CHALMERS
UNIVERSITY OF TECHNOLOGY

Bullerskydd

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Bullerskydd

- Erfarenheter från tidigare HoSANNA-projektet
- Erfarenheter från andra tidigare projekt: C/O City, Urbana akustikskärmar
- Pågående arbete

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HOSANNA – About

Holistic and sustainable abatement of noise by optimized combinations of natural and artificial means

- Years: 2009–2013
- Funding: FP7, €5.1M (EC Contribution €3.9M)
- Coordinator: Chalmers University of Technology

Web site: www.greener-cities.eu

Contact: Jens Forssén, jens.forssen@chalmers.se

HOSANNA – Partners

CHALMERS TEKNISKA HOEGSKOLA AB	SWE
STOCKHOLMS UNIVERSITET	SWE
CENTRE SCIENTIFIQUE ET TECHNIQUE DU BATIMENT	FR
THE OPEN UNIVERSITY	UK
UNIVERSITY OF BRADFORD	UK
THE UNIVERSITY OF SHEFFIELD	UK
INTERDISCIPLINARY INSTITUTE FOR BROADBAND TECHNOLOGY / GHENT UNIVERSITY	BEL
TRANSPORTOKONOMISK INSTITUTT	NOR
Müller-BBM GmbH	GER
CANEVAFLOR SAS	FR
ACOUCITE	FR
City of Stockholm, Environment and Health Administration	SWE
HANYANG UNIVERSITY	KOR

HOSANNA – Main idea

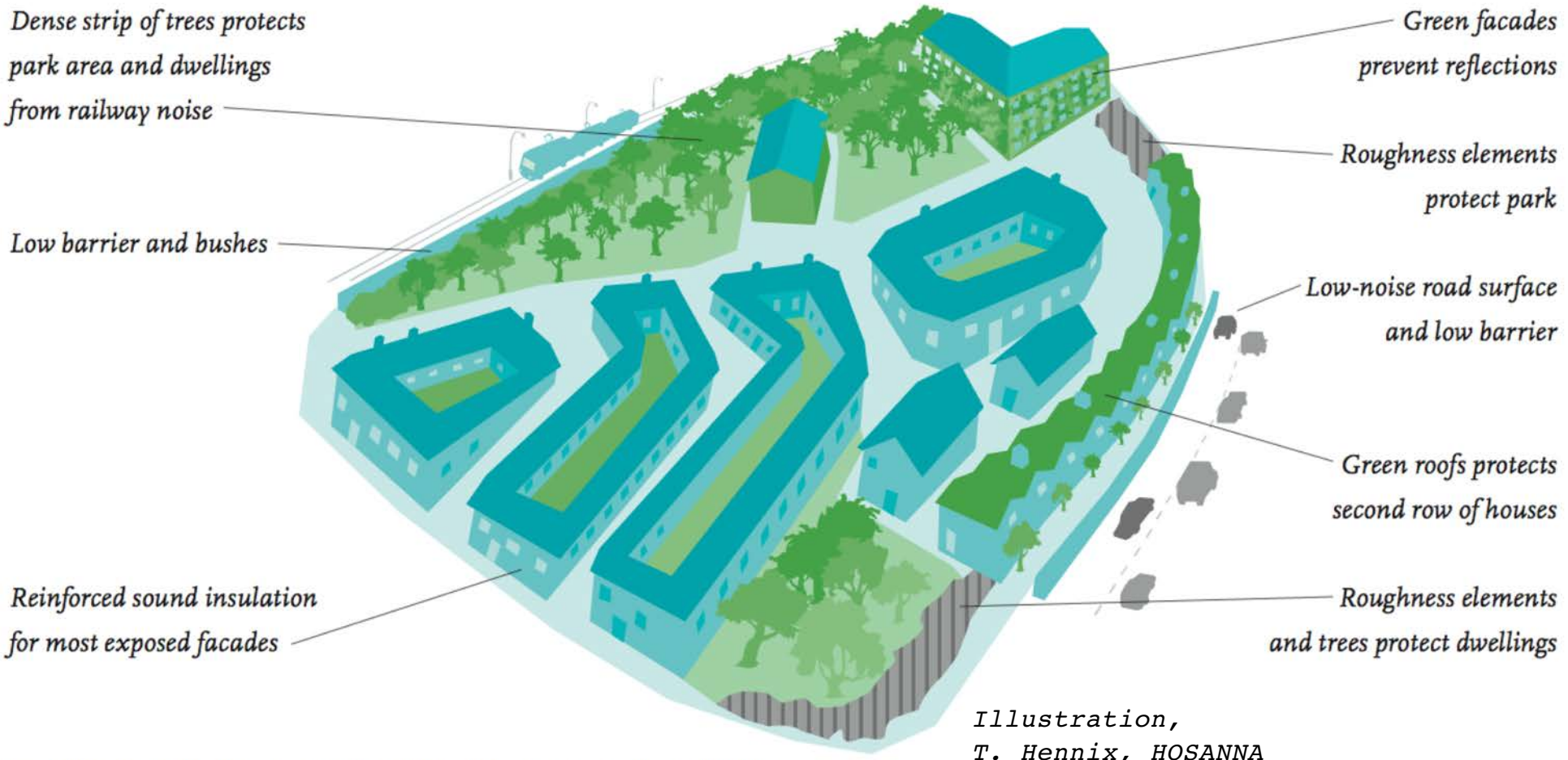
Holistic and sustainable abatement of noise by optimized combinations of natural and artificial means

The main idea of our project is to optimize the use of green areas, green surfaces and other natural elements in combination with artificial elements in urban and rural environments for reducing the noise impact of road and rail traffic.

Toolbox examples

- **Low, thick barriers (vegetated, recycled materials, stone gabions)**
- **Taller vegetated barriers (with designed tops)**
- **Vegetated façade cassettes, for use in street canyon**
- **Grass roofs**
- **Inner yard treatments (façades, balconies, openings toward street)**
- **Trees, shrubs and bushes**
- **Ground improvements**
- **Roughness elements on hard ground**

Including combinations



Combining solutions to protect the quiet sides of noise-exposed dwellings

Illustration,
T. Hennix, HOSANNA

www.greener-cities.eu

Hosanna

HOSANNA – Deliverables

- Summary brochure
- European workshops (Dec 2012–Jan 2013)
- Engineering prediction data
- Handbook: *Environmental Methods for Transport Noise Reduction* (Taylor & Francis)

Default urban case

- Two-lane urban road
- 3.5 m between lanes
- Harmonoise/Imagine source model with source heights 0.01, 0.3 and 0.75 m
- 95% light vehicles and 5% heavy
- Speed 50 km/h
- Flow 27 500 vehicles per day (1146 vehicles per hour)
- Receiver height 1.5 m

Innovative barriers (CSTB)

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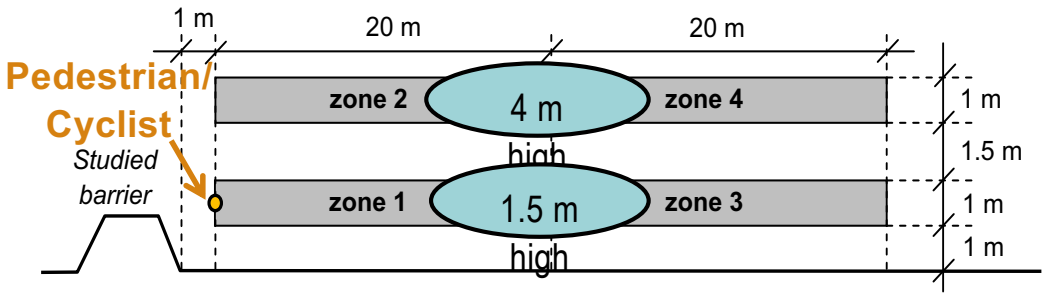
Hosanna

