How to make cities sound healthier

Designing soundscape in urban open public spaces

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OUTLINE

- Introduction: From noise reduction to soundscape creation
- A framework of designing soundscape
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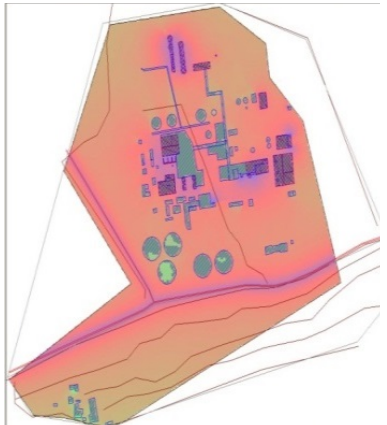
- Soundscape example

- EU COST Action on Soundscape of European Cities and Landscapes
- The way forward: Soundscape indices

Introduction:
From noise reduction to soundscape creation

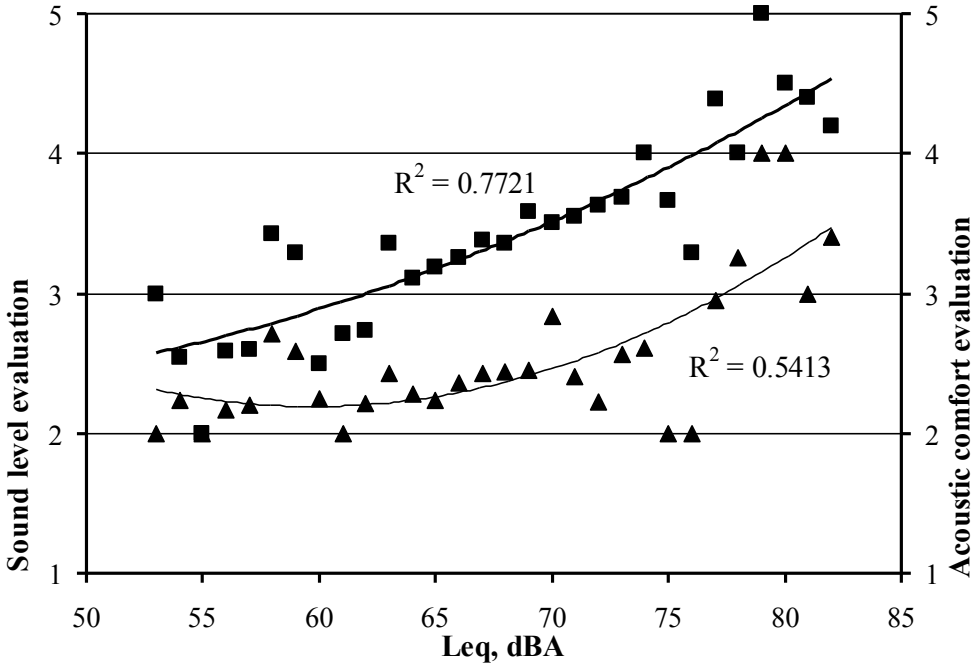
Noise: Effect and Actions

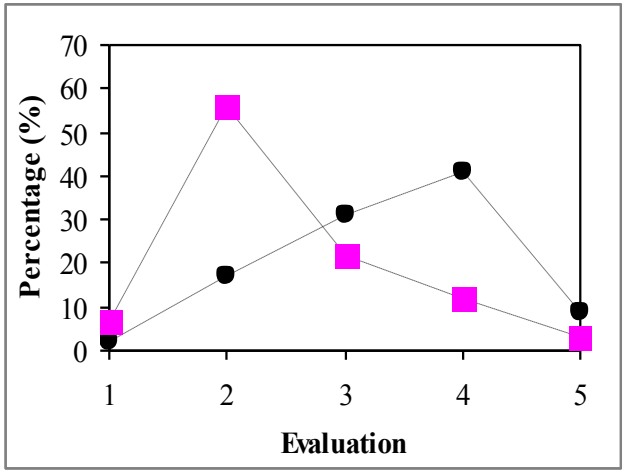
- 80 million EU citizens suffer from unacceptable environmental noise levels according to WHO.
- Social cost of transport noise 0.2-2% of GDP.
- Noise effects include hearing impairment, speech interference, sleep disturbance, cardiovascular effects, performance reduction.
- Economic impacts i.e. loss of property value.
- **EU Directive:**
  - **noise mapping.**



Noise map of an industrial site

Evaluation of acoustic comfort vs. sound level





Peace Gardens, Sheffield

1, Very quiet (very comfortable);
2, quiet (comfortable);
3, neither quiet (comfortable) nor noisy (uncomfortable);
4, noisy (uncomfortable);
5, very noisy (very uncomfortable).

SOUNDSCAPE

An acoustic environment as perceived or experienced and/or understood by a person or people, in context (BS ISO 12913-1:2014)

relating to acoustics, aesthetics, anthropology, architecture, ecology, human geography, landscape, linguistics, media arts, musicology, noise control engineering, philosophy, psychology, political science, religious studies, sociology, and urban planning

science, engineering, social science, humanity and art

From noise reduction to soundscapes creation

- Soundscape research will bring a step change in environmental acoustics by considering environmental sounds as a 'resource' rather than a 'waste'.
- This will support the design and implementation of urban sound environment that promote health, attract investment, convey cultural uniqueness and enhance quality of life.
- **EU Directive: identifying quiet areas to protect…..**

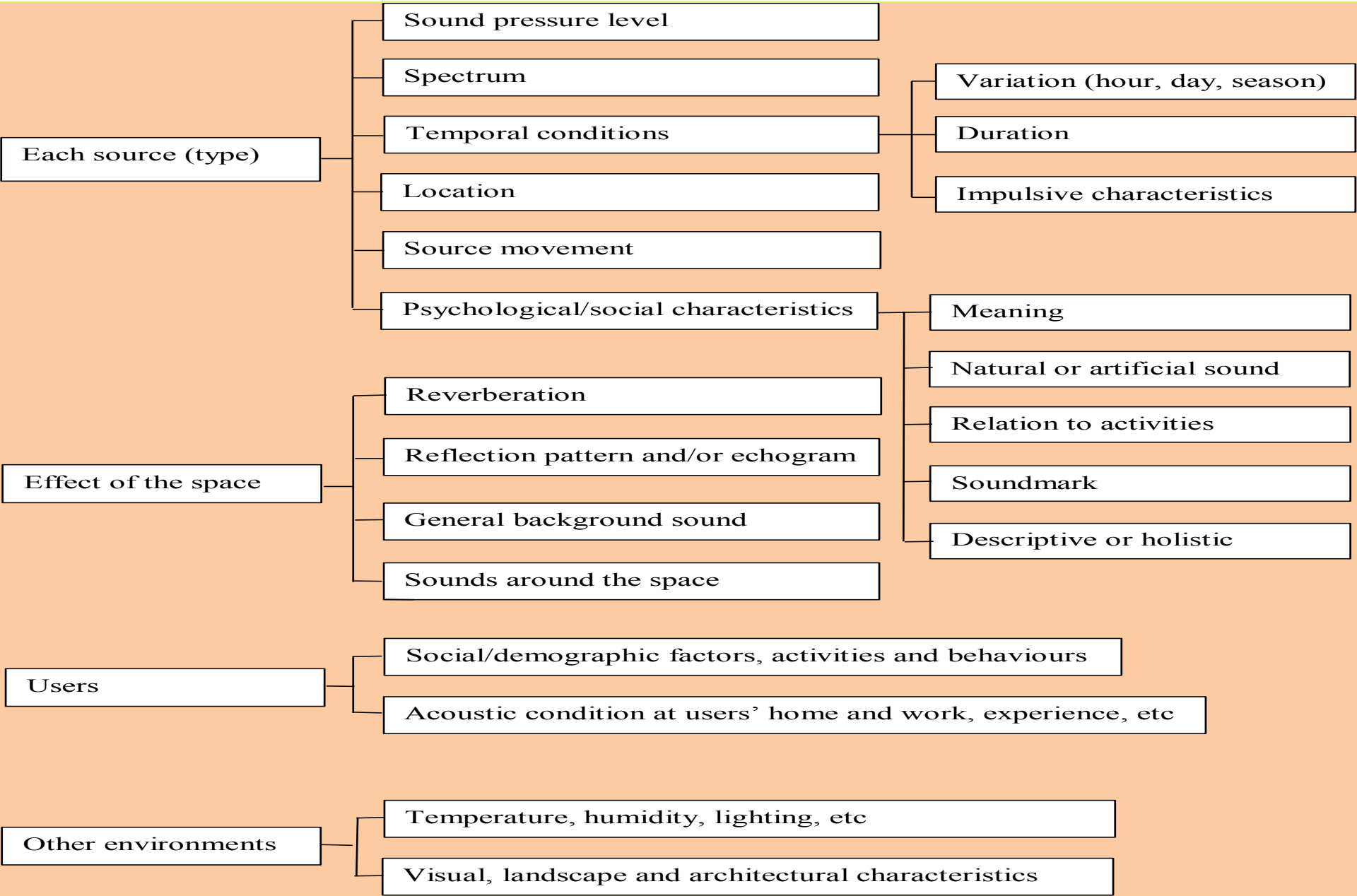
A framework of designing soundscape

EU

UK

China
etc

A framework for engineering/designing soundscape



Sounds

Active and passive sounds

- Sound sources in an urban open space can be divided into:
  - active sounds
    - relate to sounds from the activities in the space, e.g. group dancing
  - passive sounds
    - relate to the sounds from the landscape elements, e.g. fountains

Designable factors/potentials

- Spectrum – also important when using psychoacoustic magnitudes
- dynamic process
- acoustic zones and scale - suitable aural space or source-listener distance for each zone

… …

Music: a typical active sound

- People are not only interested in the music itself, but are also attracted by the activities of the players.
  - *For live music, the type of music is not important.*
- When music is played using loudspeakers, the type of music and the sound level are important.
  - *Most people don't like loud music played from loudspeakers, or from passing car.*

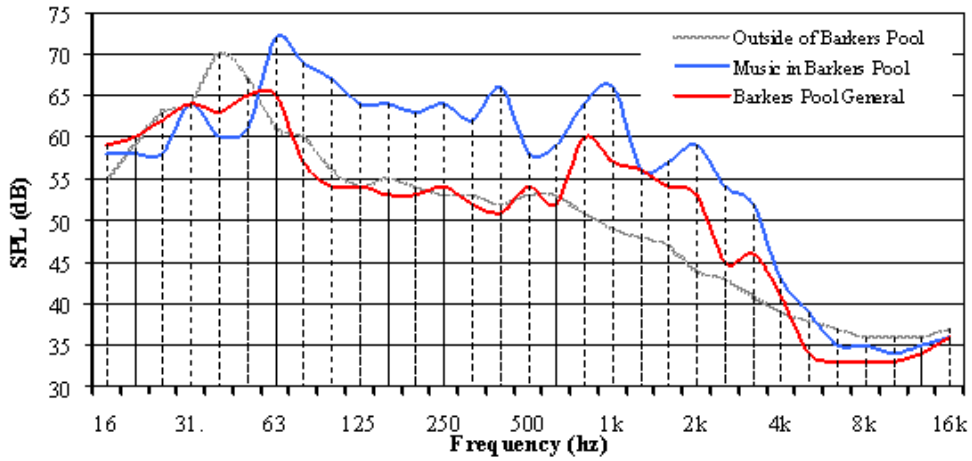


Figure 8.35 Comparison of sound spectra in the Barkers Pool

Masking

Spectrum analysis dynamic process

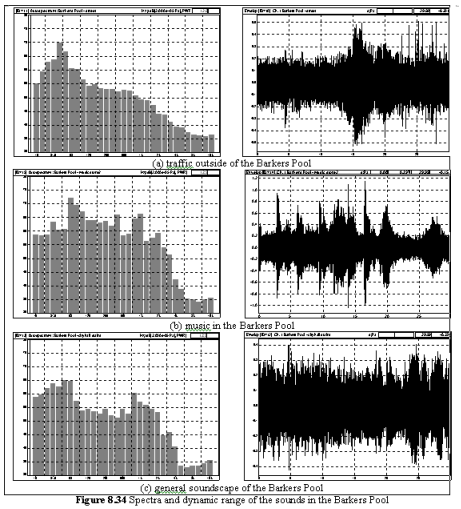


Figure 8.34 Spectra and dynamic range of the sounds in the Barkers Pool

Acoustic zones

Water: a typical passive sound

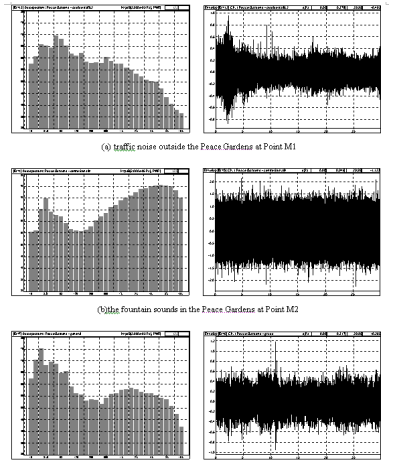
Endless effects in colouring the soundscape – 'primary soundscape quality'

