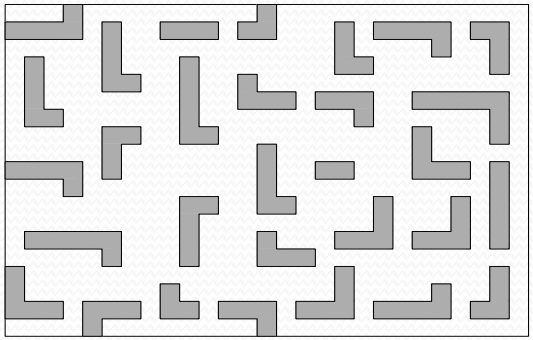


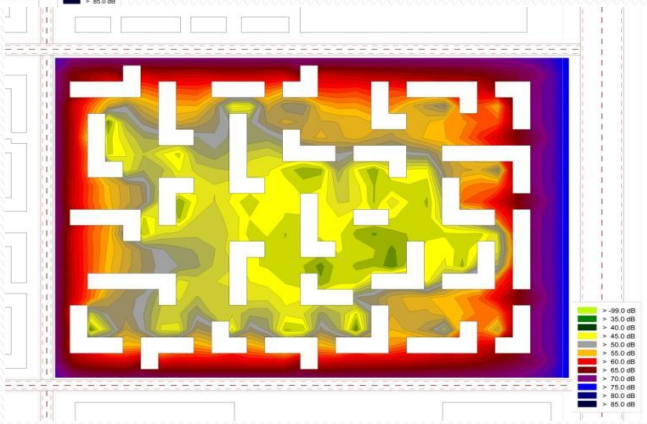




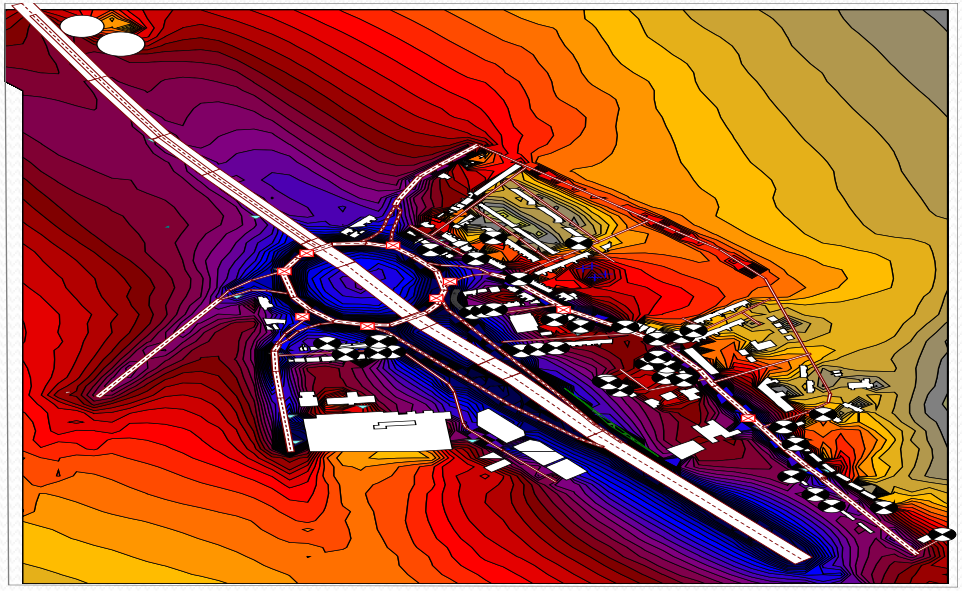
3rd generation (64.26)。

30th generation (74.13)。

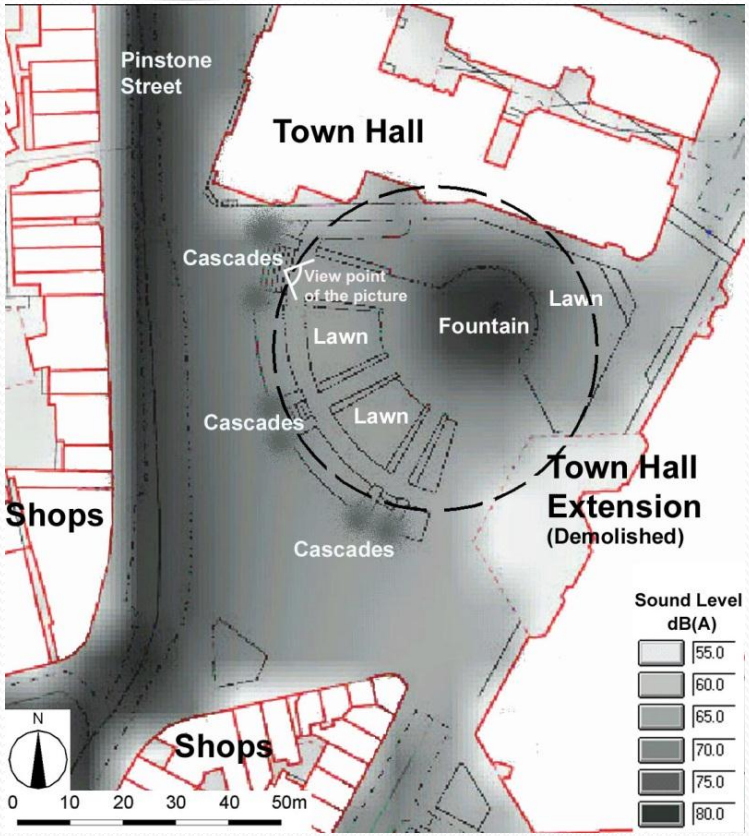




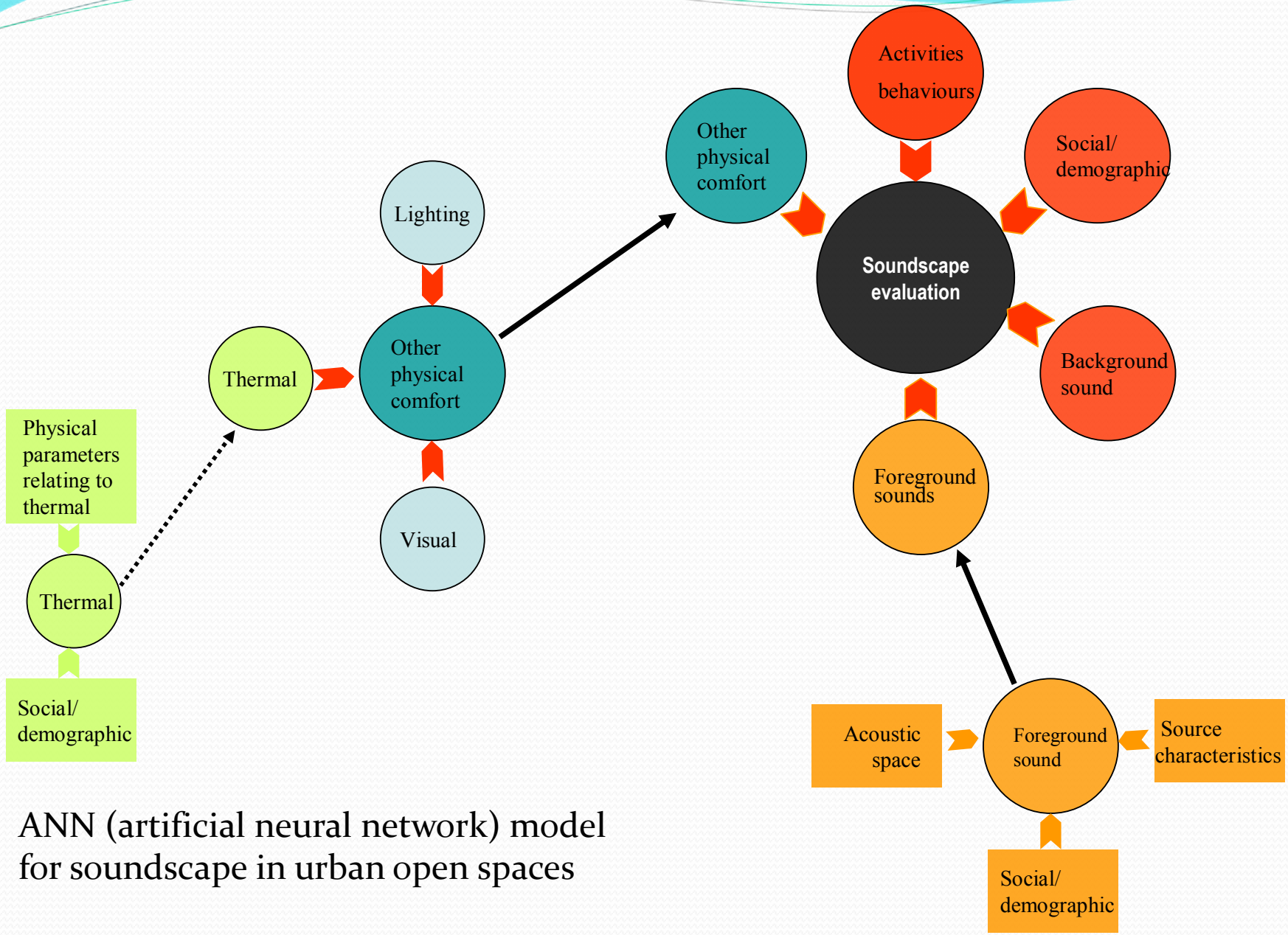