Innovative barriers

- **Approach:**

4 m high Receiver's height 1.5 m high	Urban	Rural	*Noise abatement referred to:*
Low barriers Low berms	6 dBA 8 dBA	3 dBA 5 dBA	*Untreated situation*
Substrate cover Vegetated caps Berms		3 dBA 5 dBA	*Situation with a 4m high rigid barrier at the edge*



Innovative barriers

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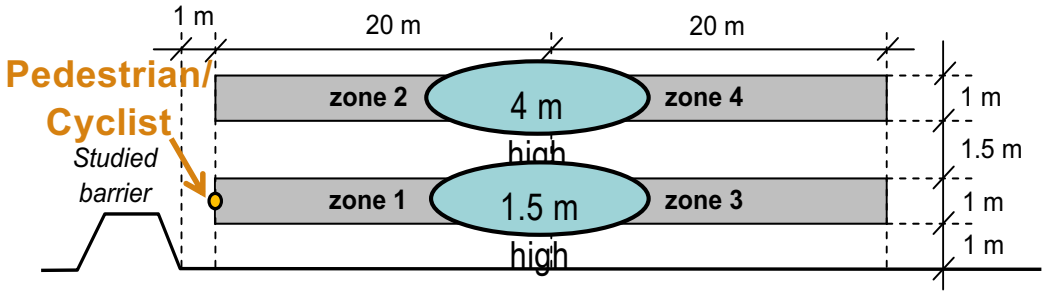
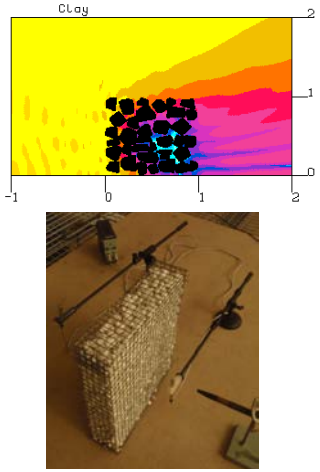


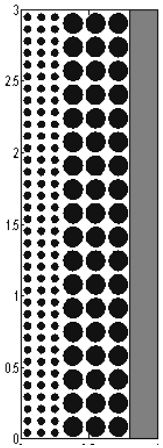
- **Many applications:**

Gabions

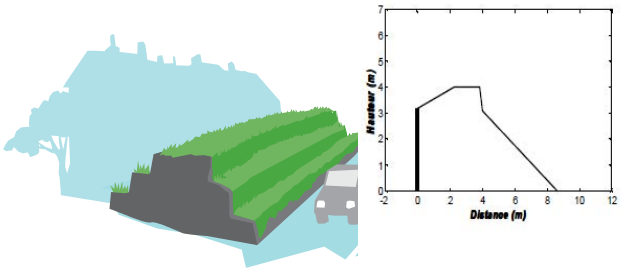


Low-height vegetated barriers

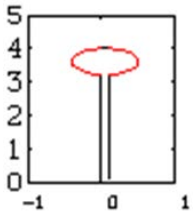
Sonic crystal assisted barriers



Complex shaped berms



Vegetated caps



Methodology

State of the Art: choice of the most adapted models

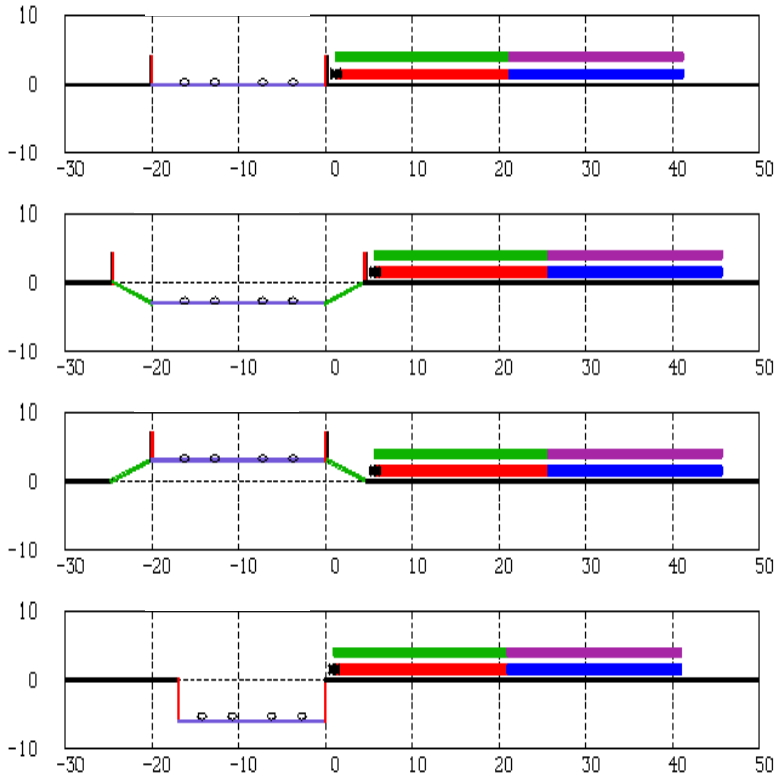
- **Acoustic impedance**
- **Sound propagation**

In this presentation

Model	Diffraction complex barriers	Ground impe-dance	Impe-dance jumps	Uneven Topo-graphy	Meteo-rology c(z)	Turbu-lence	3D possible	CPU Time
BEM	***	***	***	***	*	0	Y	Large (meshing dep) (freq. depend.)
FDTD	***	**	**	***	***	***	Y	Large (Incr. w freq)
TLM	***	**	**	***	***	**	Y	Quite large (Incr. w freq)
PE	0	***	***	*	***	**	Y	Quite large (Incr. w freq)
SSM	0	***	***	*	**	**	Y	Very low (no freq. dep)
Rays	*	***	**	**	**	*	Y	Quite large (Incr. w freq)
FFP	0	***	0	0	**	**	N	Low (Incr. w freq)

oise barriers covered with substrate

Studied configurations



Motorway / Rural

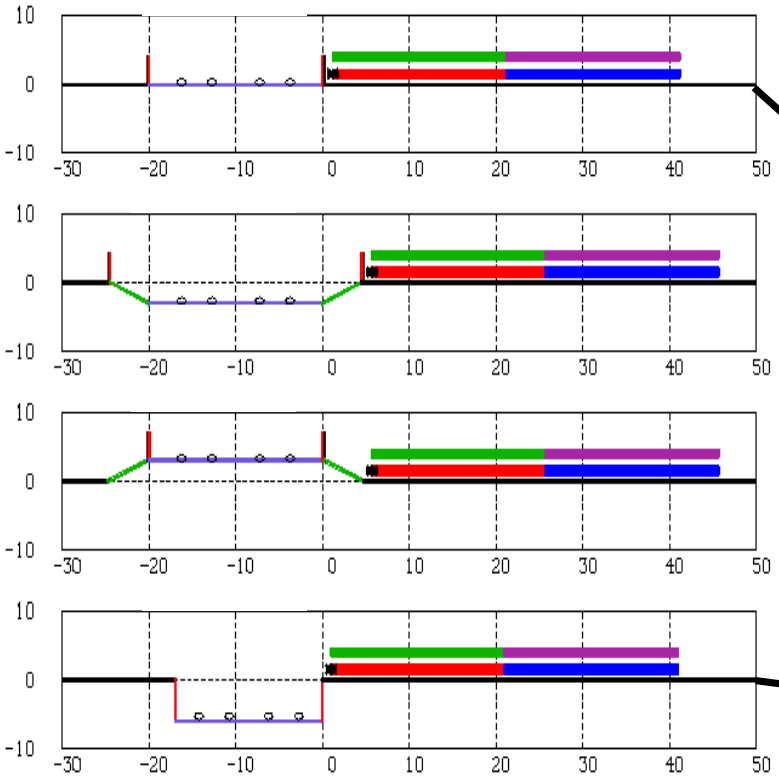
Absorbent arrangement

(Canevaflor substrate suitable for growing vegetation)