Landscape theory: 'primary landscape qualities' - water and foliage

- **Spectrum:** most water sounds have significant high frequency components around 2k to 8kHz and some of them also have notable low frequency components.

  making water sound distinctive from the background

- **Dynamic:** The flow rate of a water feature should not be constant.



(a) traffic noise outside the Peace Gardens at Point M1

(b)the fountain sounds in the Peace Gardens at Point M2

(c) the soundscape in the Peace Gardens at Point M3

Figure 8.3 Spectra and dynamic range of the sounds in the Peace Gardens

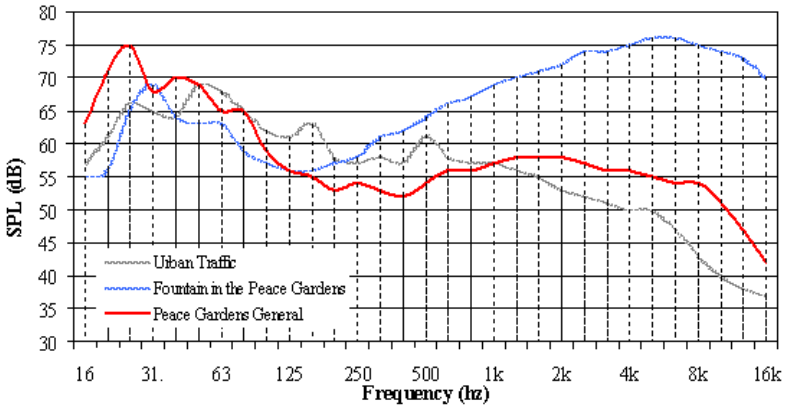


Figure 8.4 The comparison of the sound spectra in the Peace Gardens

(a) (b)

Figure 8.1 The Goodwin Fountain in the Peace Gardens

Examples showing design potentials:

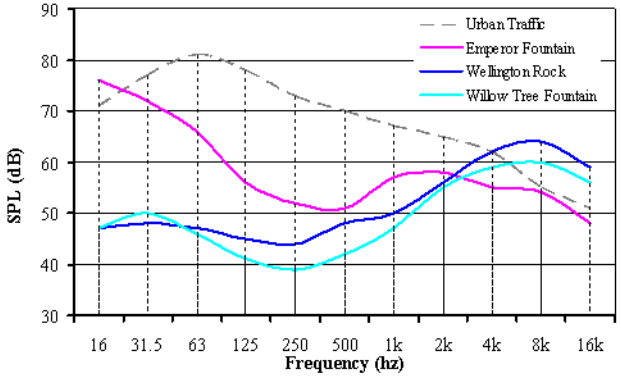
- high frequency components come from the water splash itself,

- whereas when a large flow of water is raised to a very high level and then dropped to a water body or hard surface, notable low frequency components can be generated

(a)·Emperor·Fountain·····(b)·Wellington·Rock·····(c)·Willow·Tree·Fountain¶

Figure·8.24··Fountains·in·the·Chatsworth·Garden¶

¶



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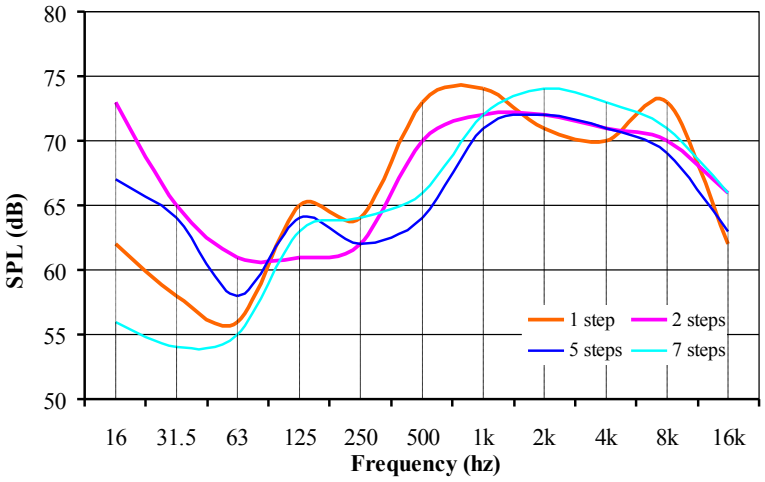
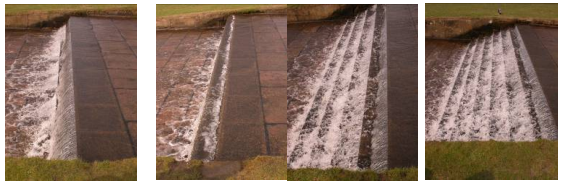
Comparison·of·the·spectra·of·the·sounds·in·the·Chatsworth·Garden·and·urban·traffic·noise¶

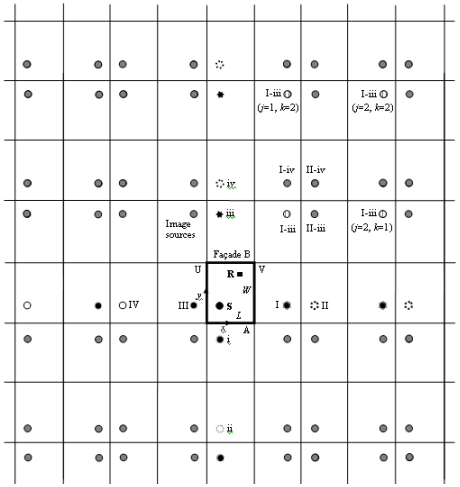
Cascade with Temple Pavilion in the Chatsworth Garden