From noise maps, to sound maps, to soundscape maps, taking perception and cultural factors into account



Noise map



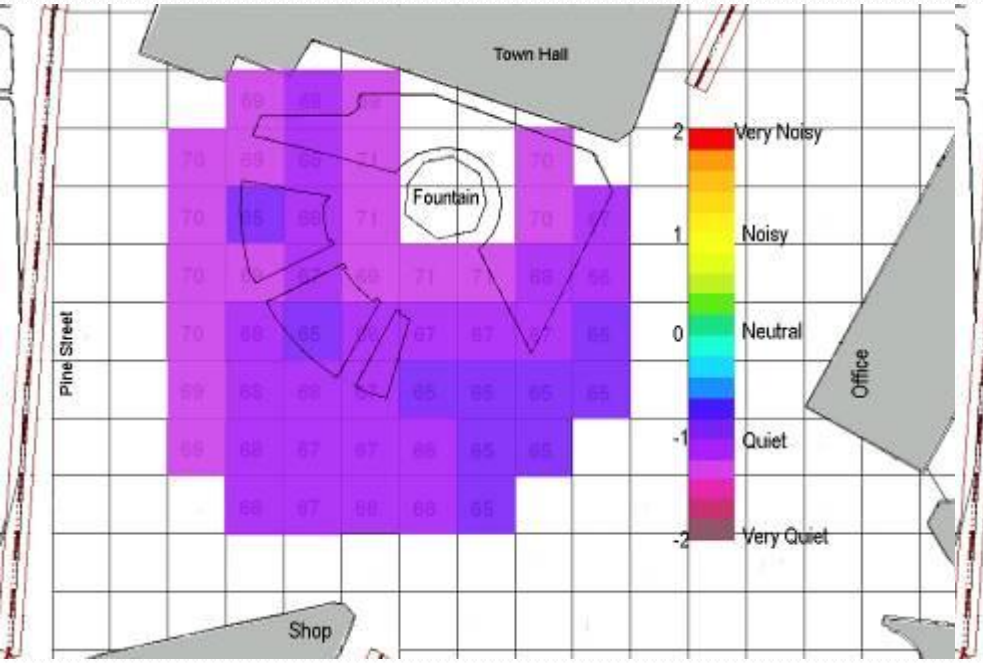
Sound map



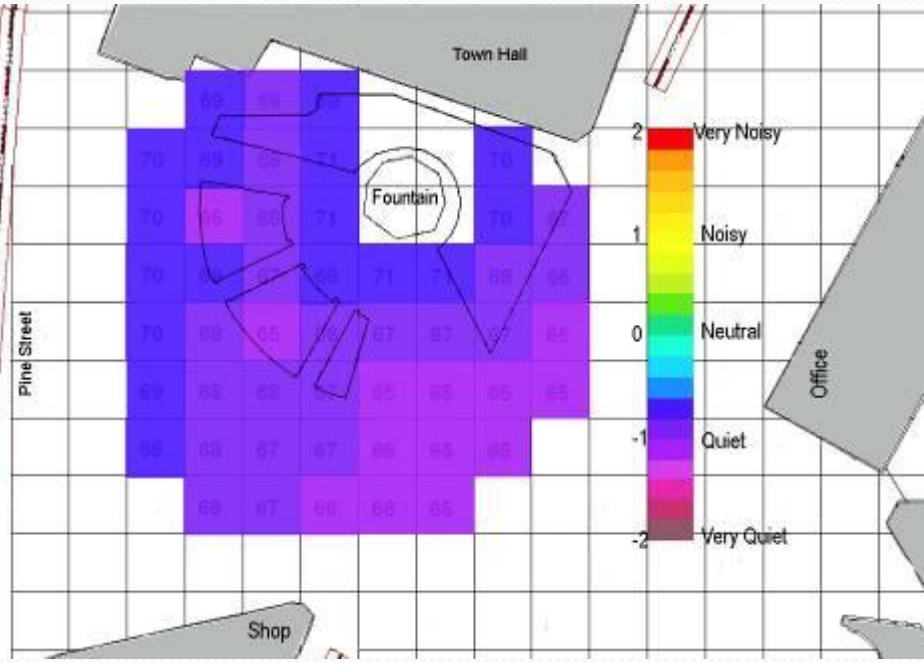
ANN (artificial neural network) model for soundscape in urban open spaces