- **T**: Totally covered (4 m high)
- **L**: Lower half (2 m)
- **C**: center zone (2 m)
- **U**: upper half (2 m)
- **A**: Alternated 0.5 m strips

oise barriers covered with substrate

Results



Motorway / Rural

Focus (Δ*IL*)

Flat

Absorbent arrangement	Pedestrian (*)	Zone 1	Zone 2	Zone 3	Zone 4
T	3.9	4.7	7.0	6.1	7.6
L	1.8	2.6	4.4	3.8	4.5
C	1.1	1.9	3.9	3.3	3.8
U	2.6	2.8	4.3	3.7	4.6
A	3.1	3.6	5.0	4.4	5.3

Objective 3 / 5 dBA

Trench

Absorbent arrangement	Pedestrian *	Zone 1	Zone 2	Zone 3	Zone 4
T	2.9	10.0	7.8	11.8	12.2
L	2.1	6.6	4.4	7.7	7.6
C	1.8	6.1	4.3	7.1	7.1
U	1.5	5.8	3.6	7.5	7.4
A	1.9	6.4	4.0	8.1	7.4

oise barriers covered with substrate

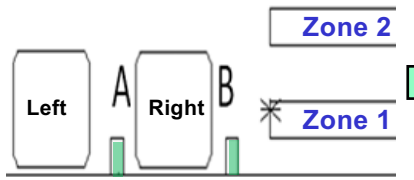
Synthesis

- Canevaflor substrate (suitable for vegetation) appears to be a very efficient alternative solution to treat classic rigid barriers
- When only half of the barriers surface is absorbent, the “strips” arrangement generally shows the best performance
- For a totally covered situation, the acoustic gain is in the range:
  - 5-8 dBA for a flat terrain,
  - 6-9 dBA for a depressed road,
  - 4-6 dBA for an embanked road,
  - 8-10 dBA for a trench (except when too close)
- The narrower the trench, the higher the acoustic gain

Low-height noise barriers

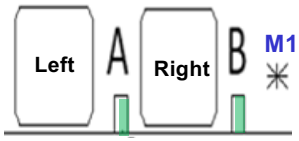
- **Inter-track low barriers (tram case)**

  Barrier= Vegetation substrate with inner rigid core



No building

Config.	Pedest.	Zone 1	Zone 2
Left B	2.7	10.3	3.5
Right B	17.1	20.4	17.8
L+R B	7.9	13.4	6.6
L+R A&B	16.7	20.4	15.7



Street canyon

Config.	M1
Left B	5.6
Right B	16.9
L+R B	10.0
L+R A&B	17.5

Low-height noise barriers

- **Inter-track low barriers (tram case)**

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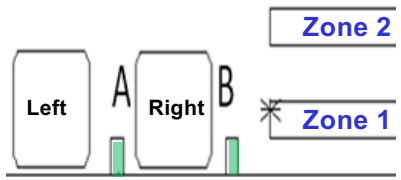

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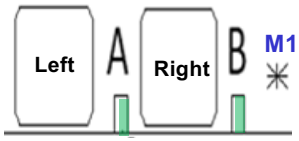
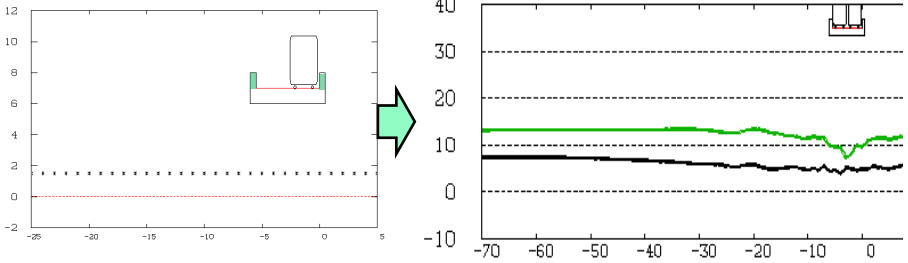


Street canyon

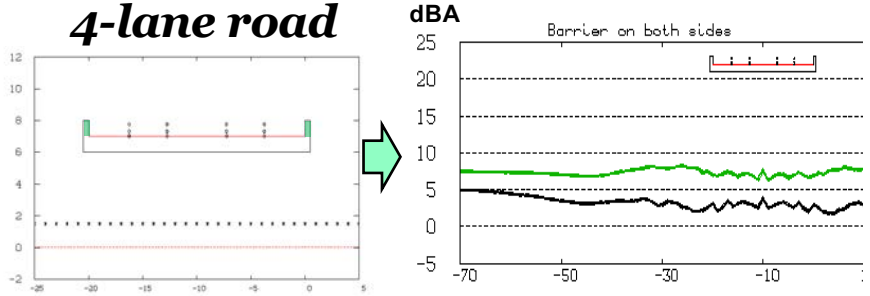
Config.	M1
Left B	5.6
Right B	16.9
L+R B	10.0
L+R A&B	17.5

- **Lightweight vegetated barriers at bridges**

Tramway



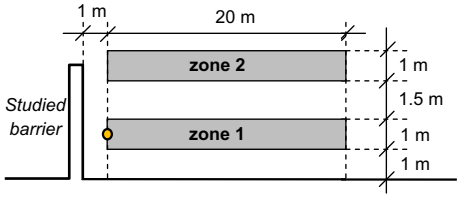
4-lane road



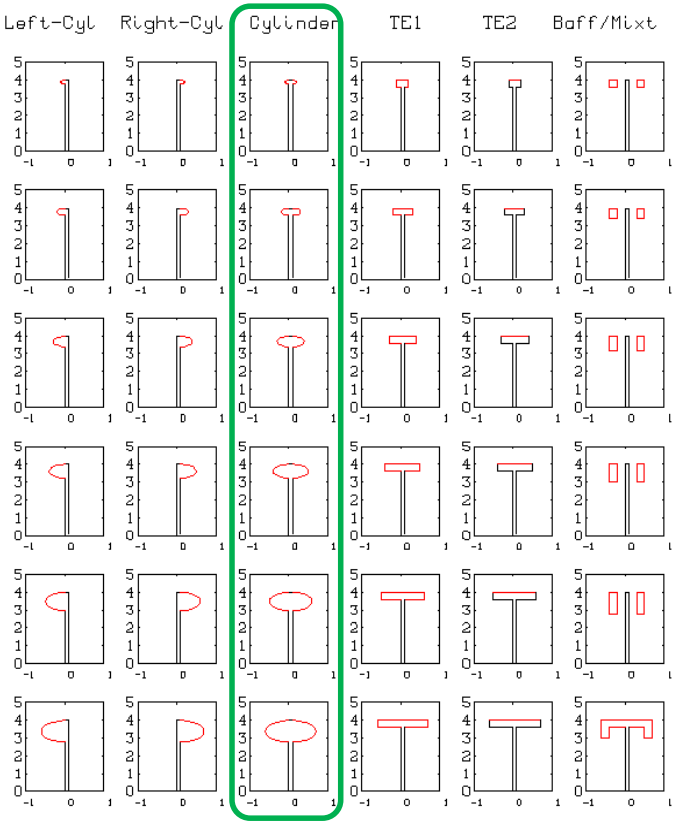
– absorbing barrier

– rigid barrier

Vegetated caps



Studied shapes (motorway)