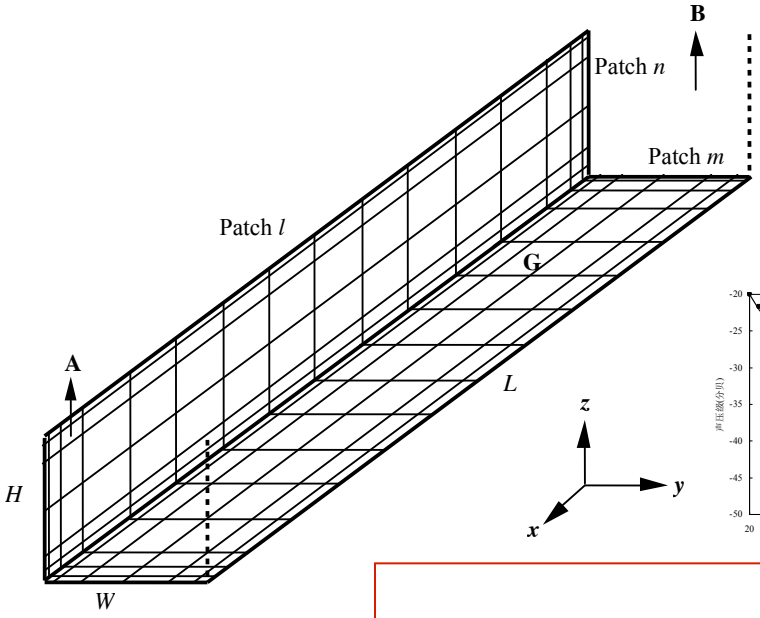


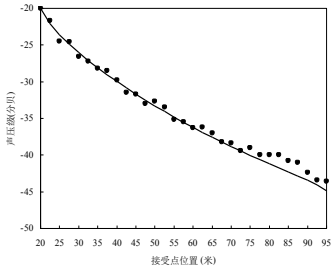
Space

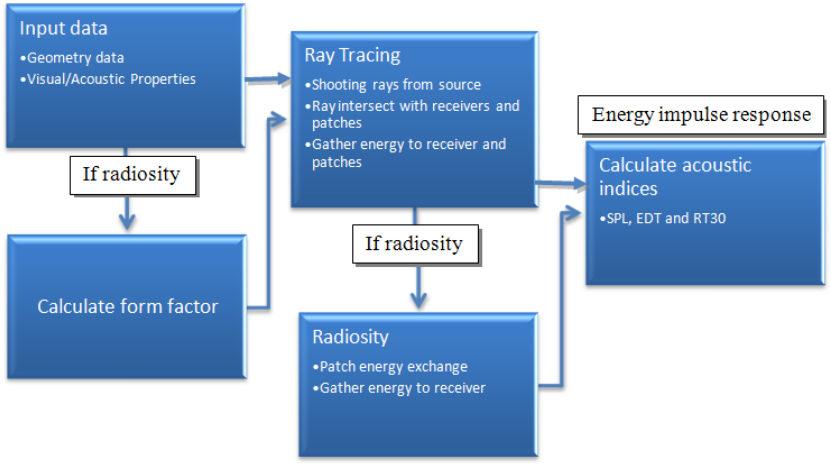
IMAGE SOURCE METHOD



RADIOSITY MODEL

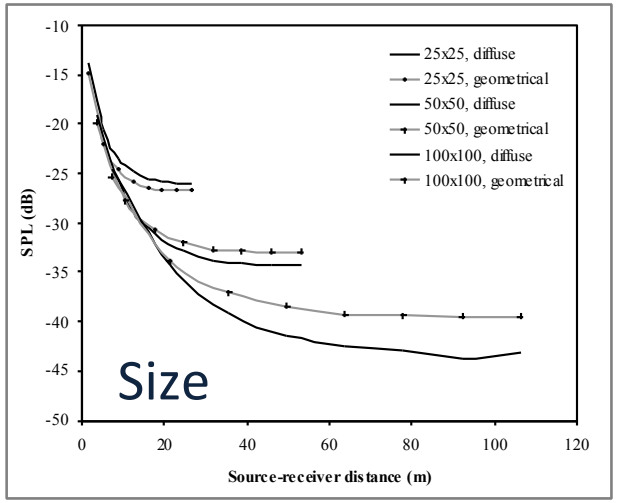


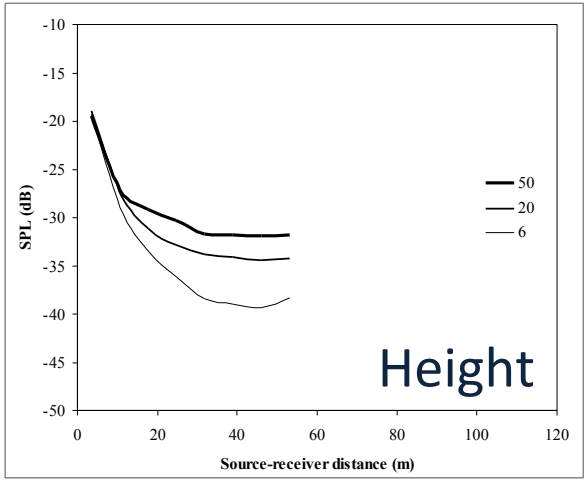


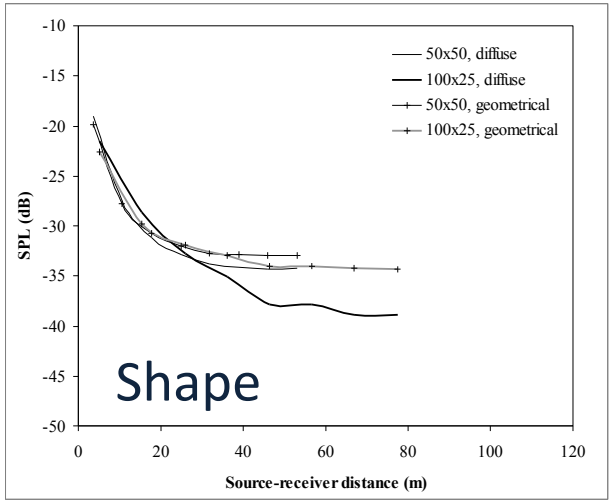


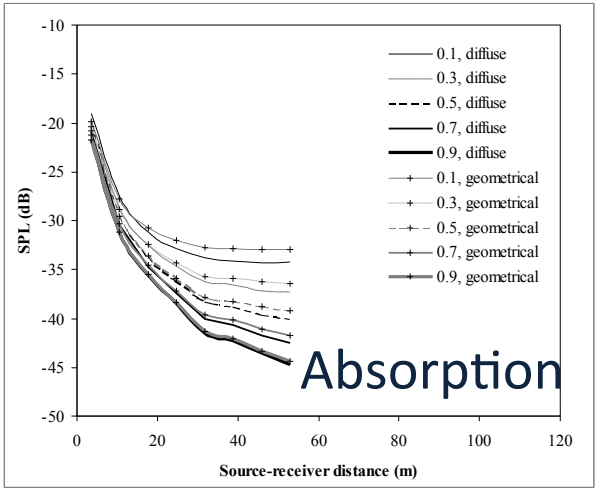
CRR – Combined Ray-tracing and Radiosity

Parameter studies using the simulation models



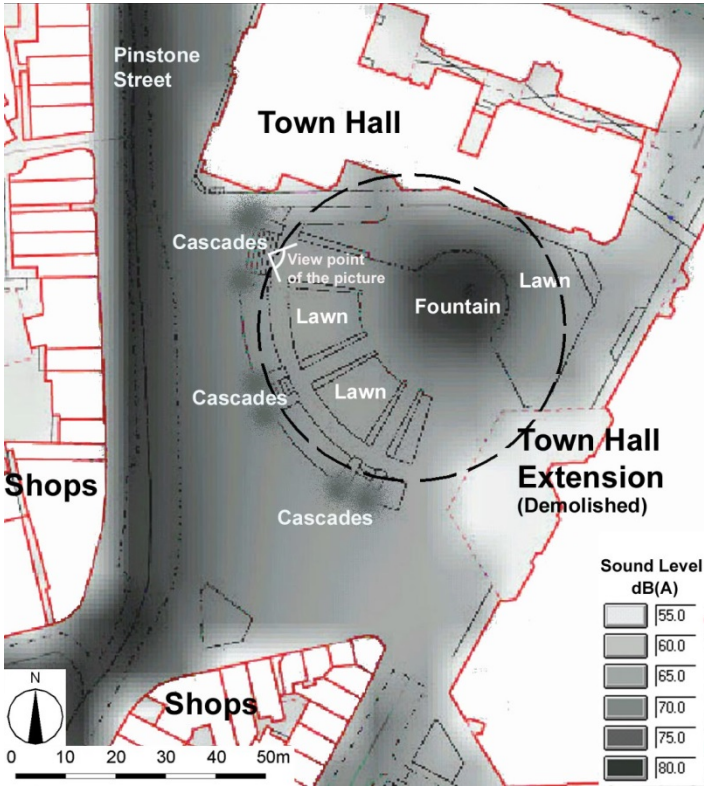






From noise map to sound map

Soundscape in different zones with/for different sounds



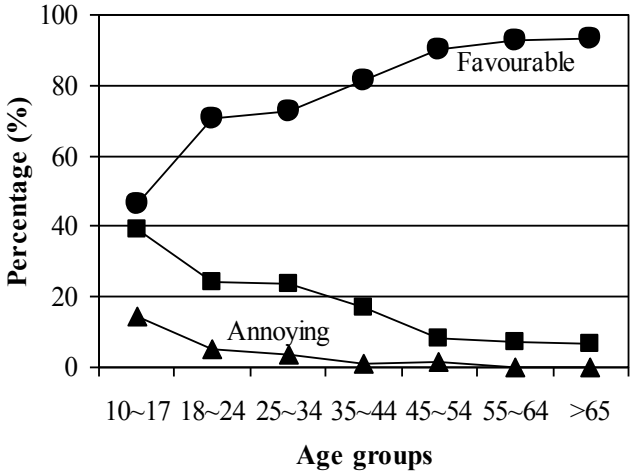
People

Sound Preferences

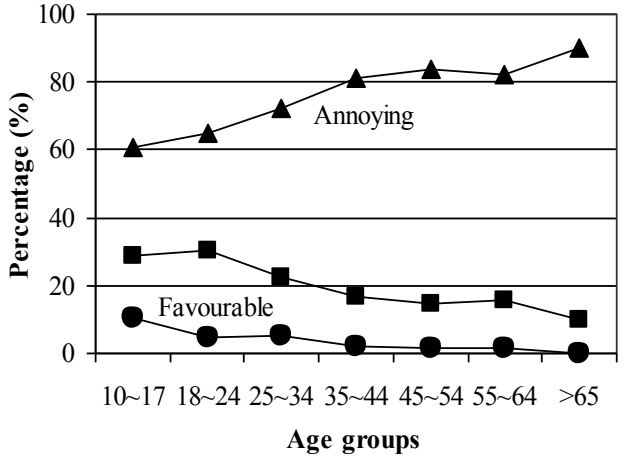
Essential preferences

- *Positive attitudes towards natural and culture-related sounds.*

Micro- preference



bird songs



car music

Difference in sound preference between age groups

Macro-preference

cultural background and long-term environmental experience play an important role in people's judgment of sound preference.

Significant difference exists for some sounds among the cities, likely caused by cultural factors.

		Alimos		Thessaloniki		Sesto San Giovanni		Sheffield		Kassel	
		Kara. Square	Seashore	Maked. Square	Kritis Square	Petazzi Square	IV Nov. Square	Peace Gardens	Barkers Pool	Florent. Square	Bahns-. platz
Water	F						27.7	84.0	74.7	80.3	74.5
	N						66.6	14.8	20.5	17.9	22.4
	A						5.7	1.2	4.8	1.8	3.1
Insects	F							37.7	33.2	34.0	23.5
	N							43.1	46.1	59.1	75.3
	A							19.2	20.7	6.9	1.2
Bells of church	F					31.1		56.8	47.9		
	N					68.9		35.4	37.6		
	A					0.0		7.8	14.5		
Music played on street	F							44.2	48.8	57.3	88.0
	N							38.3	28.8	27.2	12.0
	A							17.5	22.4	15.5	0
Surrounding speech	F	2.3	7.0		32.2	23.5	44.6	17.9	18.0	18.5	15.3
	N	77.8	77.6		17.0	69.8	47.2	68.3	69.3	80.5	84.7
	A	19.9	15.4		50.8	6.7	8.2	13.8	12.7	1.0	0
Children's shouting	F	20.3	25.5	54.1	29.5	27.4		11.7	6.9	1.7	1.0
	N	54.3	50.8	19.9	53.0	53.4		48.4	40.3	69.0	54.8
	A	25.4	23.7	26.0	17.5	19.2		39.9	52.8	29.3	44.2
Pedestrian crossing	F	5.5	8.0					8.6	12.9	7.1	
	N	89.9	84.7					62.0	58.4	17.9	
	A	4.6	7.3					29.4	28.7	75.0	
Passenger cars	F	0.6		3.5	31.3	2.7	1.6	2.4	1.0		
	N	26.0		53.0	16.6	59.8	35.4	38.7	43.6		
	A	73.4		43.5	52.1	37.5	63.0	58.9	55.4		
Passenger buses	F			3.4	1.3		1.6	3.7	2.1		
	N			52.3	84.3		39.2	38.9	37.9		
	A			44.3	14.4		59.2	57.4	60.0		
Vehicle parking	F							2.9	1.0	1.4	2.0
	N							32.2	35.3	57.9	54.7
	A							64.9	63.7	40.7	43.3
Construction	F			2.1	32.5			2.2	2.1		
	N			52.9	11.5			18.0	19.2		
	A			45.0	56.0			79.8	78.7		

Classifications for various sounds in urban open public spaces (%).

A comparative study between Sheffield, Taipei and Beijing

Bird songs as a preferred sound in their living environment:

70% in Sheffield, 32% in Taipei and 25% in Beijing.

Music from outside:

4% in Sheffield, 26% in Taipei and 43% in Beijing

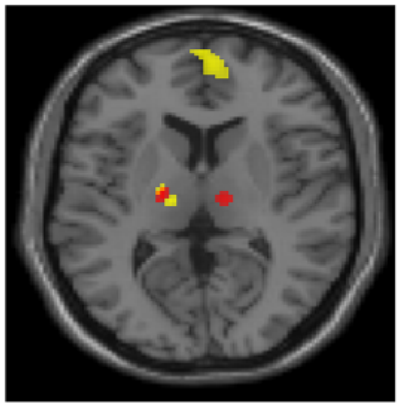
Environment

if a place is very hot or very cold, perhaps none cares about soundscape…

aural-visual interactions

	Factors		
	1	2	3
Temperature	.696		
Sunshine	.650		
Brightness	.599		
Wind	-.532		.521
View		.769	
Sound level		-.734	
Humidity			.828

Factor analysis of the overall physical comfort evaluation. Kaiser-Meyer-Olkin measure of sampling adequacy, 0.613; cumulative, 55.1%; extraction method, principal component analysis; rotation method, varimax with Kaiser normalization; N=9200.