Mapping Examples based on ANN

Maps of Sound Level Evaluation: different age groups



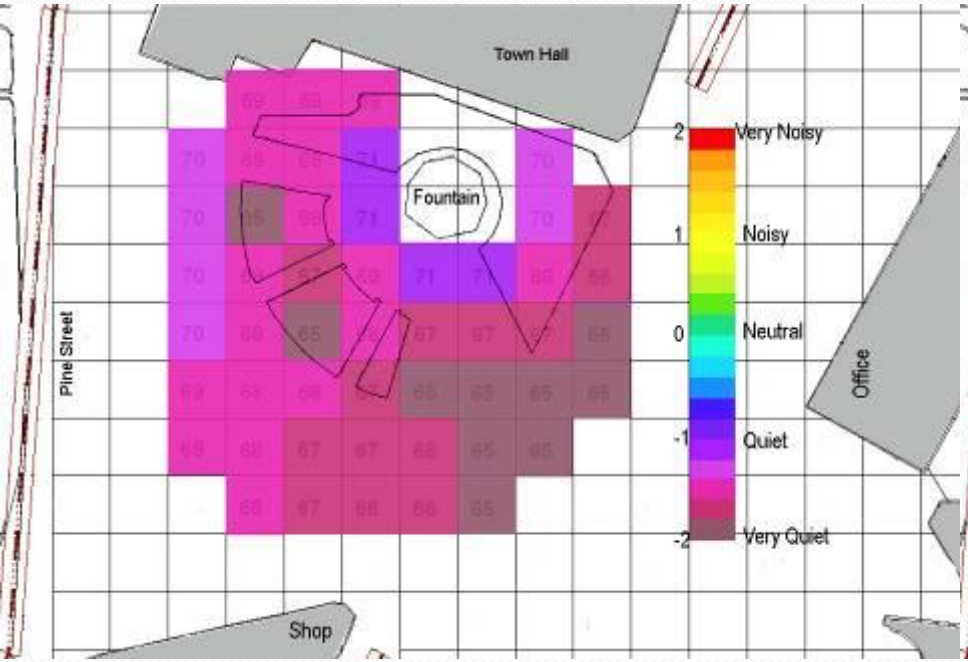
Age Group 13-18



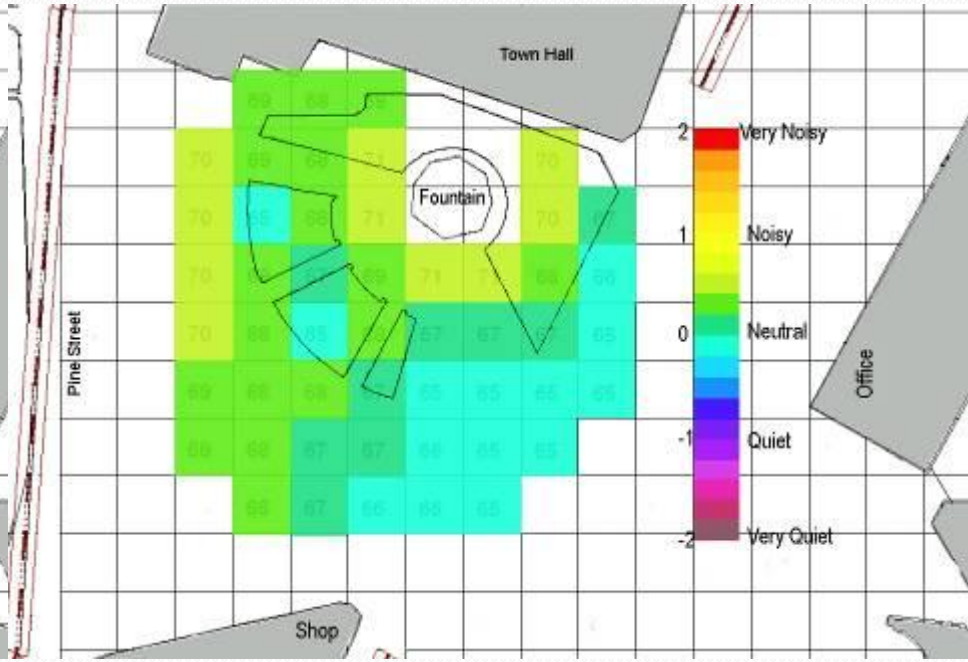
Age Group > 65

- Young people feel the square quieter than old people.

Maps of Sound Level Evaluation: different education groups



Secondary education level group



High education level group

- Higher education people feel the square noisier than the secondary education level group.

Urban morphology and soundscape masking

Masking as an important tool in assessment of sonic environments and an efficient design technique in urban design and planning
- may happen in various contexts, such as sound propagation, meaning of sound events and perceiver's multisensory (multimodal) integration.

Urban morphology, which concerns not only the spatial structure and character of a metropolitan area, city, town or village, but also social and cultural factors, is at the root of urbanism and urban design.

Overall aims:

- whether and how urban morphology influences soundscape in terms of auditory masking
- what parameters of urban morphology are correlated to auditory masking
- guidelines for urban design and planning

Two Main Research Lines for Masking:

- Attenuation of unwanted sound as target

Design of noise barrier in Sheaf Square, Sheffield

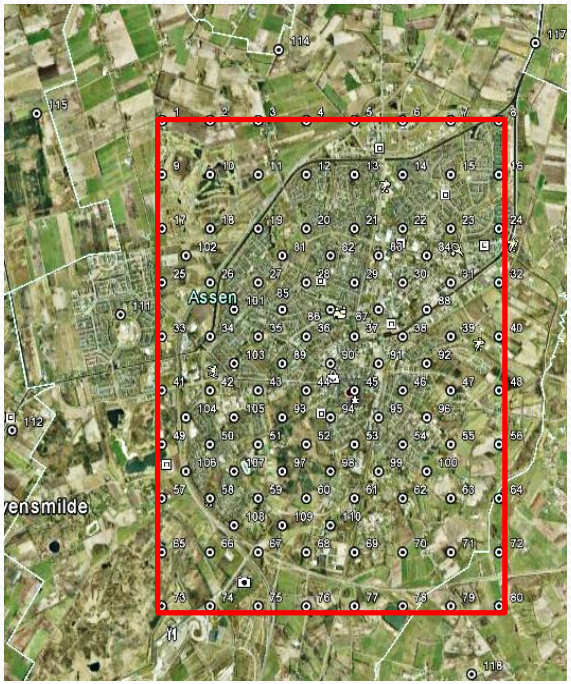
- positive masking are related to not only the realising of masking of unwanted sounds by wanted sound, but also the total loudness
- more feasible and favourable to create positive masking in relatively quiet areas and quiet façades in a noisy environment

- Enhancement of wanted sound as masker

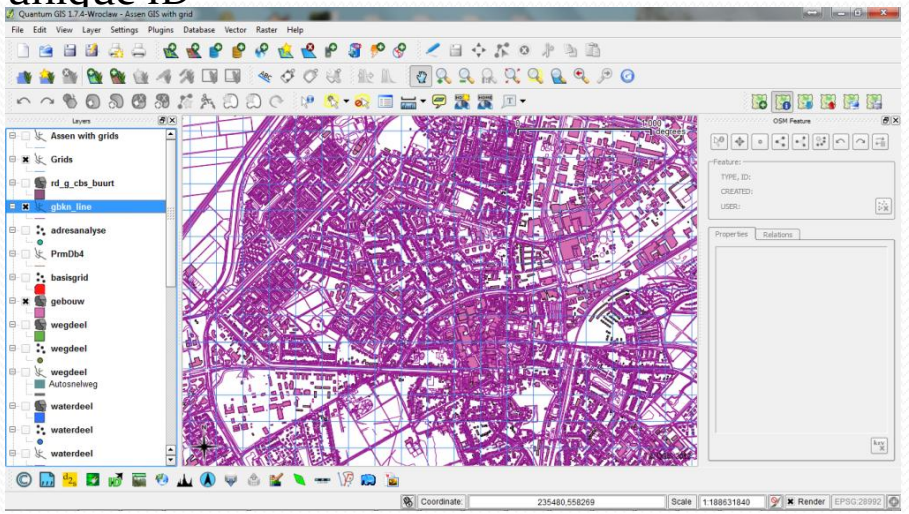
- positive masking may be enhanced through increased audibility of wanted sounds as masker in term of aural-visual interaction
-when the sounds are related to the scenes, people can obtain a more comfortable feeling by the aural-visual interaction

Design of fountain as the entrance to the headquarters in Wattens, Austria of Swarovski Crystal. Photo by Michael Slonecker