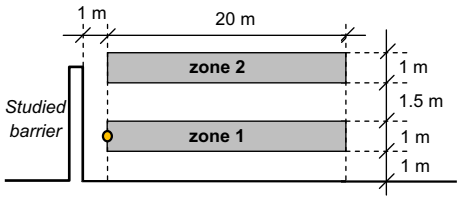
Red: vegetation substrate with inner rigid core

Focus…

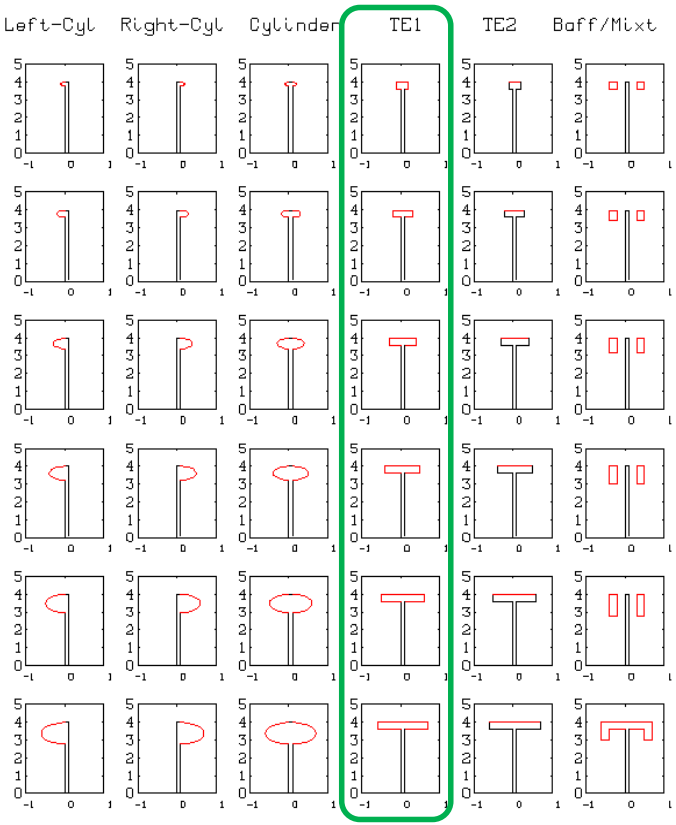
Cylinder

Gains	Pedestrian	Zone 1	Zone 2
$IL_{ref,rigid}$	***21.9***	***19.5***	***15.8***
ΔIL (r=10 cm)	**4.1**	**3.0**	**1.5**
ΔIL (r=20 cm)	**7.1**	**3.5**	**1.7**
ΔIL (r=30 cm)	**9.1**	**3.9**	**1.9**
ΔIL (r=40 cm)	**10.7**	**4.3**	**2.1**
ΔIL (r=50 cm)	**12.2**	**4.8**	**2.4**
ΔIL (r=60 cm)	**13.2**	**5.2**	**2.6**

Vegetated caps



Studied shapes (motorway)



Red: vegetation substrate with inner rigid core

Focus…

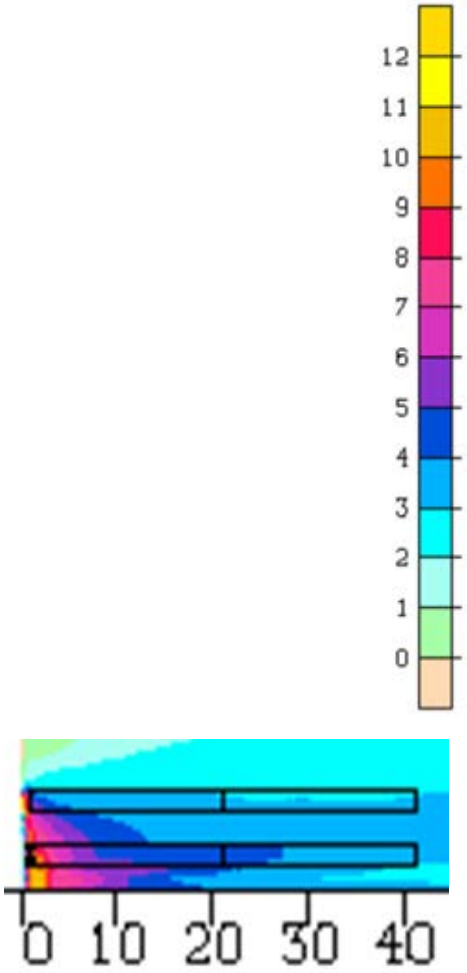
T-shape

Gains	Pedestrian	Zone 1	Zone 2
$IL_{ref,rigid}$	***21.9***	***19.5***	***15.8***
ΔIL (40 cm)	**6.1**	**3.4**	**1.9**
ΔIL (60 cm)	**8.2**	**4.3**	**2.5**
ΔIL (80 cm)	**9.8**	**5.1**	**3.0**
ΔIL (100 cm)	**11.2**	**5.8**	**3.4**
ΔIL (120 cm)	**12.5**	**6.4**	**3.8**
ΔIL (140 cm)	**13.7**	**7.0**	**4.2**

Vegetated barrier caps

Synthesis (Δ*IL*)

- **Typical noise reduction of 5 dBA** (1.5 m high) **appears to be feasible:**
  - **Cylinder: minimum diameter 100 cm**
  - **T-shape (all absorbent): minimum width 80 cm**
  - **T-shape (rigid lower part): minimum width 120 cm**
  - **Vertical baffles: minimum height 50 cm**
- **For pedestrians close behind the barrier, values up to 10 dBA and more**
- **The closer to the barrier, the more effective; so this mitigation solution is first dedicated to pedestrians, cyclists, small recreational areas**



Concluding summary

- **Canevaflor substrate shows to be very well adapted to solutions such as low barriers and vegetated caps**
  (this product can be vegetated → no loss of sound absorbing properties)

- **The acoustical effect of adding an extra inter-lane (street) or inter-track (tramway) vegetated low barrier is very significant**

- **The use of classic, smooth trapezoidal berms for rural transportation corridors does not appear to be the most efficient noise abatement solution using earth**

- **Low vegetated barriers at the edge of bridges seems to be a very promising (easy to set) solution in order to improve the soundscape for pedestrian and cycle paths underneath**

Recycled materials
(University of Bradford)