Beijing

Correlations

		Quiet	Views
Quiet	Pearson Correlation	1	.677**
	Sig. (2-tailed)		.000
	N	80	80
Views	Pearson Correlation	.677**	1
	Sig. (2-tailed)	.000	
	N	80	80

**. Correlation is significant at the 0.01 level

Taipei

Correlations

		Quiet	Views
Quiet	Pearson Correlation	1	.638**
	Sig. (2-tailed)		.000
	N	200	200
Views	Pearson Correlation	.638**	1
	Sig. (2-tailed)	.000	
	N	200	200

**. Correlation is significant at the 0.01 level

Sheffield

Correlations

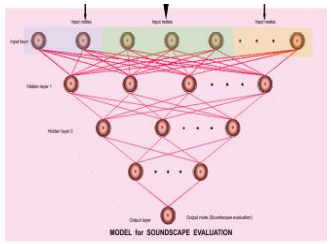
		Quiet	Views
Quiet	Pearson Correlation	1	.519**
	Sig. (2-tailed)		.000
	N	200	200
Views	Pearson Correlation	.519**	1
	Sig. (2-tailed)	.000	
	N	200	200

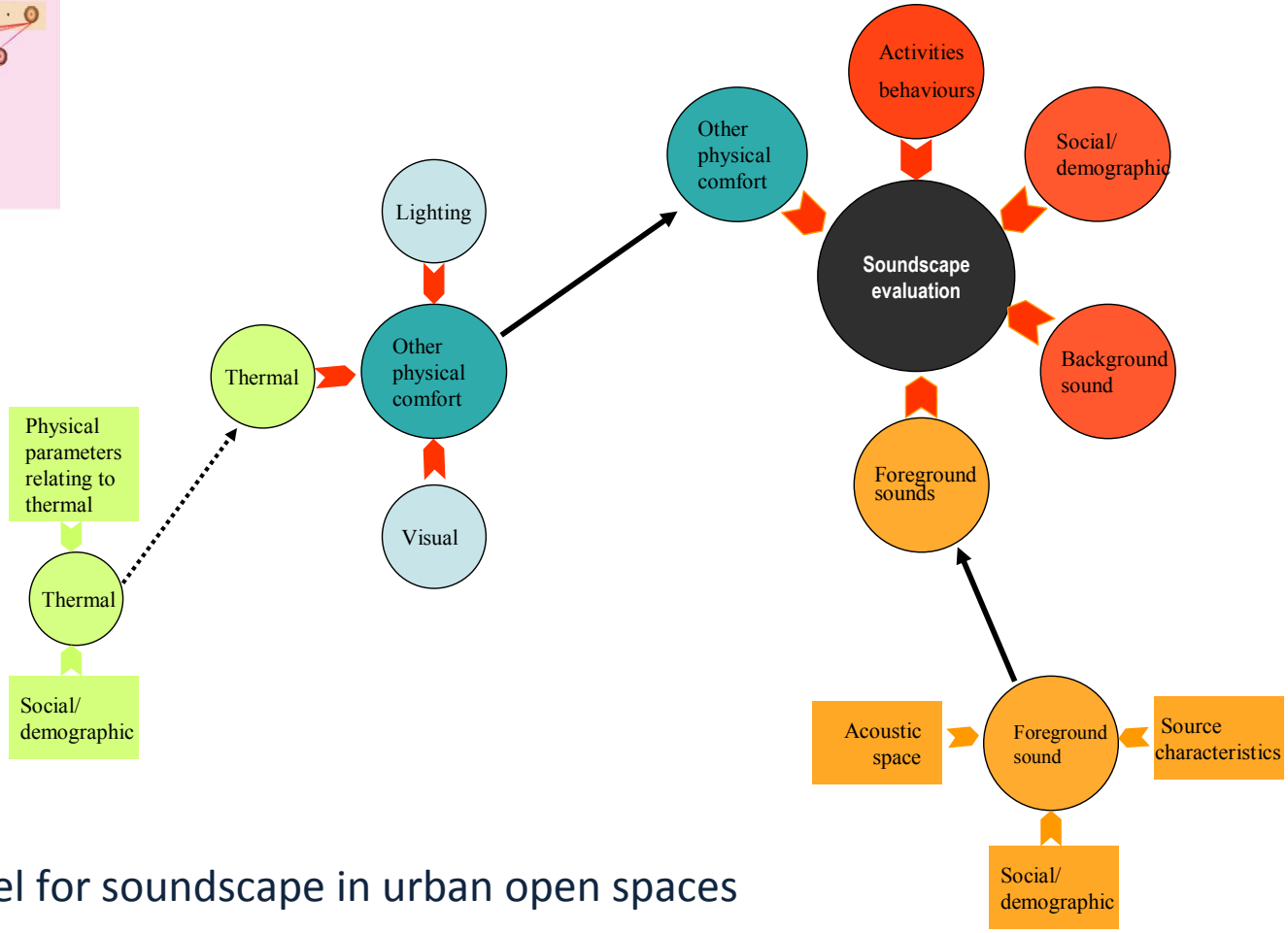
**. Correlation is significant at the 0.01 level

Correlation between quiet and view when choosing a living environment

Design tools

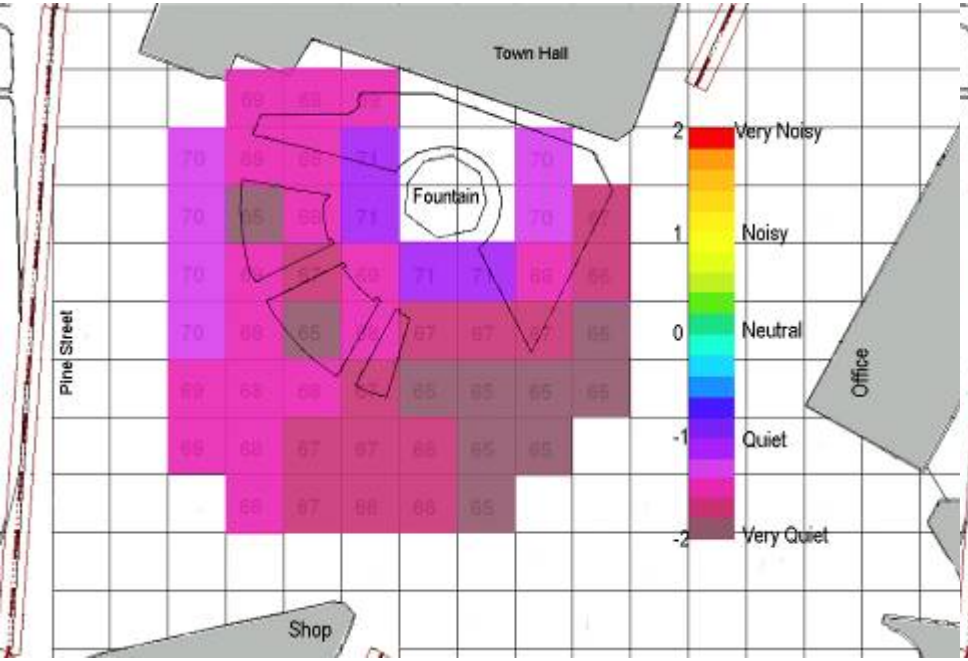
Artificial neural network (ANN) models



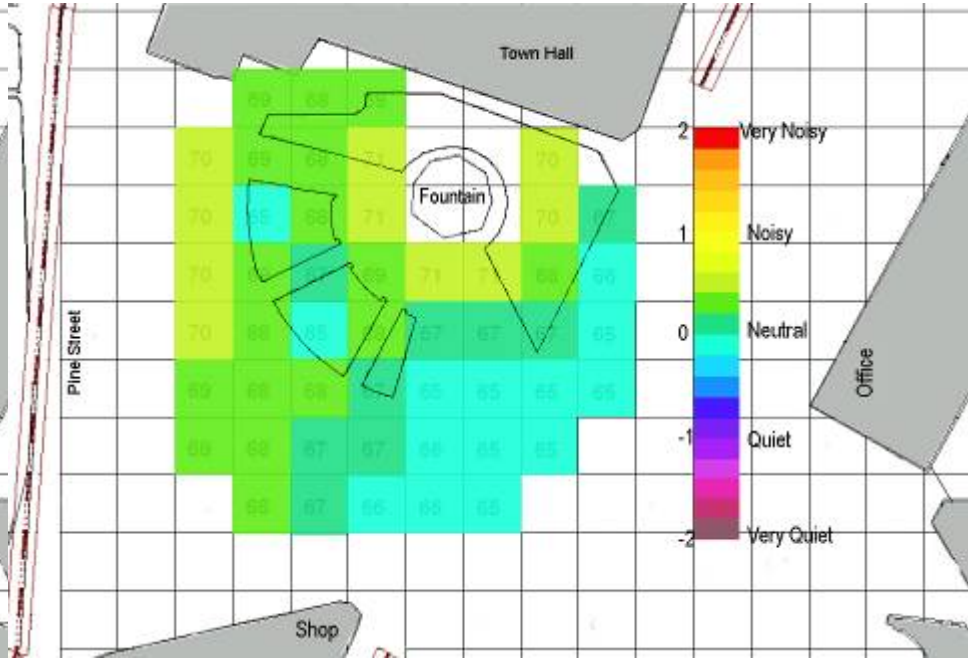


ANN model for soundscape in urban open spaces

Soundscape mapping based on ANN



Secondary education level group

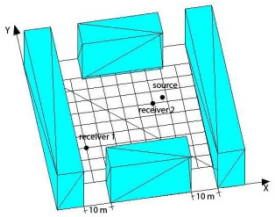


High education level group

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

Acoustic animation and auralisation

- To aid urban soundscape design and for public participation, it would be useful to present the 3D visual environment with an acoustic animation tool
- Challenges
  - Multiple sources
  - Source and receiver all moving
  - Calculation speed fast
  - But: calculation accuracy less critical



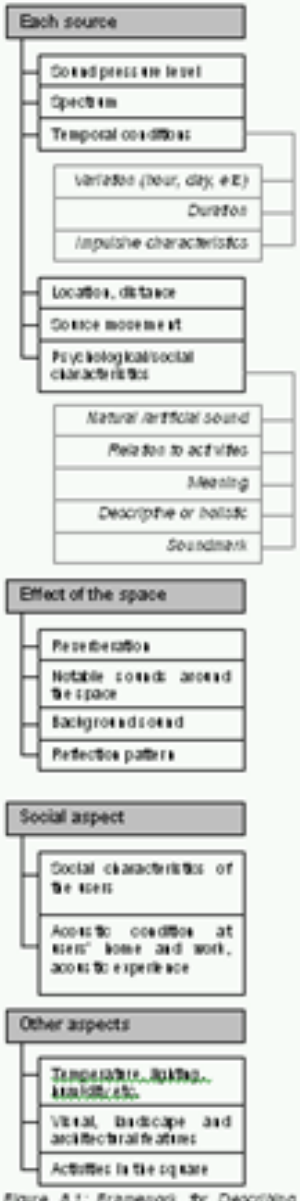


Figure 8.1: Framework for Describing Soundscape in Urban Open Public Spaces

8 ACOUSTICS

8.1 Soundscape description

To design a good acoustic environment in an urban open public space, not only physical aspect, but also social, psychological, and physiological aspects should be considered. Soundscape and acoustic comfort study focus on relationships between ear, human being, sound environment and society. It is also important to consider the interaction between sonic environment and microclimate conditions, as described in other chapters of this booklet.

A model for describing the soundscape in urban open public spaces is shown in Figure 8.1. The description includes four parts, namely characteristics of each sound source, acoustic effect of the space, social aspect, and other aspects. Since in different locations of an urban open public space the soundscape could be rather different, the description should be based on a number of typical receivers.

Sounds in an urban open public space can be defined as keynotes, signals/foreground sounds and soundmarks [1]. Keynotes are in analogy to music where a keynote identifies the fundamental tonality of a composition around which the music modulates. Foreground sounds, also termed 'signals', are intended to attract attention. Sounds that are particularly regarded by a community and its visitors are called "soundmarks", in analogy to landmarks.