GIS Database and Sampling

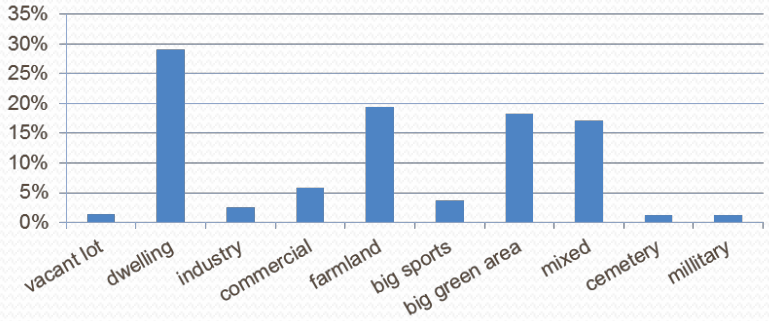


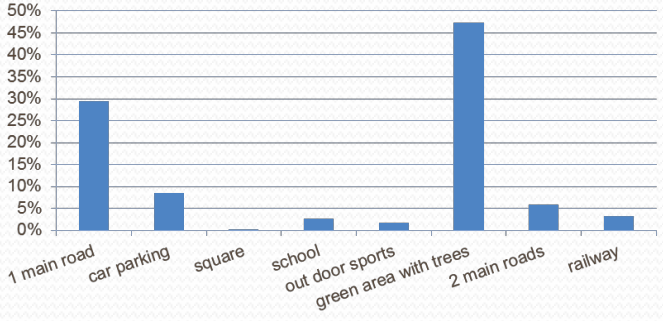
- Build a GIS (Geographic Information System) database of 763 grids (250m*250m) of the built-up area of Assen for Sensorcity Project, named with unique ID



Source: Assen GIS Database from Cognitive group, INCAS3

- Sample the grids with their land use and acoustic features for the site selection





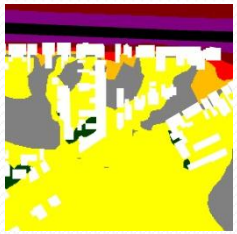
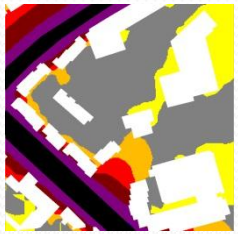
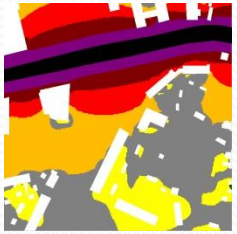
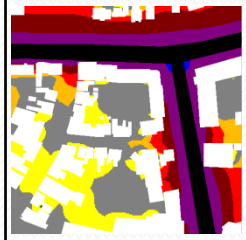
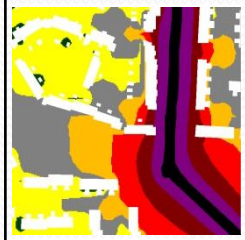
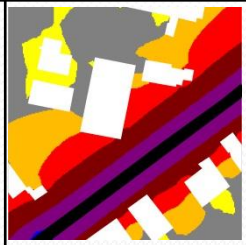
Indices from perspective of masking:

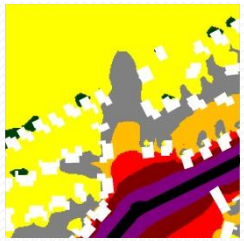
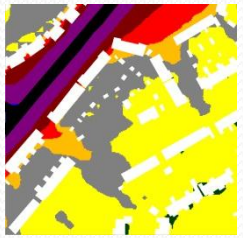
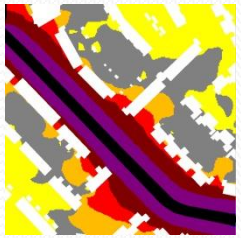
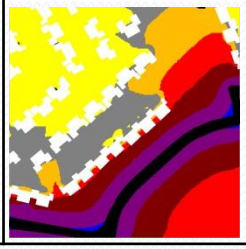
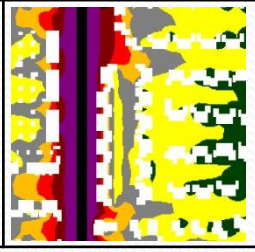
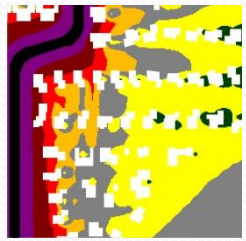
- Urban morphology
- Spatial sound level
- Spatial sound level distribution

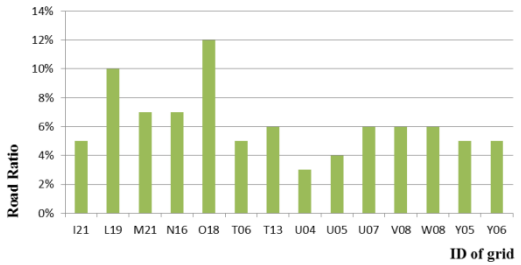
Attenuation of unwanted sound as target	**Urban morphology:** • Building Coverage Ratio; • Road Ratio; • Accessible Space Ratio;	**Attenuation in spatial sound levels:** • Lmax-Lmin (on façade); • Lmax-Lmin (in open area); • L10-L90 (on façade); • L10-L90 (in open area); • L20-L80 (on façade); • L20-L80 (in open area);	**Area for different masking design:** • % of area with SPL <50 dB(A) (Quiet); • % of area with SPL 50-60 dB(A) (Medium); • % of area with SPL 60-70 dB(A) (Loud); • % of area with SPL >70 dB(A) (Very loud);
Enhancement of wanted sound as masker	**Urban morphology:** • Building Coverage Ratio; • Green Ratio; • Length of Green Area Boundary; • Green Area to Building Ratio	**Area with different sound levels:** • % of area with SPL <40 dB (Quiet); • % of area with SPL 40-50 dB (Medium); • % of area with SPL 50-60 dB (Loud);	**Area for enhanced masking via aural-visual interaction**: • % of area with visible sound source in the areas with SPL of < 40 dB, 40-50 dB and 50-60 dB, respectively; • % of area with SPL of < 40 dB, 40-50 dB and 50-60 dB in the area with view of sound source, respectively

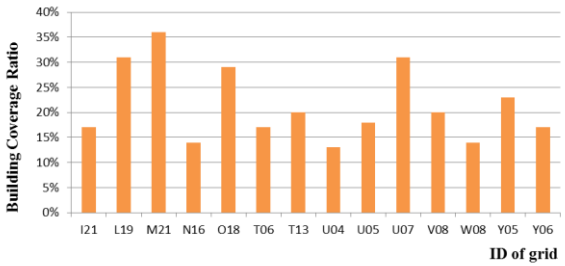
Attenuation of Unwanted Sound as Target for Masking

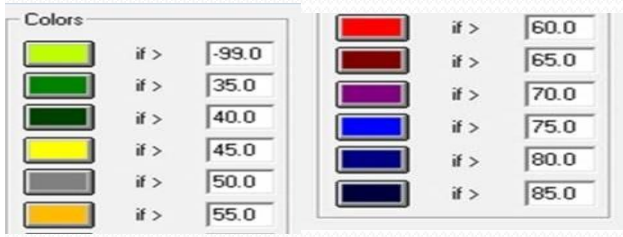
Traffic noise mapping of the 14 sampled sites in residential and mix-used areas