Combining green and recycled products

(i) Sound absorbing

mixed soil and granulated waste

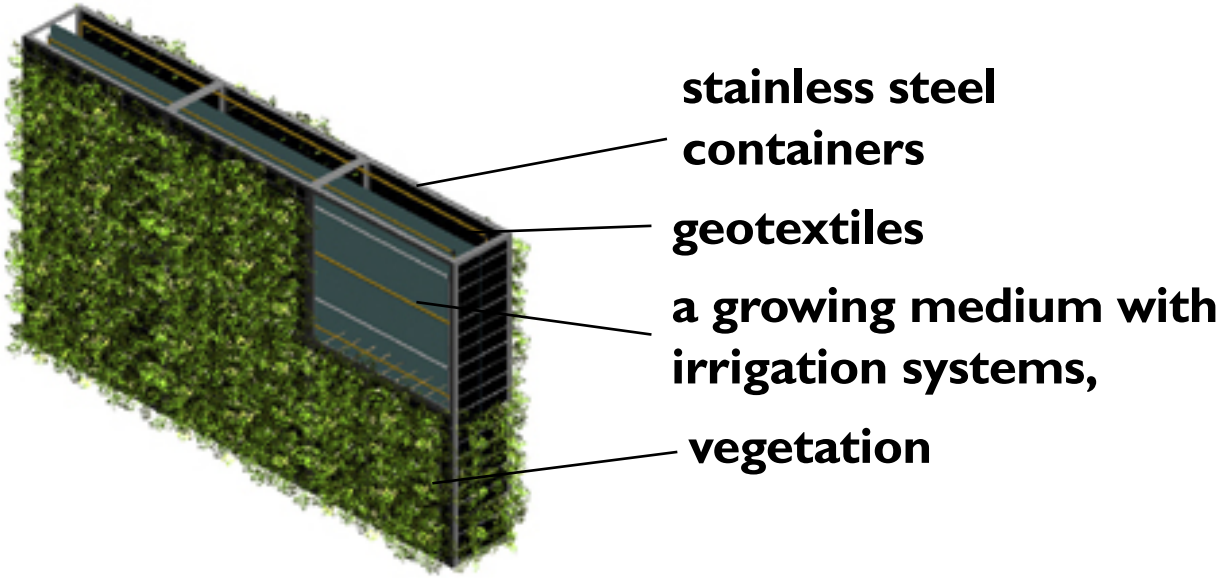
(ii) Sound absorbing and soil retention

soil with a front layer of lightly consolidated waste

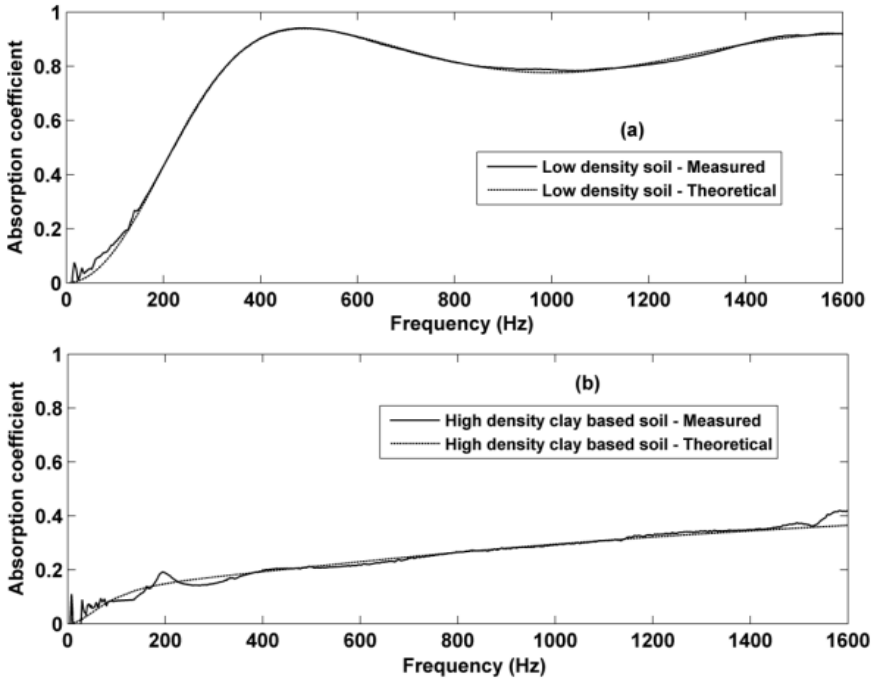
(iii) Sound absorption and transmission

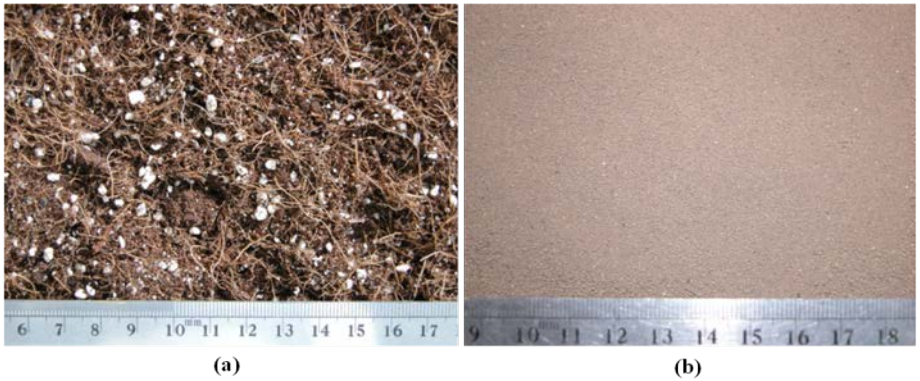
soil with a back layer of densely consolidated waste

Acoustic absorption and transmission loss applications



Low maintenance high performance low density soil – acoustic models



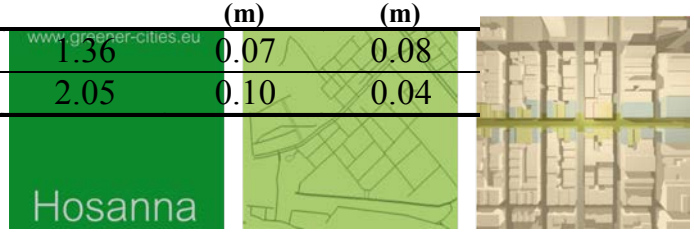


(a) Low density soil (b) Normal garden soil – Clay based

Summary of soil properties

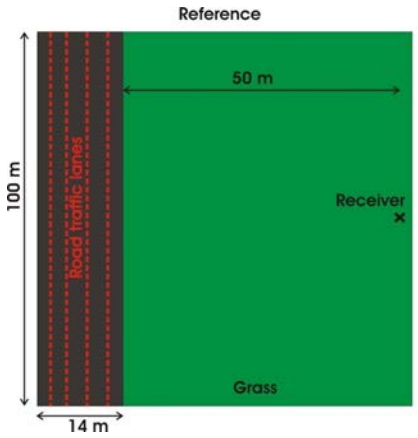
High porosity and low flow resistivity increases sound absorption performance of low density soil.

Soil type	Flow resistivity (exp.) (Pa.s/m^2)	Flow resistivity (theor.) (Pa.s/m^2)	Porosity (exp.)	Porosity (theo.)	Tortuosity (exp.)	Tortuosity (theo.)	Thickness (exp.) (m)	Thickness (theo.) (m)
Substratum	7,600	7,218	0.76	0.76	-	1.36	0.07	0.08
Clay based	566,350	620,650	0.39	0.39	-	2.05	0.10	0.04