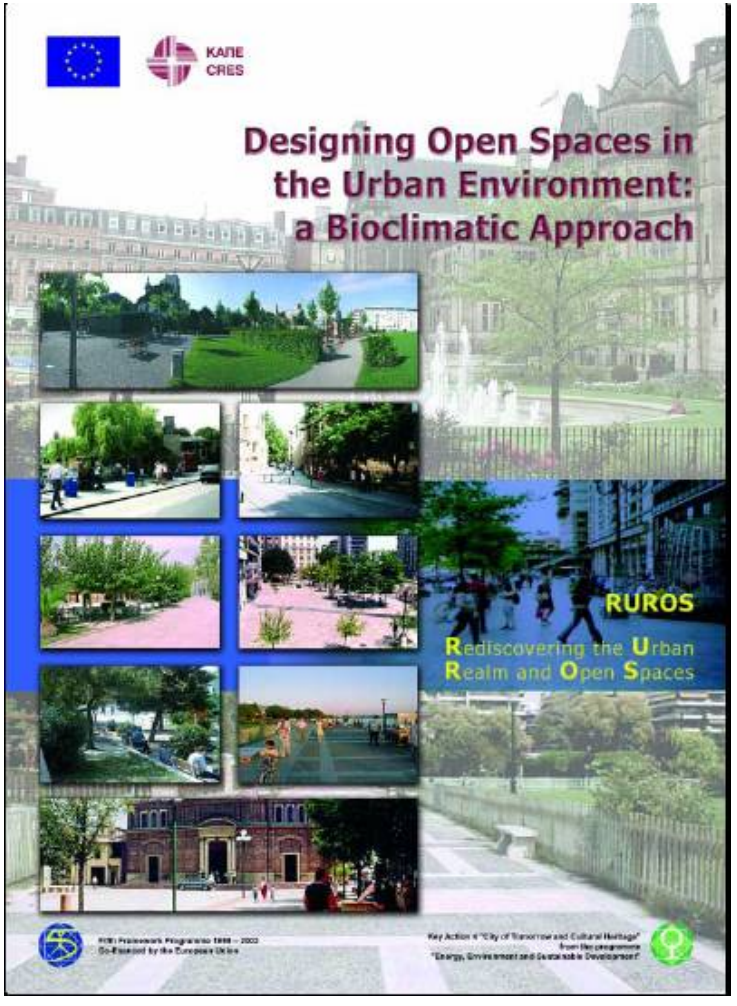
For each sound source, the sound pressure level (SPL), spectrum, temporal conditions, source location and the distance from the users, source movement, and the psychological and social characteristics should be considered. For the sound level, both steady-state and statistical SPL [2] should be considered. It is measured in dBA, a weighting system corresponding to human beings feeling towards sounds. For the spectrum, if tonal component is noted, it might be useful to consider narrowband spectrum [2].

The acoustic effect from an urban open public space is important. Boundaries and landscape elements may cause reverberation in an urban open space, which affects the acoustic comfort. Reverberation can be expressed using decay curves or reverberation time (RT). Reverberation time is defined as the time taken for a sound to decay 60dB after the cut-off of the source. The RT is usually obtained from –5dB to –35dB on a decay curve [2]. The EDT, which is highly correlated with speech intelligibility, is based on the decay from 0 to –10dB. In both cases the slope is extrapolated to correspond to 60dB decay [2-3]. In addition to reverberation, reflection pattern and/or echogram should be checked for possible acoustic defects like echoes and focus effect [2-3]. It is also useful to know the general background noise and special sound sources around the urban open space investigated/designed as well as in the whole city. It has been shown that the surrounding acoustic environment may affect subjective evaluation of an urban open space.

Social aspects of the users also play an important role and thus relevant information should be obtained. This includes gender, age group, place of living (i.e. local resident or from other cities), previous acoustic experience, the acoustic environment at home and working places, as well as general cultural and education background [4-6].

The interaction between acoustic comfort and other factors like thermal and visual comfort also needs to be taken into account. For example, the effects of visual images reduce the negative impression of sound quality and the amount is sometimes equivalent to a 10dB reduction in SPL.

Design guidelines



Soundscape example

Waterscape and Soundscape in Sheffield

SHEFFIELD

Waterscape and the City

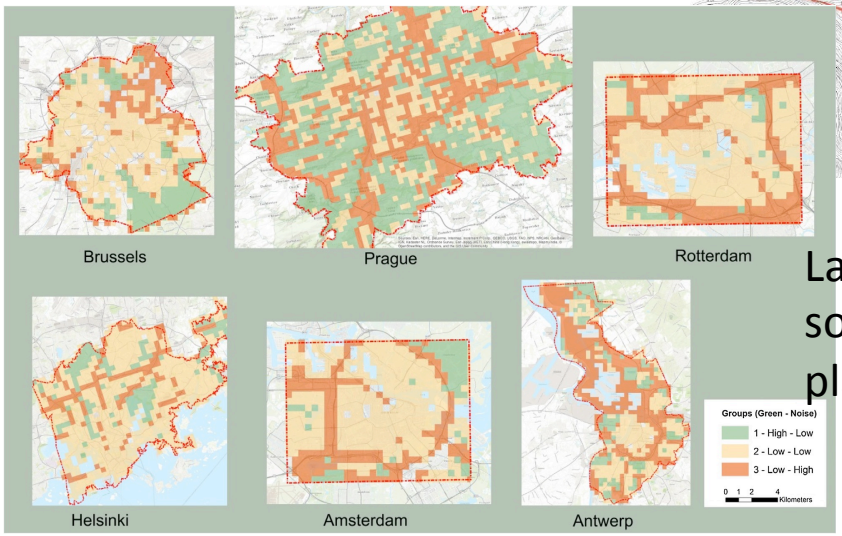
Other soundscape examples

Soundscape conservation

Rural soundscape

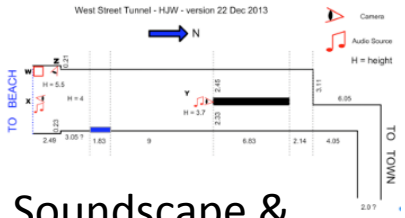
Traffic

Soundscape management:

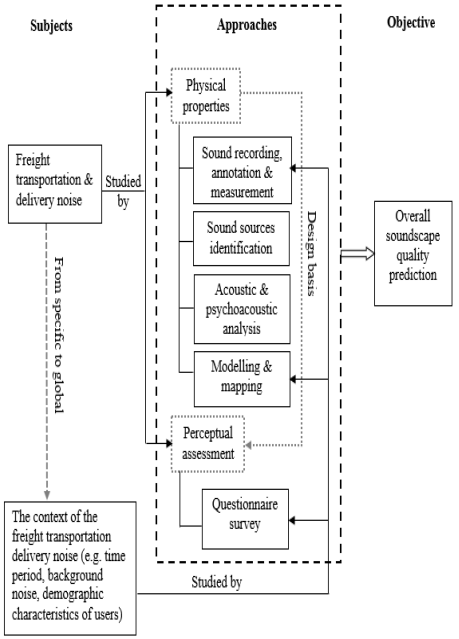


Large scale soundscape planning

Delivery sounds



Soundscape & crime/safety



http://soundscape-cost.org/

COST on

Soundscape of European Cities and Landscapes

(1) Understanding and exchanging
(2) Collecting and documenting
(3) Harmonising
(4) Creating and designing
(5) Outreaching and training

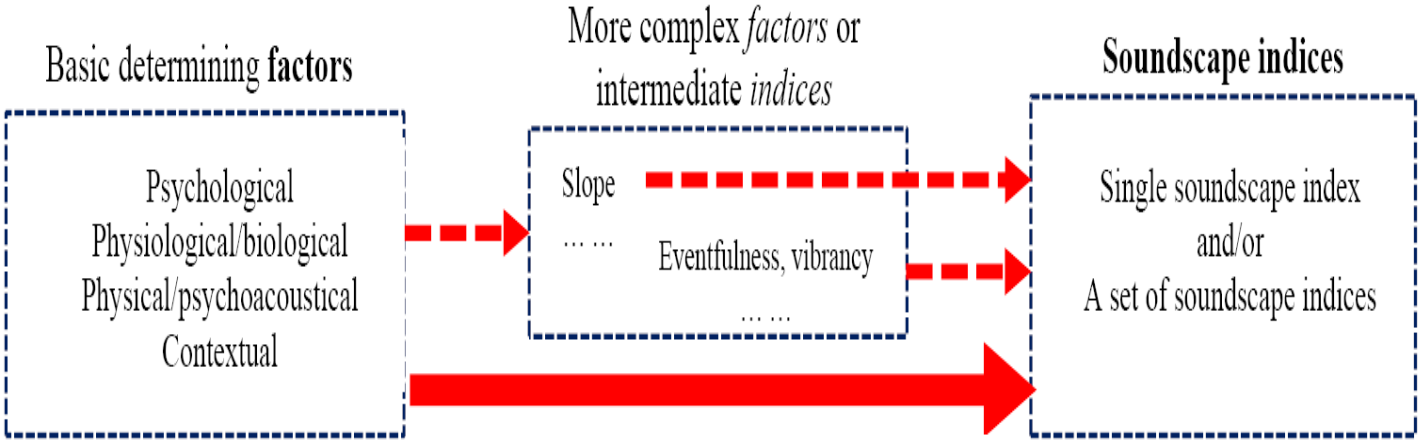
COST (European Cooperation in Science and Technology) is one of the longest-running European instruments supporting cooperation among scientists and researchers across Europe [http://www.cost.esf.org/]

The way forward

Soundscape indices (SSID)

adequately reflecting levels of human comfort

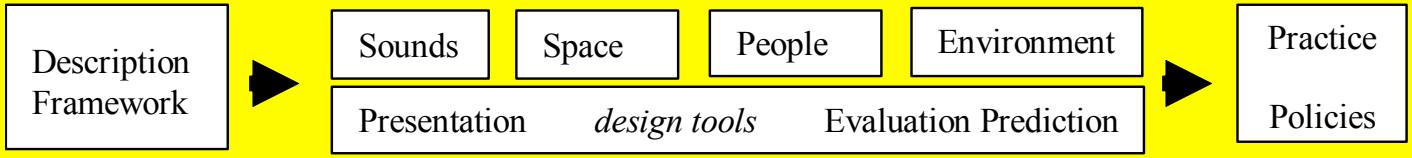
Our current EU ERC project



Concluding remarks

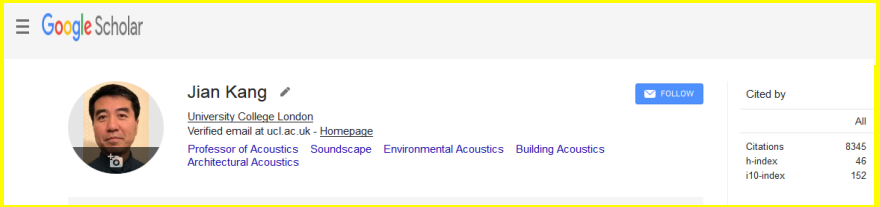
- *Tendency from noise reduction to soundscape creation*

- Potentials of designing soundscape



Kang, J. (2007) *Urban sound environment*. Taylor & Francis incorporating Spon, London.

Kang, J. and Schulte-Fortkamp, B. (ed.) (2016) *Soundscape and the built environment*. Taylor & Francis incorporating Spon, London.



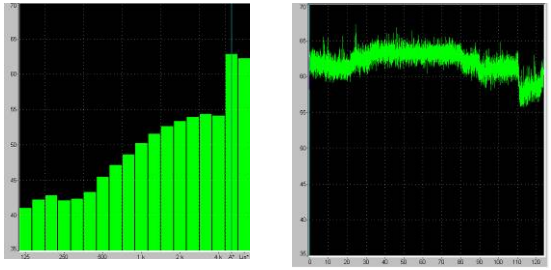
ACKNOWLEDGEMENTS

- The Acoustics Groups at UCL and Sheffield, and external research partners for their contributions in various aspects of this integrated research.