I21	L19	M21	N16	O18	T06	T13
						

U04	U05	U07	V08	W08	Y05	Y06
						

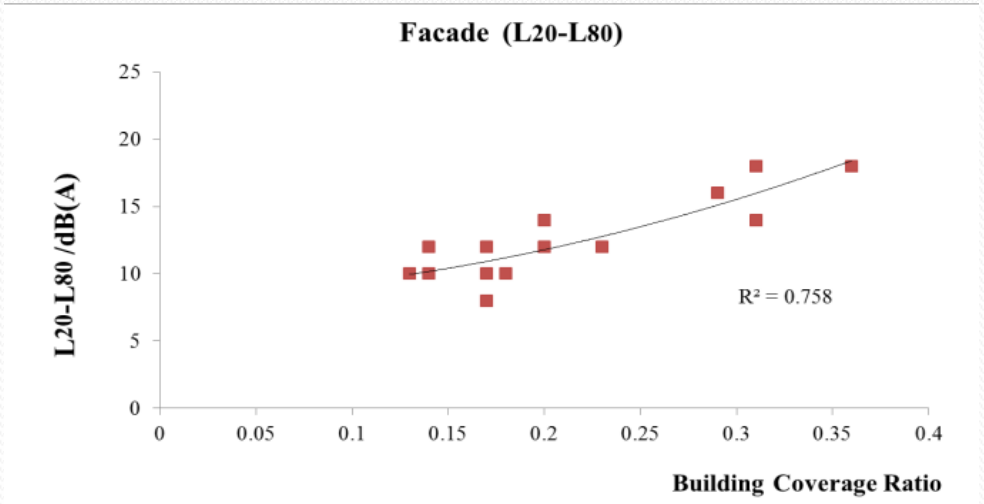


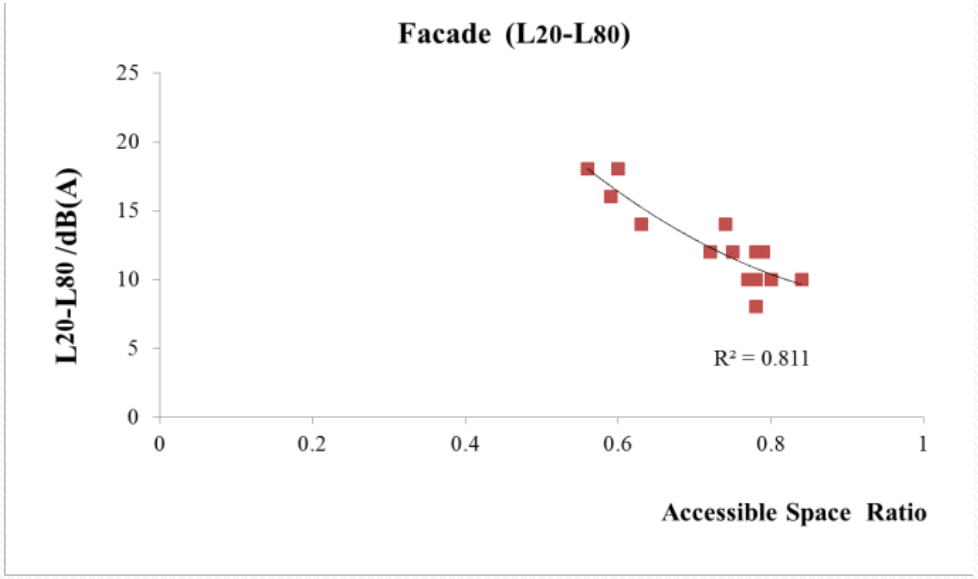




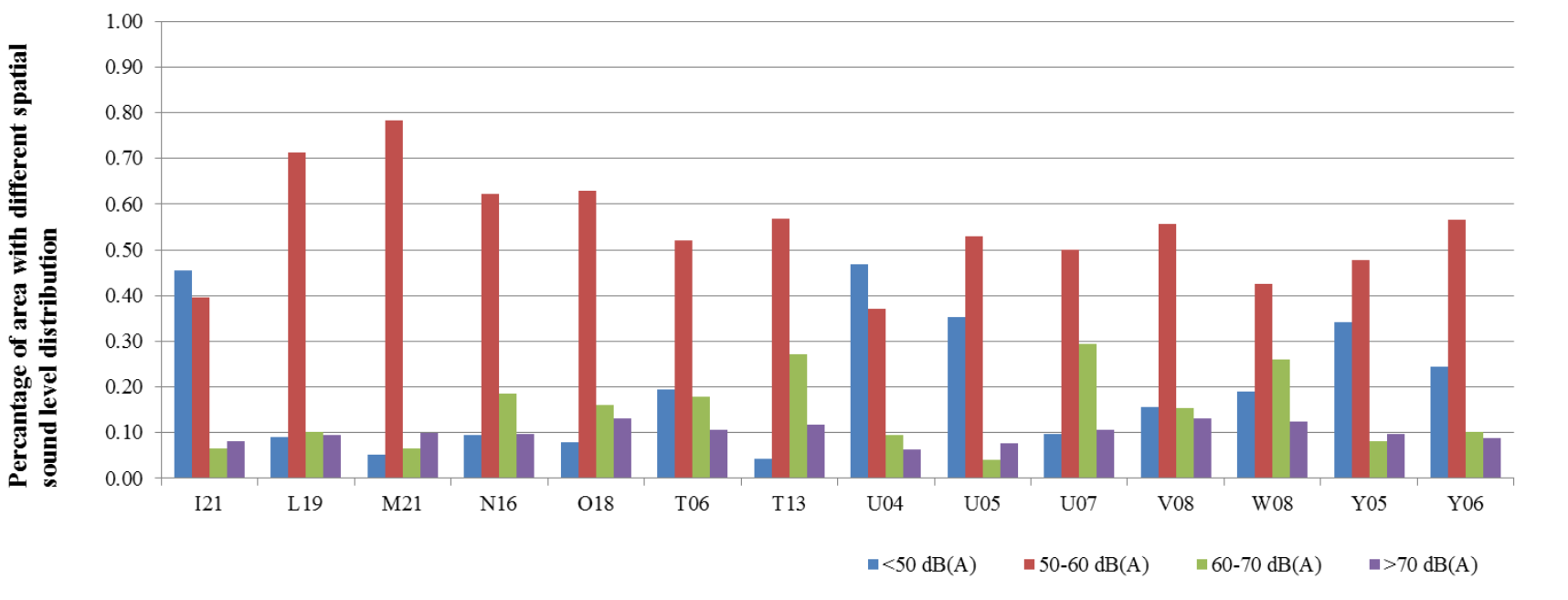
Attenuation in Sound Levels

- L20-L80 is the only index highly correlated to the urban morphological indices.
- Masking in quiet areas possible in the sites with higher building coverage or less accessible space.
- Indices related to quiet façades, rather than in open areas, are highly correlated to urban morphological indices.