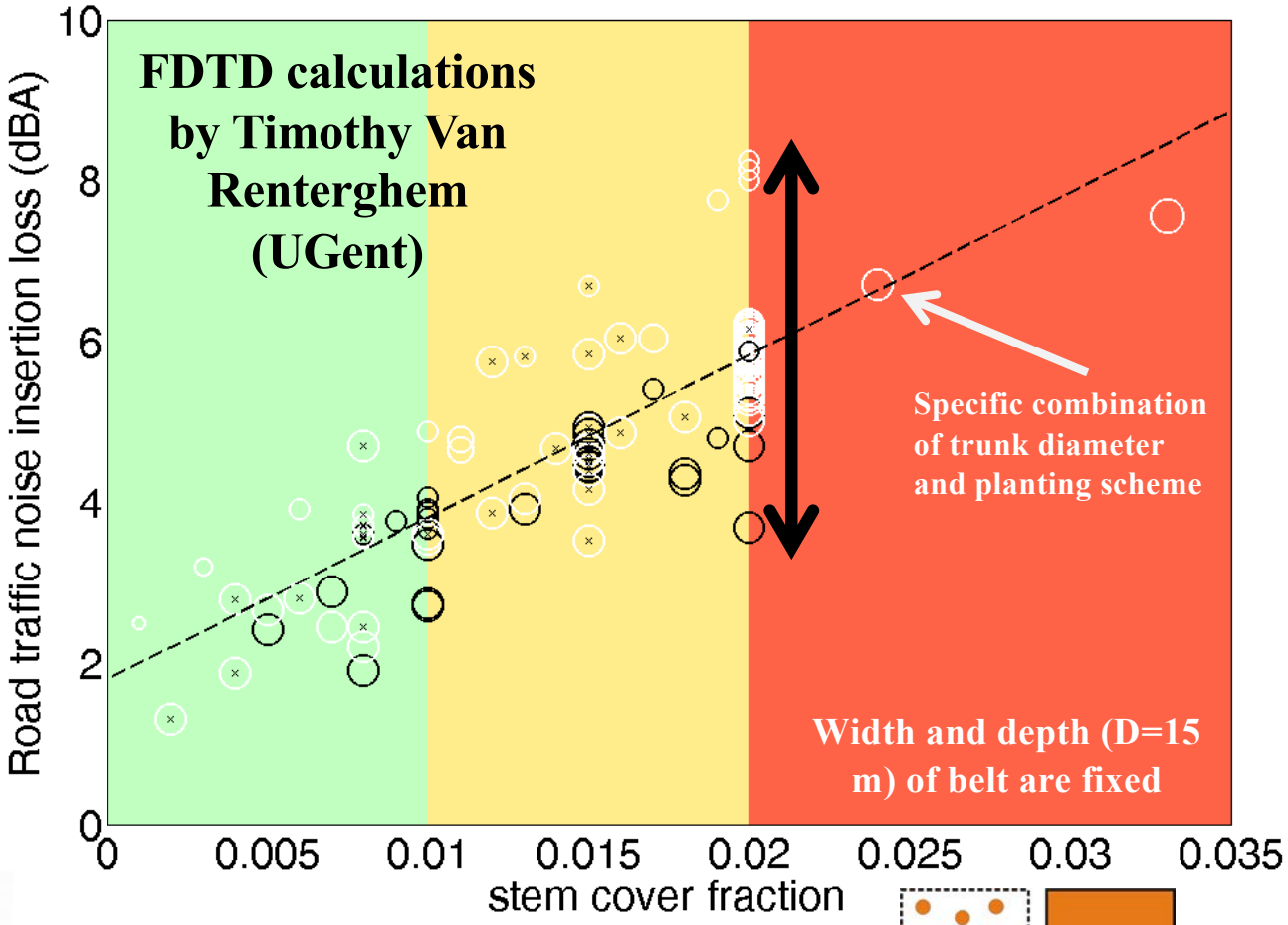
Trees (iMinds/UGent)

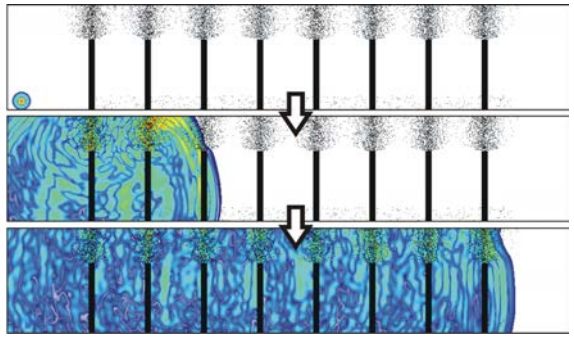
Tree belts along roads: planting schemes matter