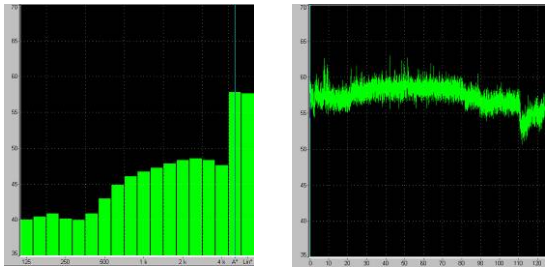
- This research has been funded by the European Commission, EPSRC, Royal Society, British Academy, and Lloyd's Foundation.

Sound variation away from the source

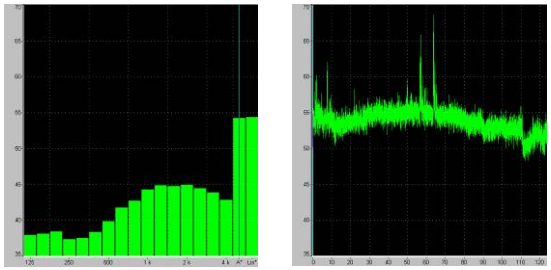
PEACE GARDENS



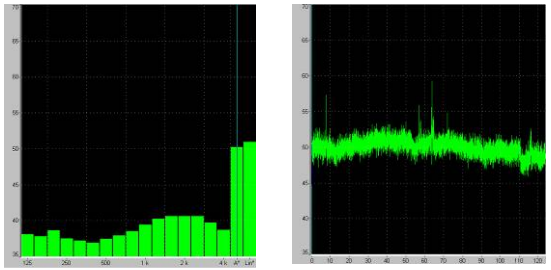
1 m from source



4 m from source



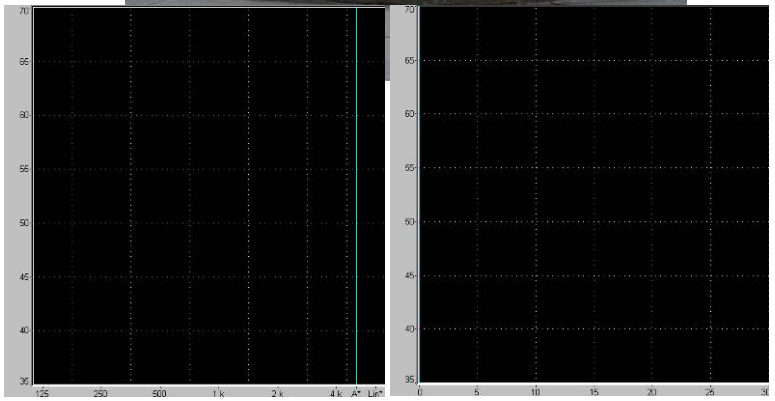
9 m from source



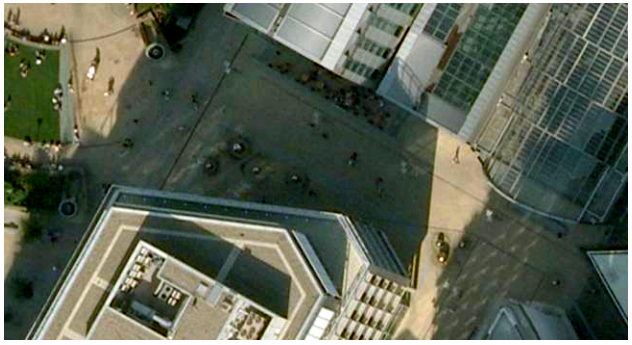
19 m from source

Large Fountain in the Peace Gardens

Attention masking



Ball fountain in the Millennium Square



The sounds from the ball fountains are hardly to be heard… Contrary to the Peace Garden beside, the square is much more quiet.

SHEAF SQUARE

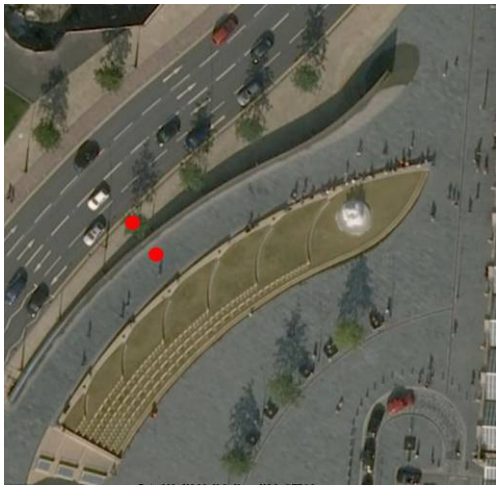
1. Steel barrier
2. Medium cascade

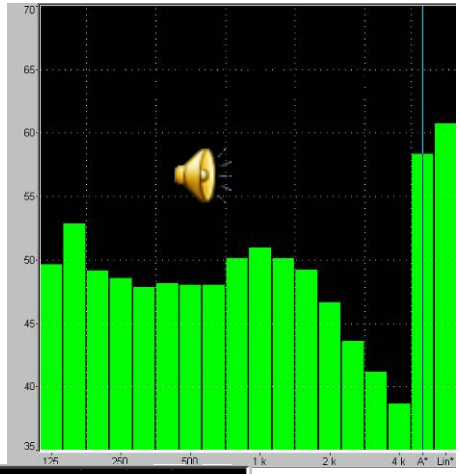
3-6. Big fountain (1,3,5,10m)