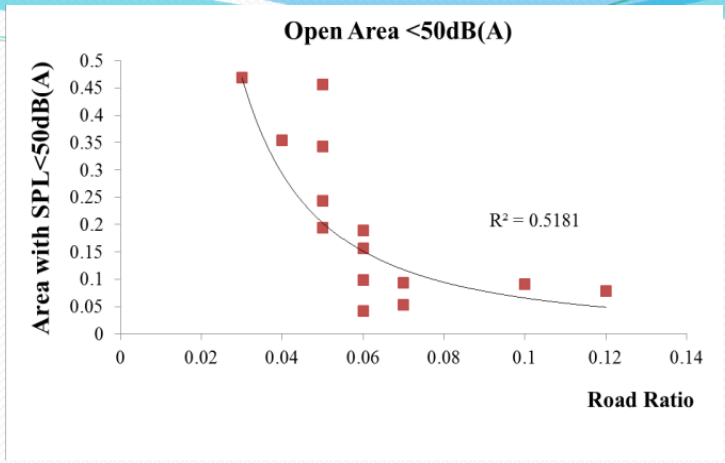


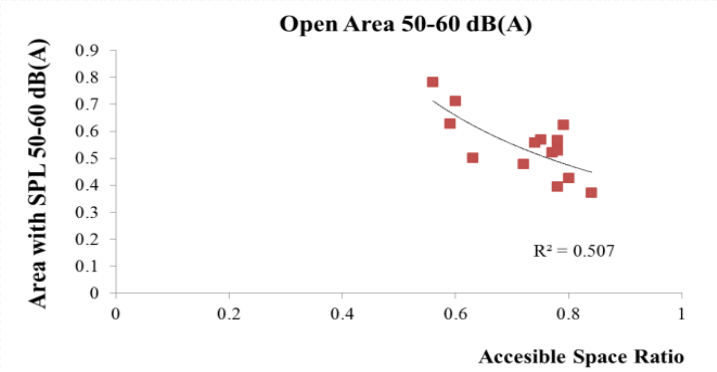
Area for Different Masking Design

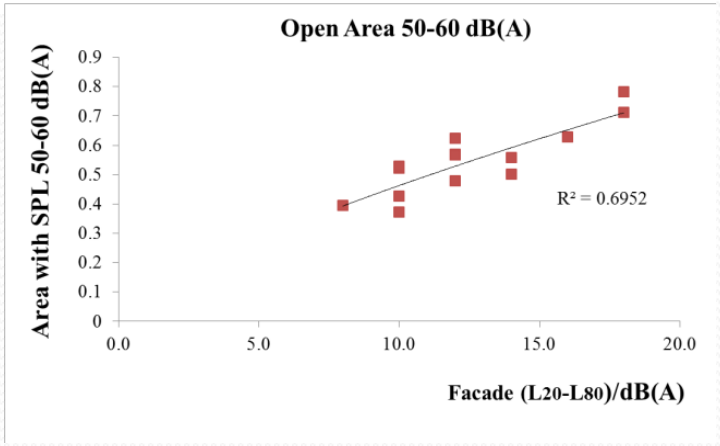


- For the area with traffic noise SPL of 50-60 dB(A), masking could be designed by using water <70 dB(A), for open public spaces.
- Such areas are very common, showing potential for the creation of quiet areas.

- The percentage of the areas with SPL < 50 dB(A) is rather varied in the 14 sites and decreases with the increase of Road Ratio.
- The percentage of the areas with SPL 50-60 dB(A) decreases with increasing Accessible Space Ratio.
- The L_{20}-L_{80} on façade is correlated to the amount of quiet areas.







Sound Interference in Energetic Masking

- Frequency and sound level
- Distance and loudness

Traffic noise and water sound

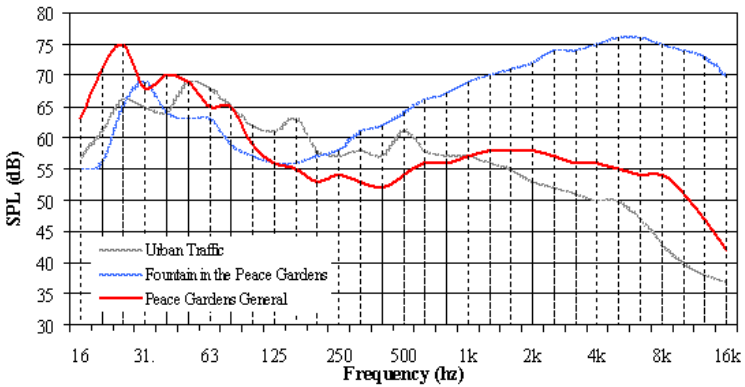
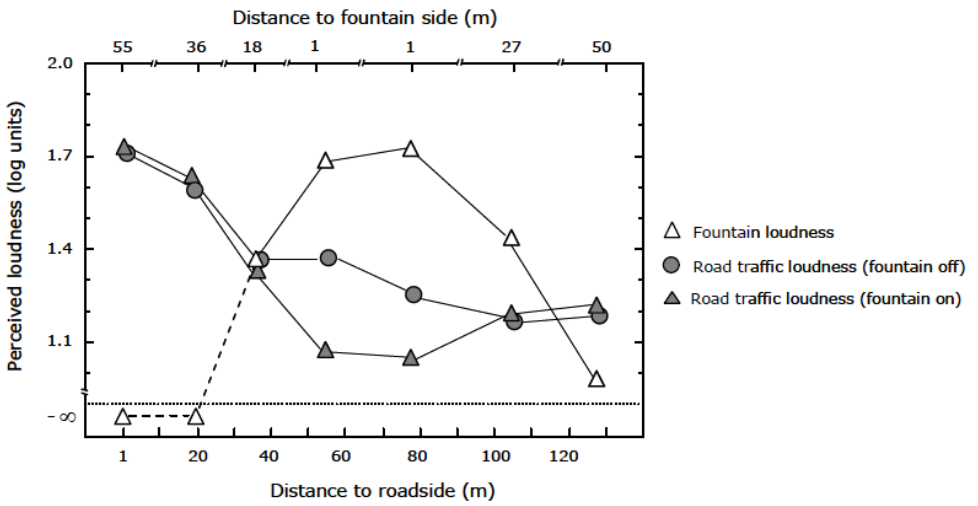


Figure 8.4 The comparison of the sound spectra in the Peace Gardens

Kang, J (2007), Urban Sound Environment. Taylor Francis, London.

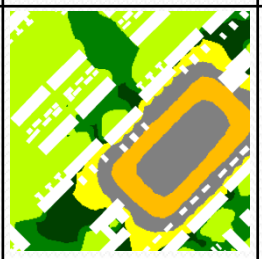
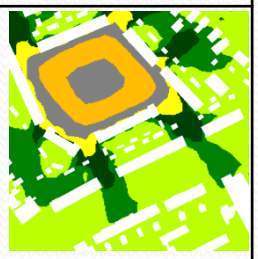


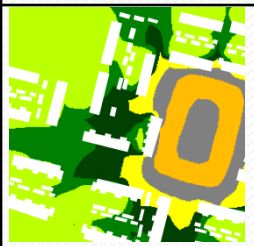
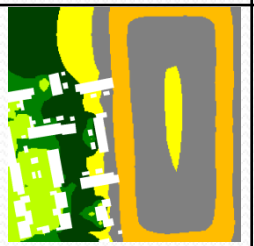
M. E. Nilsson, J. Alvarsson and M. Rådsten-Ekman, "Loudness of Fountain and Road Traffic Sounds in a City Park. Proceedings of the Sisteenth International Congress on Sound and Vibration 2009, Krakow, Poland.

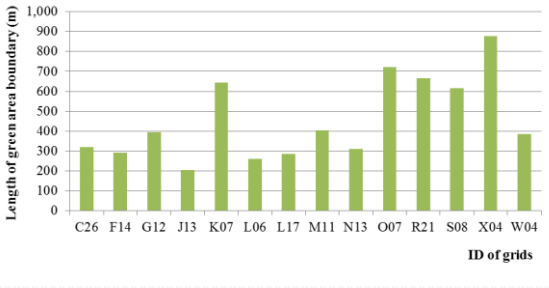
Similarly, traffic noise and birdsong ...