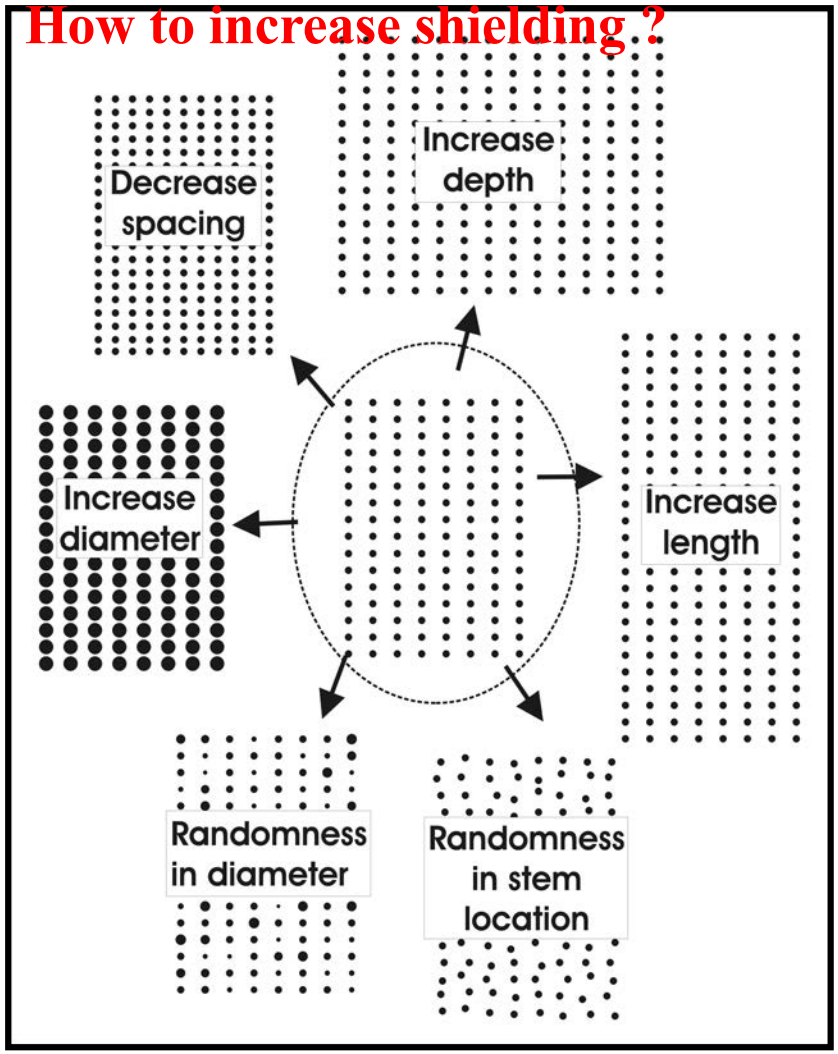
85 % 15 %

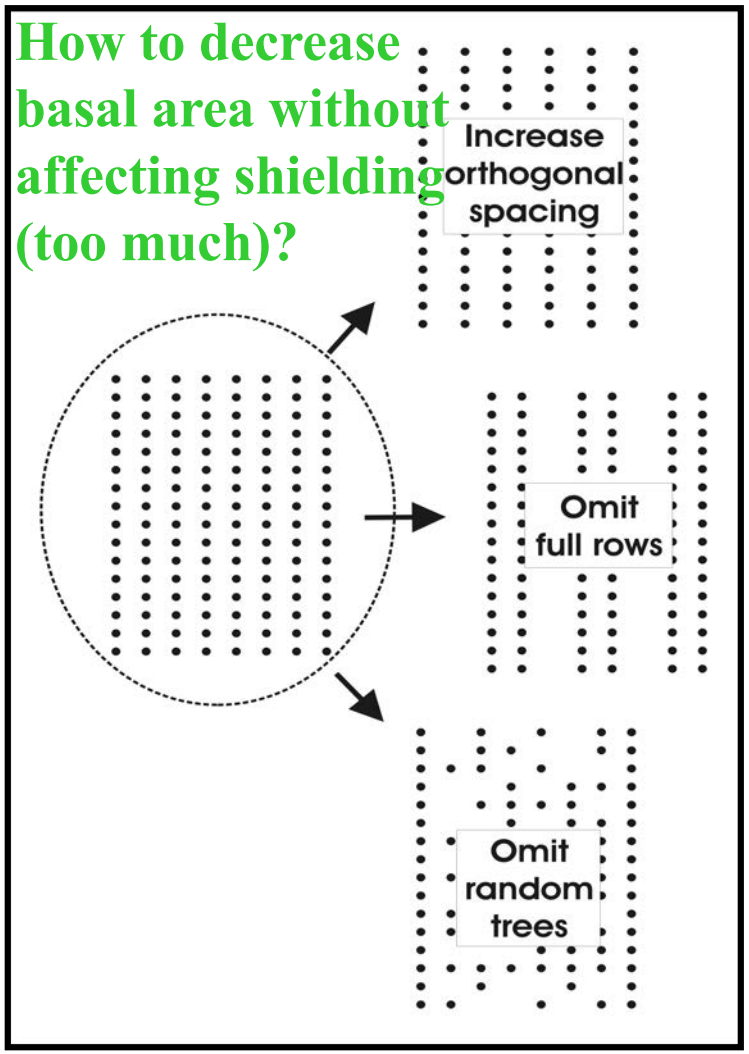
70 km/h





Tree belts along roads: guidelines





Tree belts

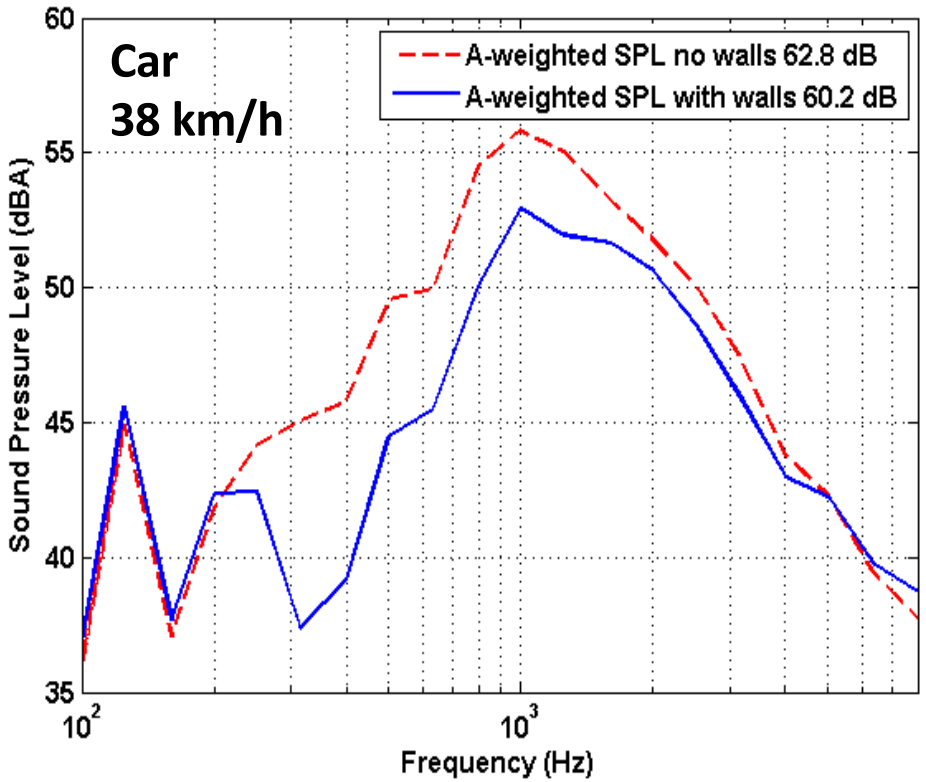
Ground treatments (OPU, CSTB)

Pass-by Measurements with brick arrays

1440 household bricks deployed on an asphalt car park

Square lattice of bricks
Cell walls two bricks (0.2 m) high and 0.05 m thick
Cell dimensions 0.2 m × 0.2 m
16 m long
total width 1.1 m

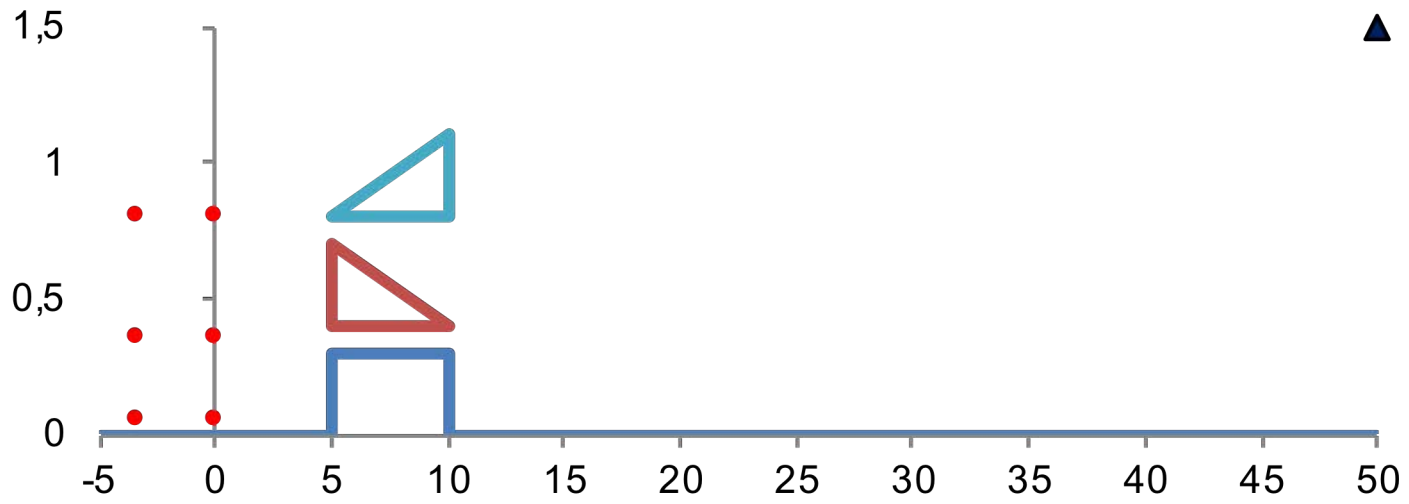
Results of car pass-by tests at 1.5 m high receiver 10 m away