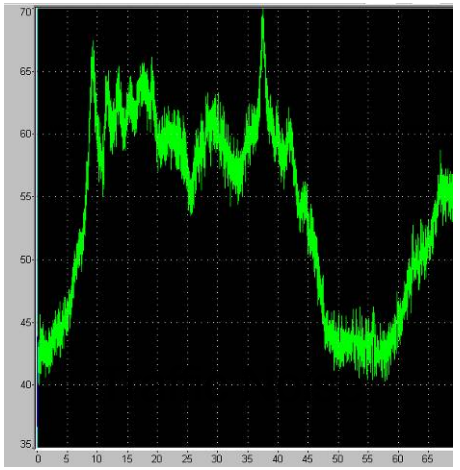
7. Small cascade L1
8. Small cascade L3

The Waterscape in the Sheaf Square

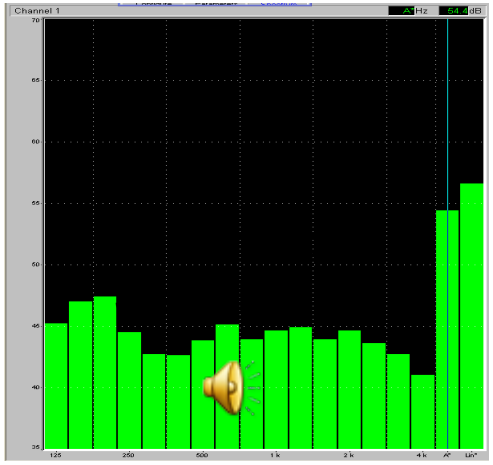
Steel Barrier

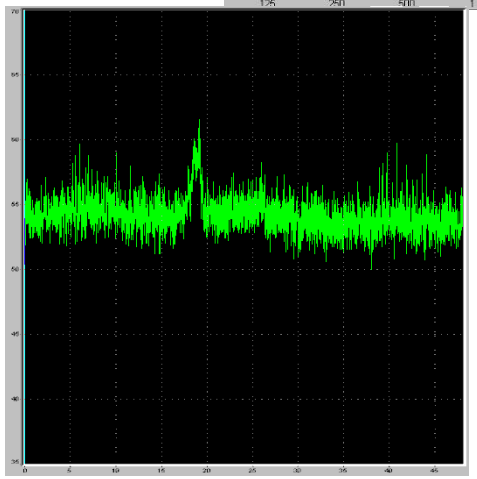






1 m from road

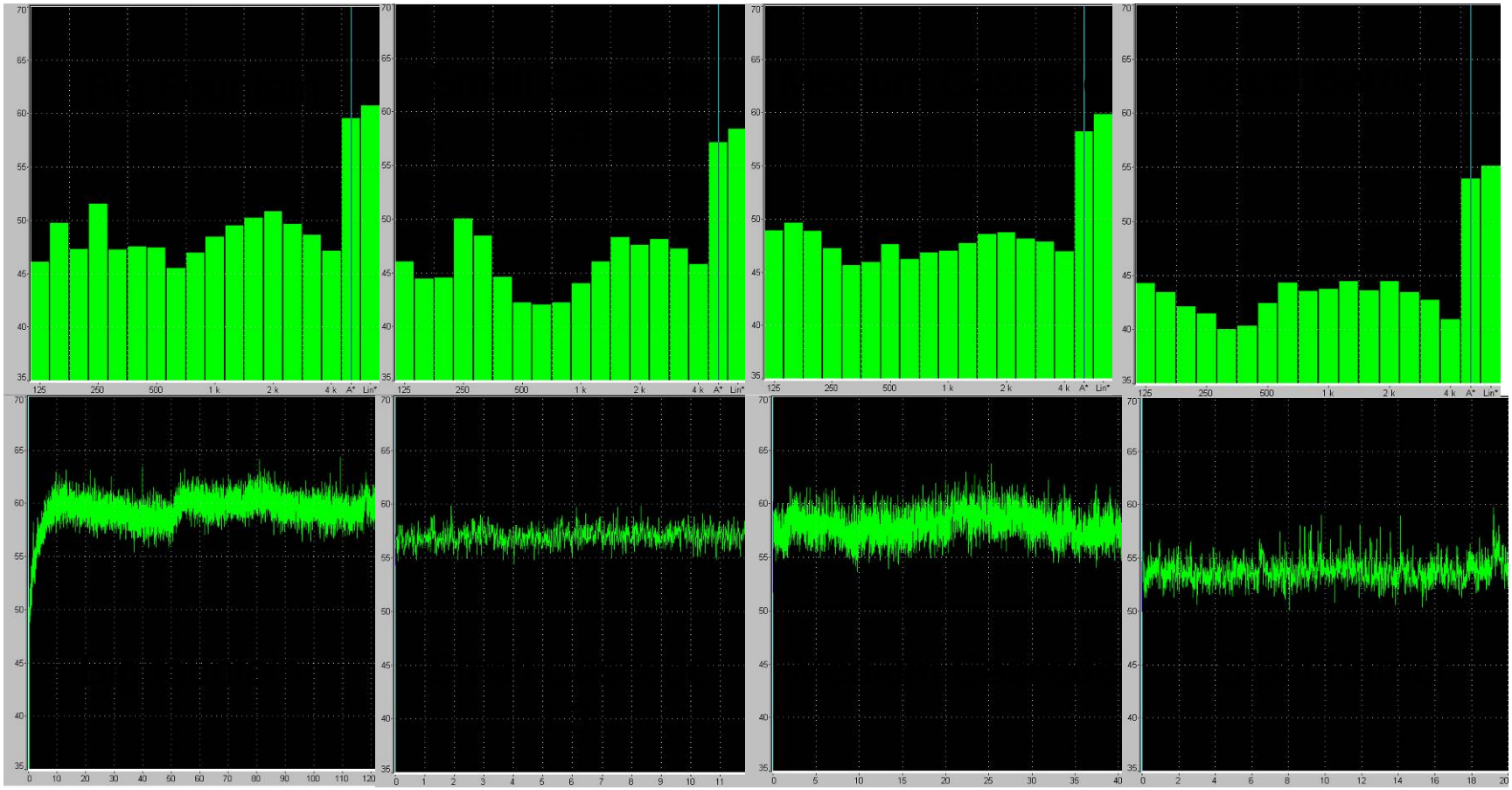


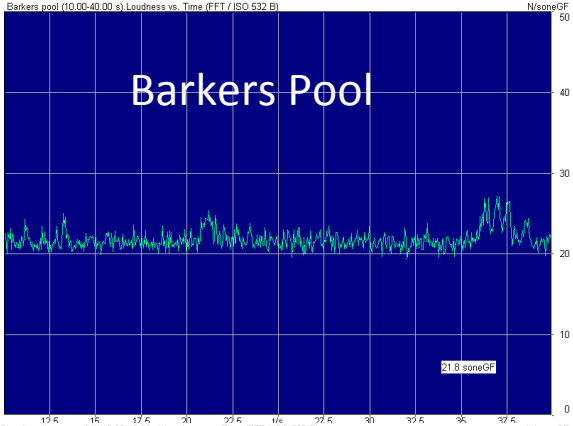


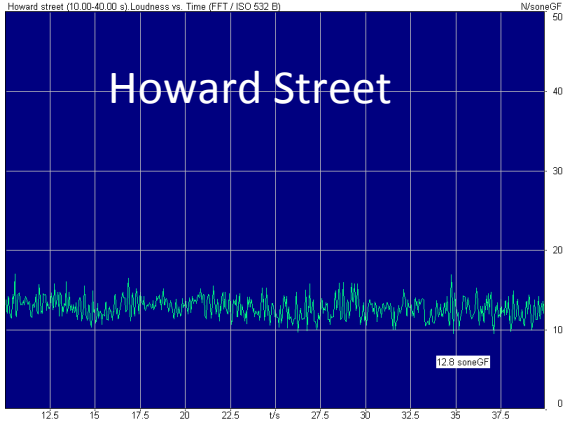
Behind
Steel Barrier

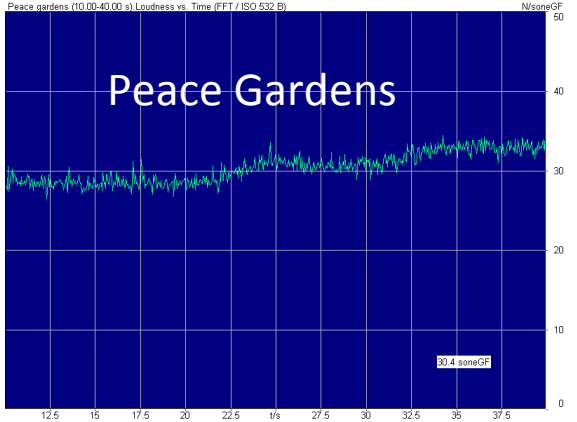
1 m from source

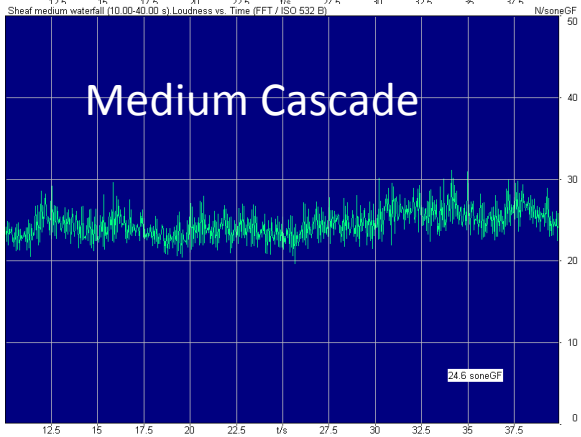
Water Diversity

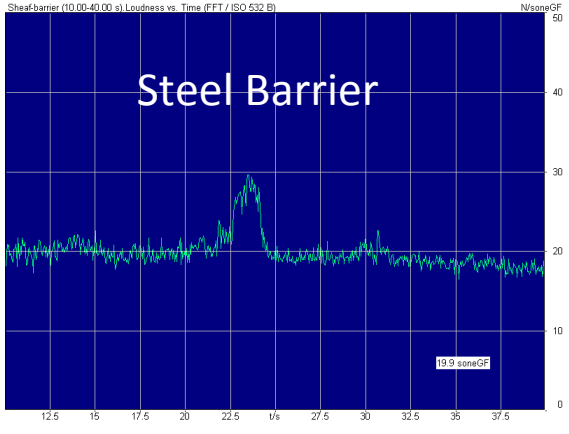


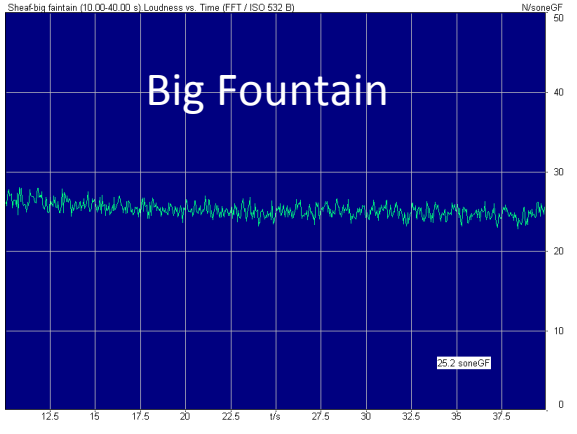

Barkers pool (10.00-40.00 s) Loudness vs. Time (FFT / ISO 532 B)
N/soneGF
Barkers Pool
21.8 soneGF
t/s

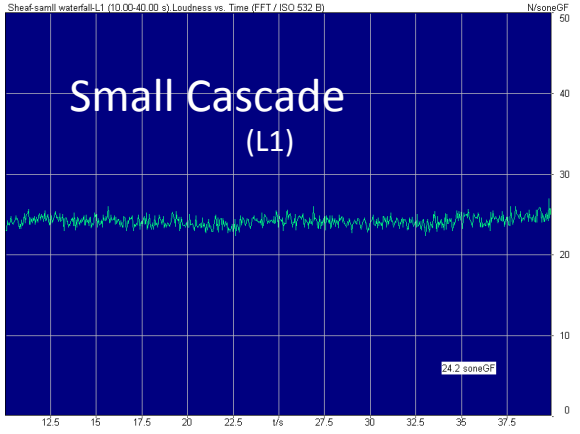

Howard street (10.00-40.00 s) Loudness vs. Time (FFT / ISO 532 B)
N/soneGF
Howard Street
12.8 soneGF
t/s

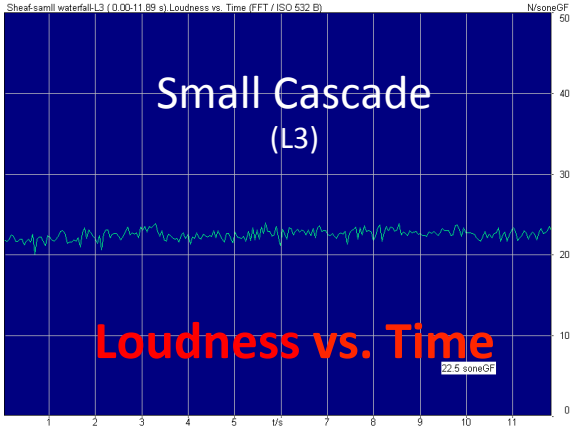

Peace gardens (10.00-40.00 s) Loudness vs. Time (FFT / ISO 532 B)
N/soneGF
Peace Gardens
30.4 soneGF
t/s


Sheaf medium waterfall (10.00-40.00 s) Loudness vs. Time (FFT / ISO 532 B)
N/soneGF
Medium Cascade
24.6 soneGF
t/s


Sheaf-barrier (10.00-40.00 s) Loudness vs. Time (FFT / ISO 532 B)
N/soneGF
Steel Barrier
19.9 soneGF
t/s


Sheaf-big faintain (10.00-40.00 s) Loudness vs. Time (FFT / ISO 532 B)
N/soneGF
Big Fountain
25.2 soneGF
t/s

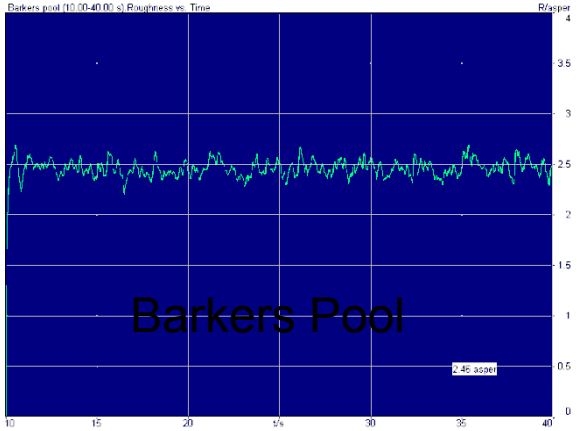

Sheaf-samll waterfall-L1 (10.00-40.00 s) Loudness vs. Time (FFT / ISO 532 B)
N/soneGF
Small Cascade
(L1)
24.2 soneGF
t/s

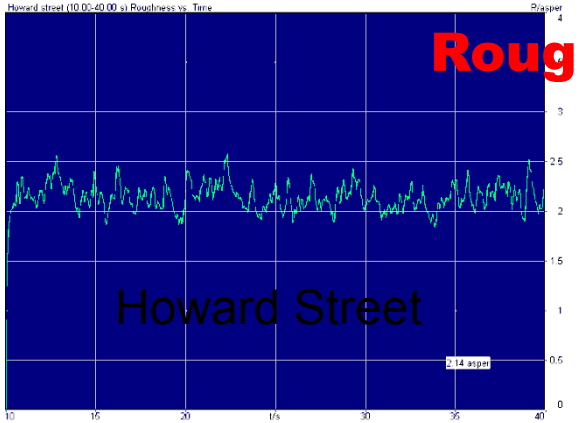

Sheaf-samll waterfall-L3 (0.00-11.89 s) Loudness vs. Time (FFT / ISO 532 B)
N/soneGF
Small Cascade
(L3)
Loudness vs. Time
22.5 soneGF
t/s

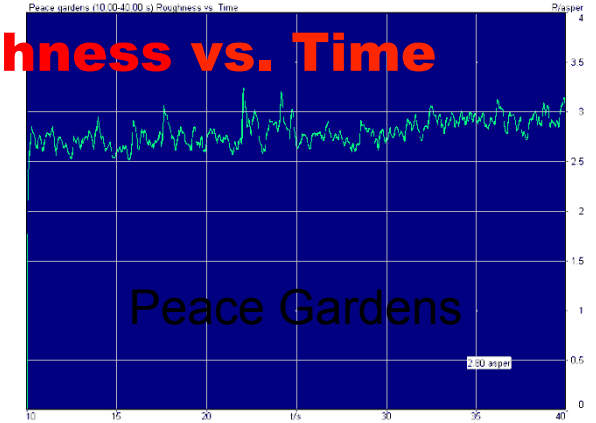

Sheaf-traffic (10.00-40.00 s) Loudness vs. Time (FFT / ISO 532 B)
N/soneGF
Traffic Noise
24.6 soneGF
t/s