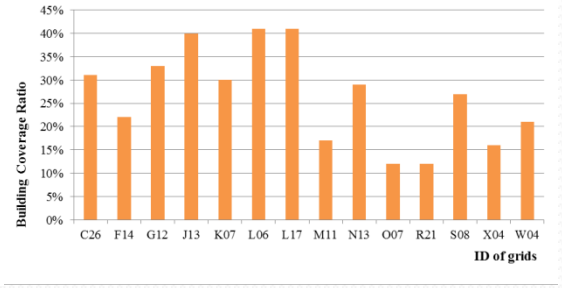
Enhancement of Wanted Sound as Masker:

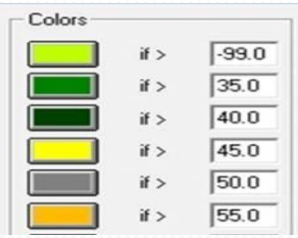
Birdsong mapping of the 14 sites in residential areas

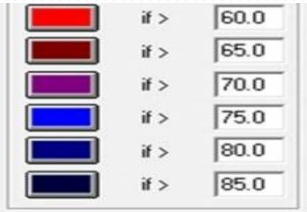
C26	F14	G12	J13	K7	L06	L17
						

M11	N13	O07	R21	S08	W04	X04
						





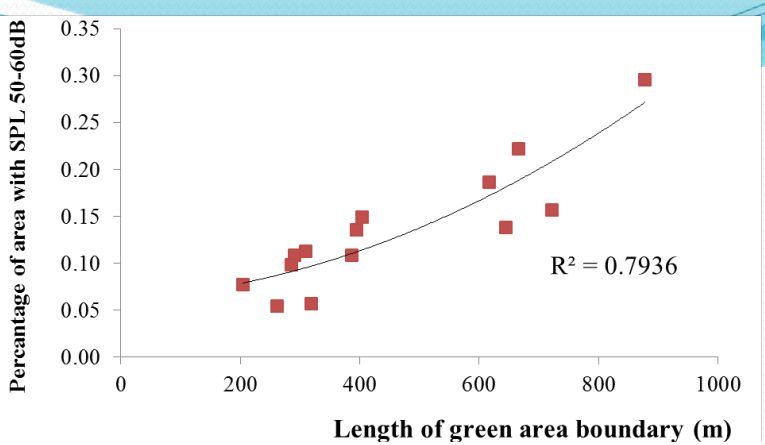


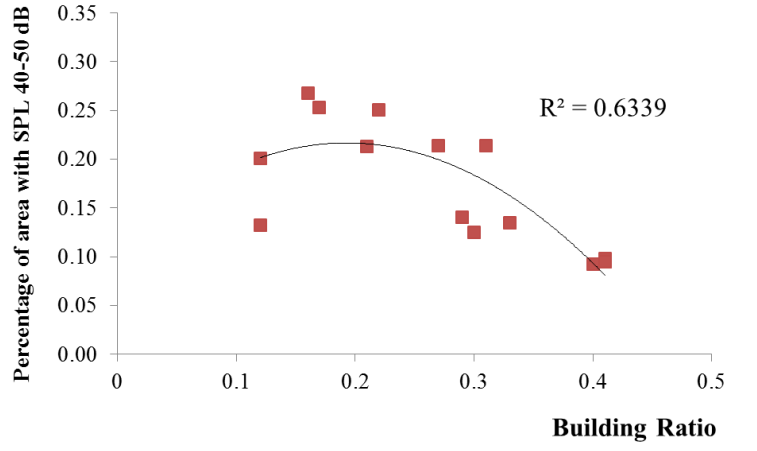


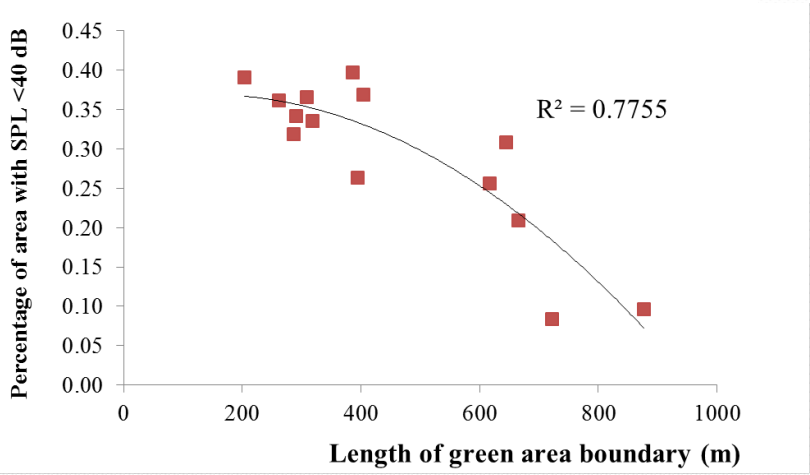
- The birdsong was set as 80 dB, 2kHz, single band point source.
- The layout of trees as habits for birds is decided by three main reasons: the real situation of vegetation in Assen, enlargement of birdsong incidence and 'edge-effect' in ecology. The height of sound source is set as 10 meters.

Area with Different Sound Levels

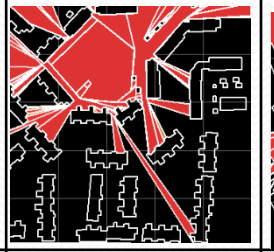
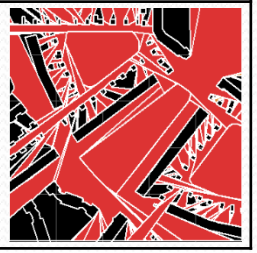
- The percentage of the areas with birdsong SPL 50-60 dB is only highly correlated to length of green area boundary, not green area ratio.
- The areas with SPL 40-50 dB decrease with the building ratio, but not related to green area size or circumference.
- The percentage of the areas with birdsong SPL < 40 dB is also more correlated to green area circumference than its size