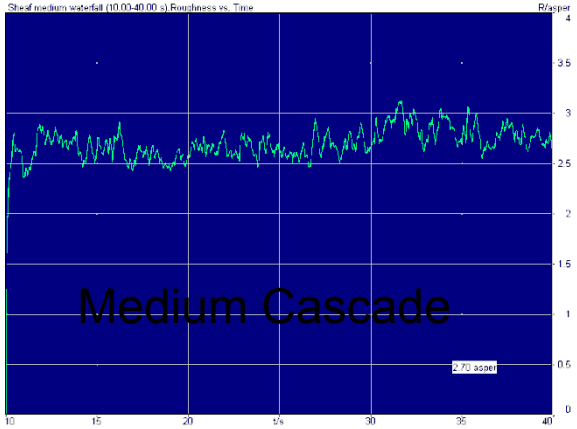
Psychoacoustics

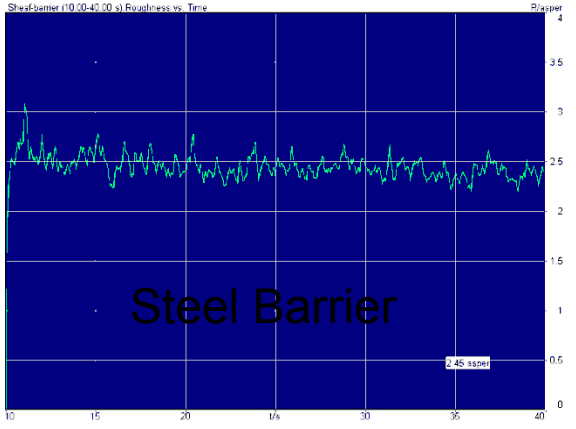
Roughness vs. Time

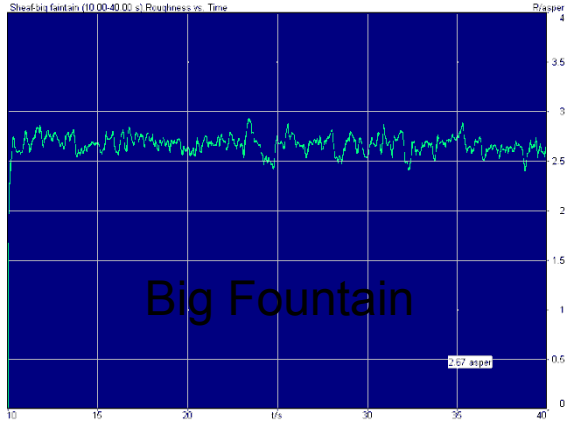


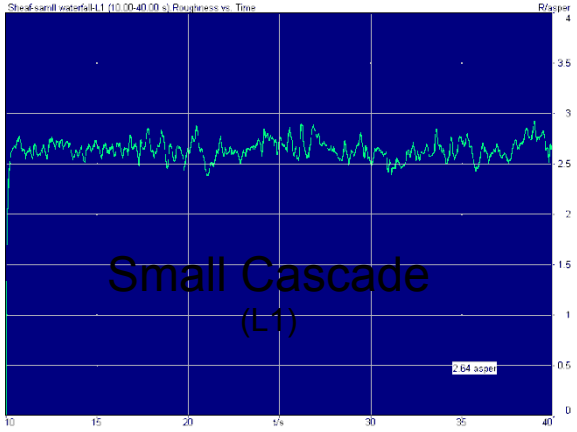


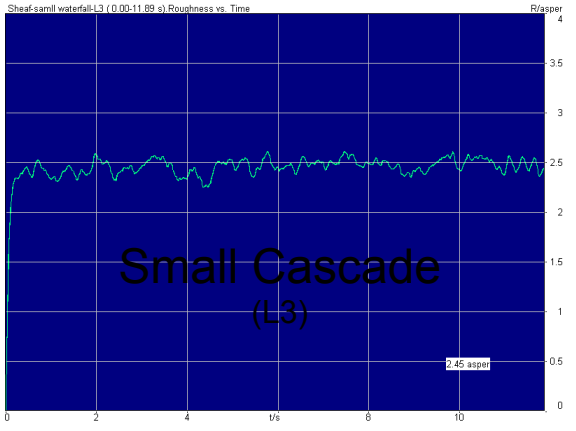


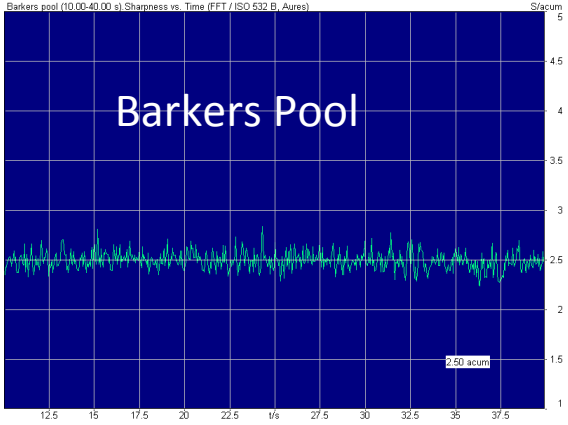


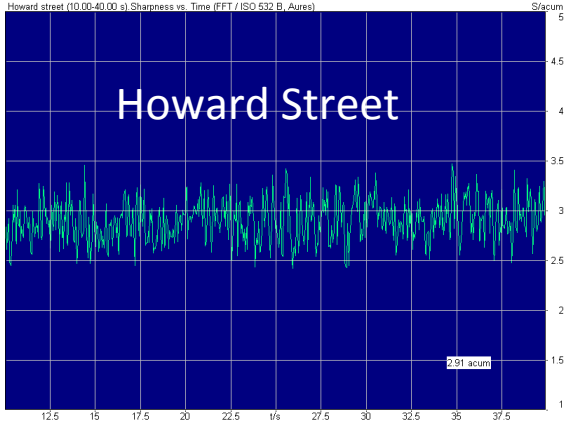


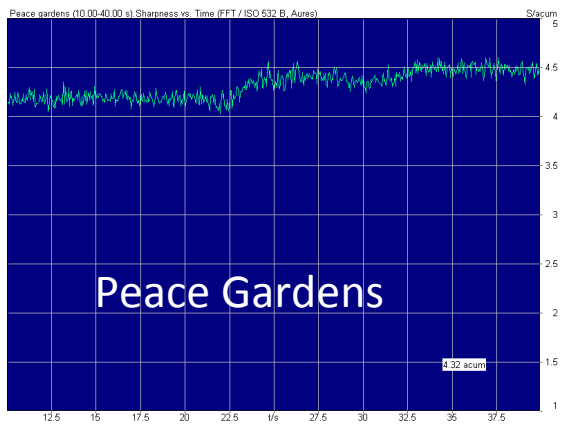


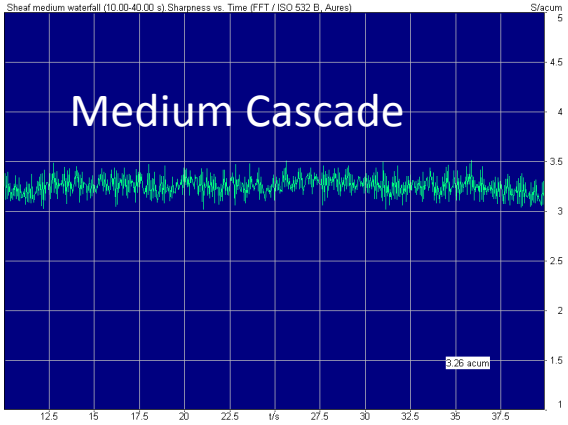


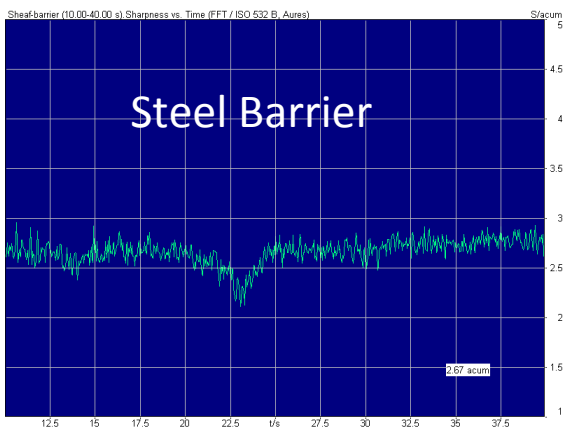


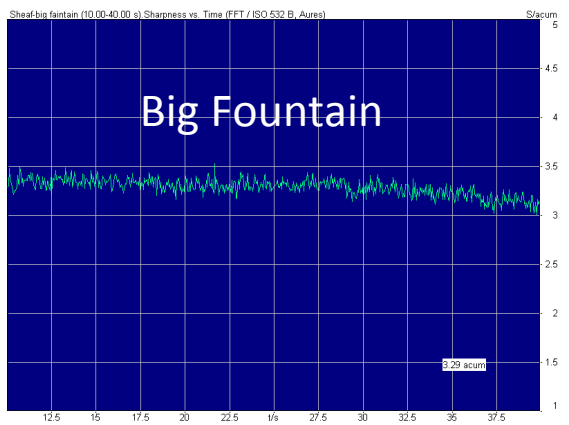

Barkers pool (10.00-40.00 s).Sharpness vs. Time (FFT / ISO 532 B, Aures)
S/acum
Barkers Pool
2.50 acum
t/s

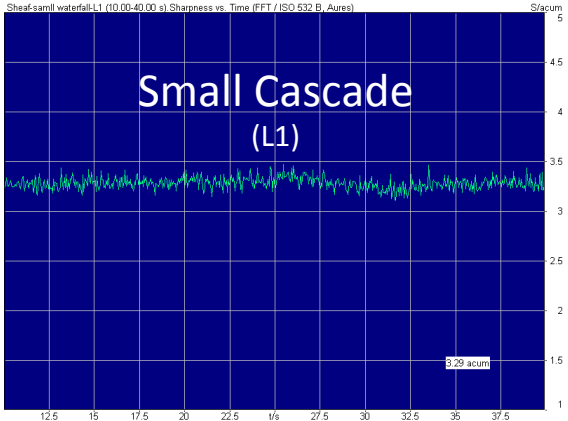

Howard street (10.00-40.00 s).Sharpness vs. Time (FFT / ISO 532 B, Aures)
S/acum
Howard Street
2.91 acum
t/s

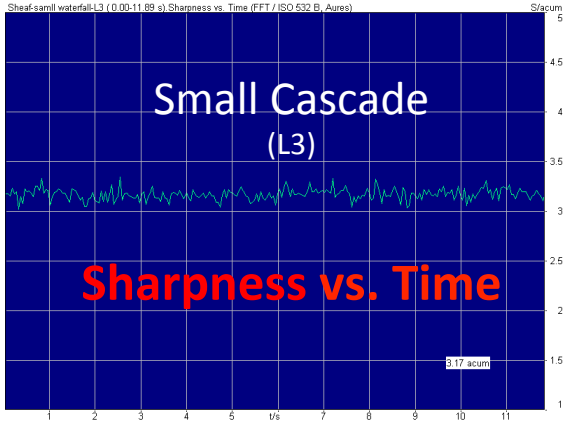

Peace gardens (10.00-40.00 s).Sharpness vs. Time (FFT / ISO 532 B, Aures)
S/acum
Peace Gardens
4.32 acum
t/s


Sheaf medium waterfall (10.00-40.00 s).Sharpness vs. Time (FFT / ISO 532 B, Aures)
S/acum
Medium Cascade
3.26 acum
t/s


Sheaf-barrier (10.00-40.00 s).Sharpness vs. Time (FFT / ISO 532 B, Aures)
S/acum
Steel Barrier
2.67 acum
t/s


Sheaf-big faintain (10.00-40.00 s).Sharpness vs. Time (FFT / ISO 532 B, Aures)
S/acum
Big Fountain
3.29 acum
t/s


Sheaf-samll waterfall-L1 (10.00-40.00 s).Sharpness vs. Time (FFT / ISO 532 B, Aures)
S/acum
Small Cascade
(L1)
3.29 acum
t/s


Sheaf-samll waterfall-L3 (0.00-11.89 s).Sharpness vs. Time (FFT / ISO 532 B, Aures)
S/acum
Small Cascade
(L3)
Sharpness vs. Time
3.17 acum
t/s


Sheaf-traffic (10.00-40.00 s).Sharpness vs. Time (FFT / ISO 532 B, Aures)
S/acum
Traffic Noise
2.17 acum
t/s