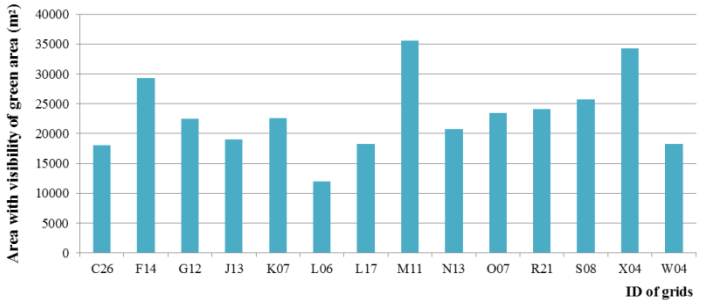






Visibility graphs of green areas in the 14 sites by Isovist in Space Syntax

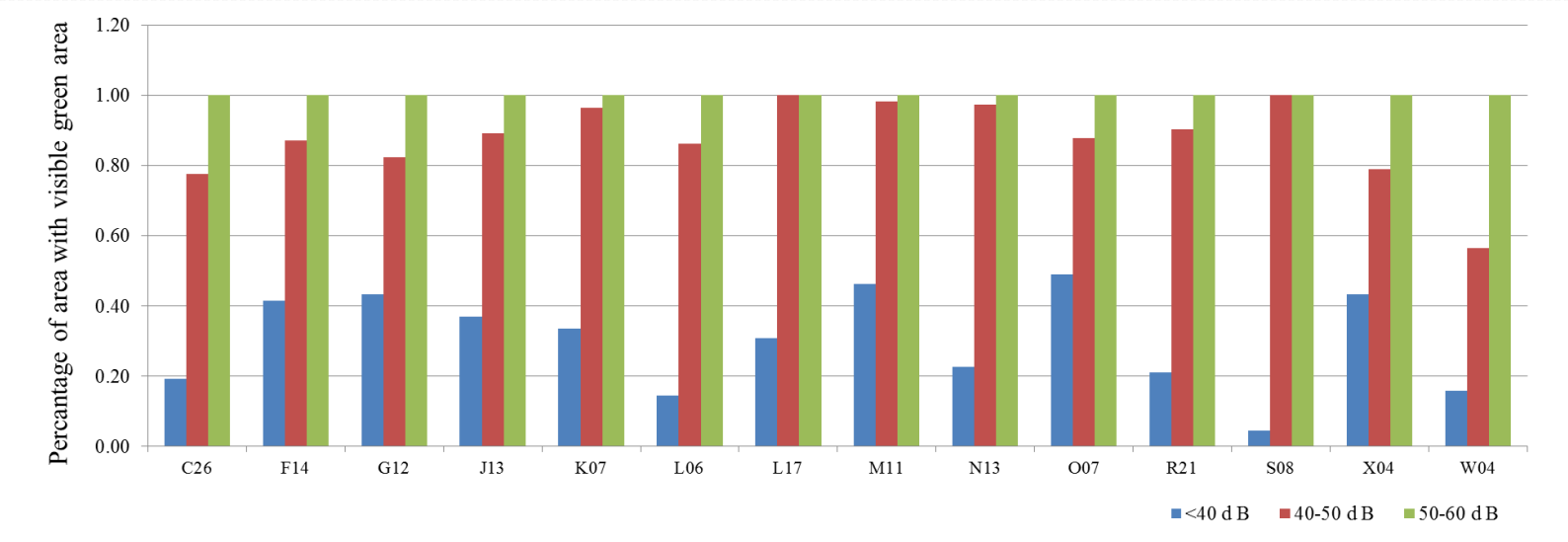
C26	F14	G12	J13	K7	L6	L17
						
M11	**N13**	**O7**	**R21**	**S8**	**W4**	**X4**
						



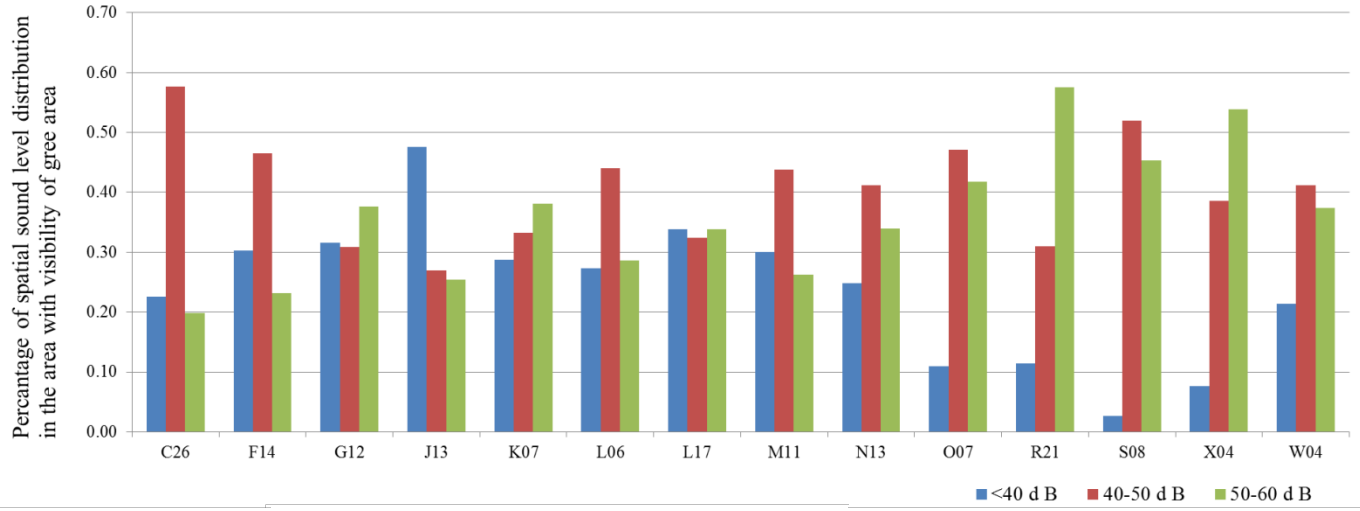
Area with visibility of green area

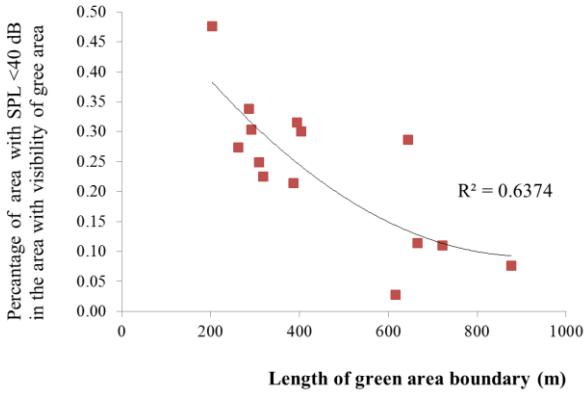
The green area with boundary of trees is considered as an agent in space syntax. It can be seen with direct sight lines at the eye-height in the red area.

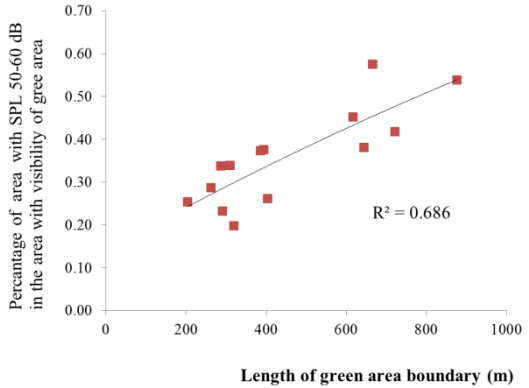
Enhance Masking via Aural-visual Interaction:

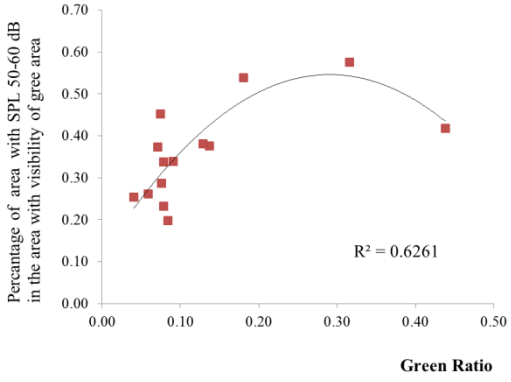


- The green area can be seen
  - - in almost all the areas with SPL 50-60 dB,
  - - >60% of the area with SPL 40-50 dB
  - - <50% of the area with SPL <40 dB
- The percentage is not correlated to the urban morphological indices.









- The area with green area view is more covered by relatively louder birdsong (50-60 dB) when the length of green area boundary, rather than green ratio, is bigger.
- Length of green area boundary is therefore an important urban morphological index.

Initial findings:

- From the perspective of masking, urban morphology indeed has correlation with the spatial sound level attenuation and distribution.
  - L20-L80, for example, is an important index relating to urban morphology – relevant to reducing unwanted sound, as basis for masking.
  - Sound level attenuation of masking target decreases with increasing accessible space ratio significantly both in open area and on façade .
  - Increase of green area boundary rather than size is important in terms of masking by birdsong.
  - It is more possible to obtain enhanced masking effects by aural-visual interaction in the area with louder birdsong.
  - Potential for considering aural-visual interaction in improvement of soundscape comfort through landscape design demonstrated
- Masking can therefore be considered as one promising tool, relating to different urban structures.

- *More systematic study being carried out*

Summary

- Relationships between urban sound environment and social-economic factors;
- Noise resistance of different urban structures;
- From noise maps, to sound maps, to soundscape maps, taking perception and cultural factors into account;
- Relationships between urban morphology and soundscape masking

Acknowledgements

- EU, China NSF, EPSRC for financial support.
- H Xie, B Wang, H Wu, L Yu for contribution to this presentation.
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