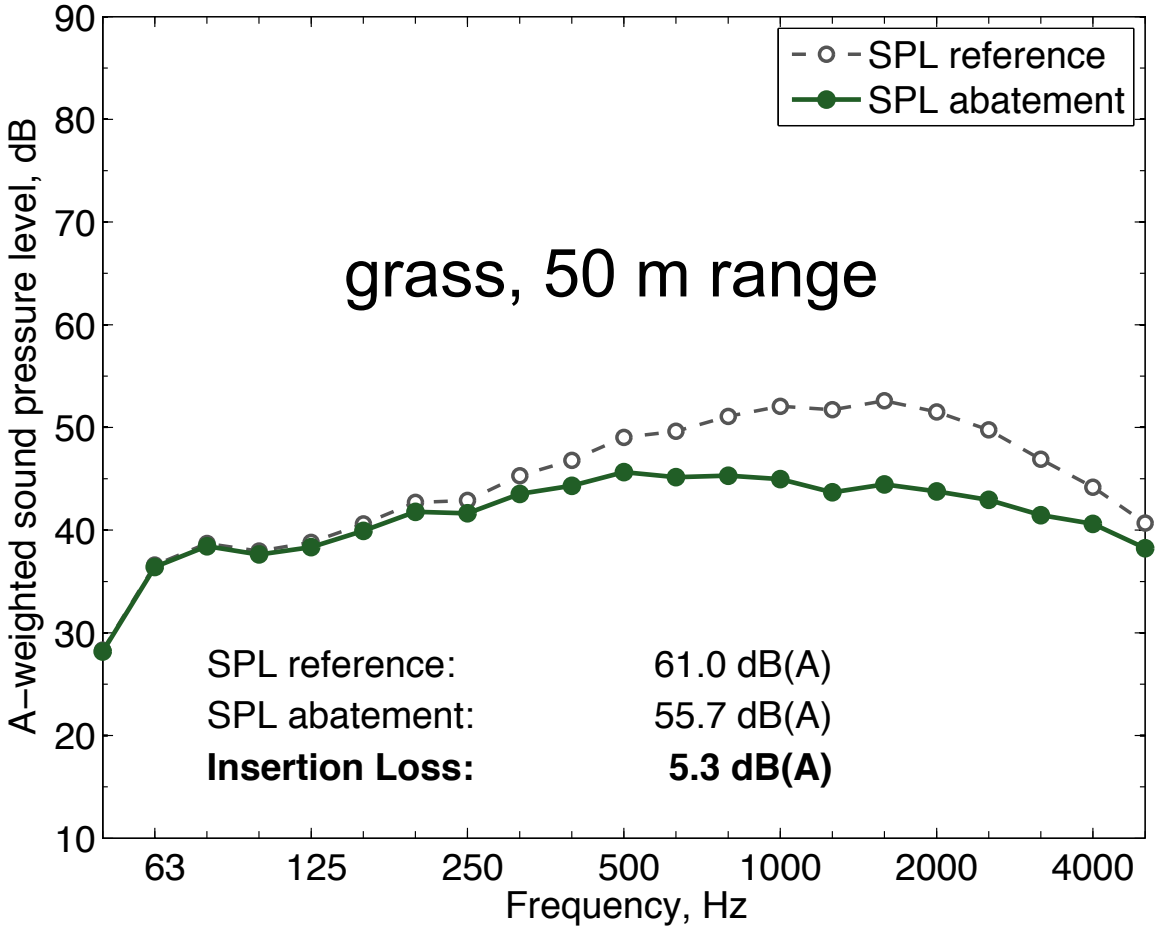
Insertion loss 2.6 dB

In-plane and raised ‘soft’ strips

- A raised ‘grass’ strip is predicted to result in 6 dB insertion loss (3 dB more than in-plane strip) at 1.5 m receiver
- A raised strip with slope ca 1 dB less effective

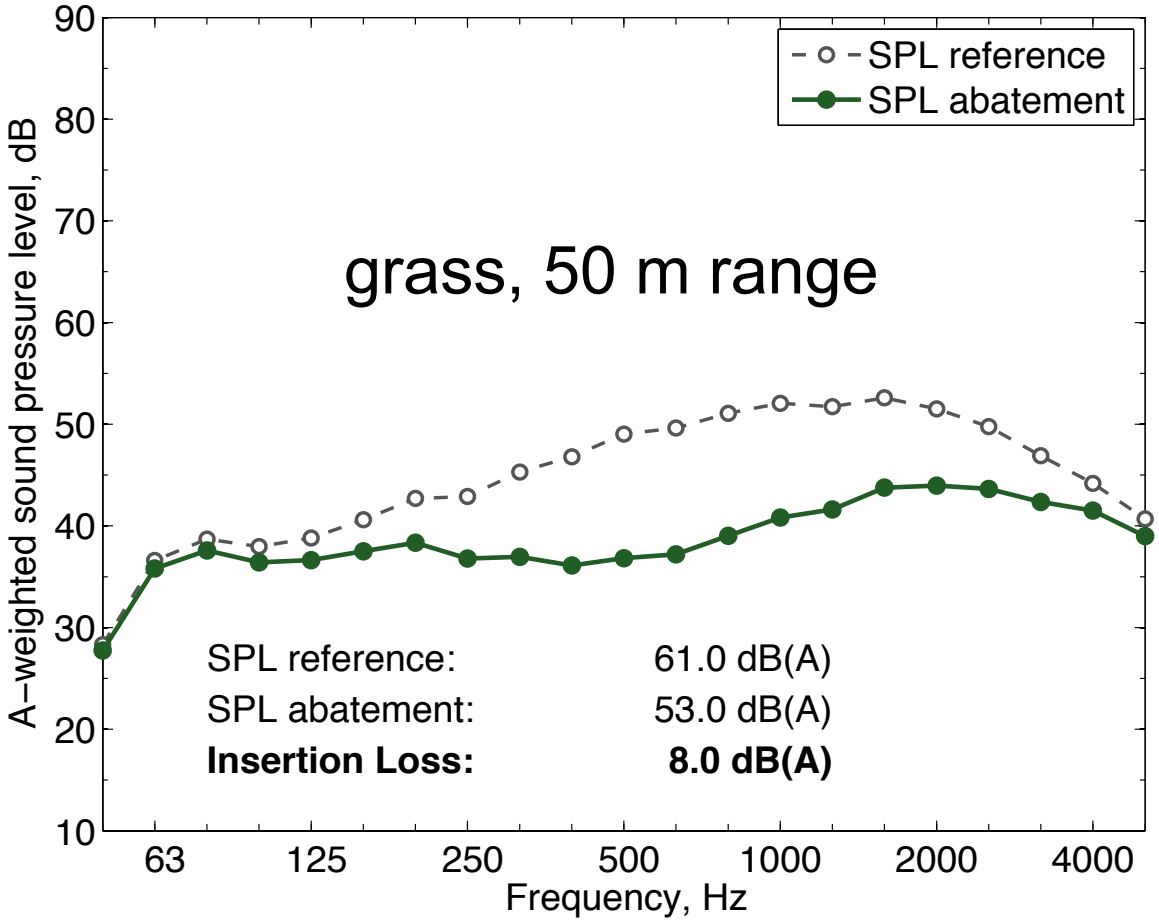


Grass land: lawn/football field



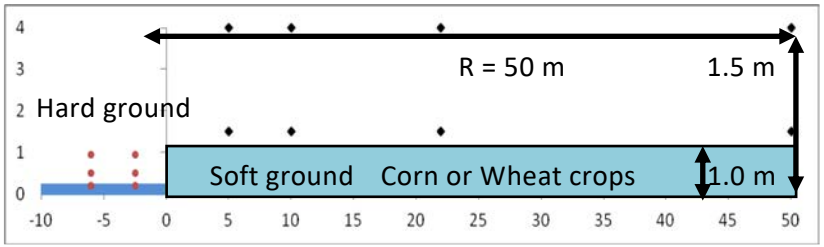
The Open University, UK: Attenborough, K., Taherzadeh, S., et al.

Grass land: thick, porous substrate



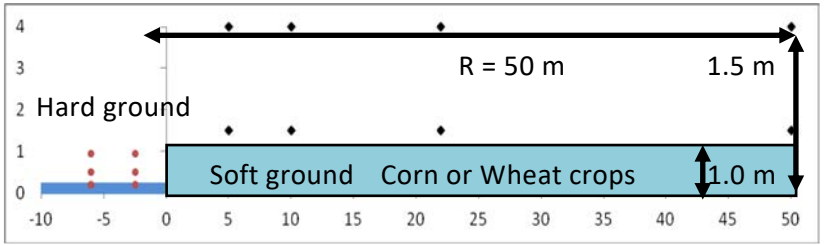
Soft ground and crops

Surface description	2-Lane road Insertion Loss (dB)
sports field (high flow resistivity)	5.5
Arable ground only (low flow resistivity)	8.4
Arable ground + dense corn	13.7

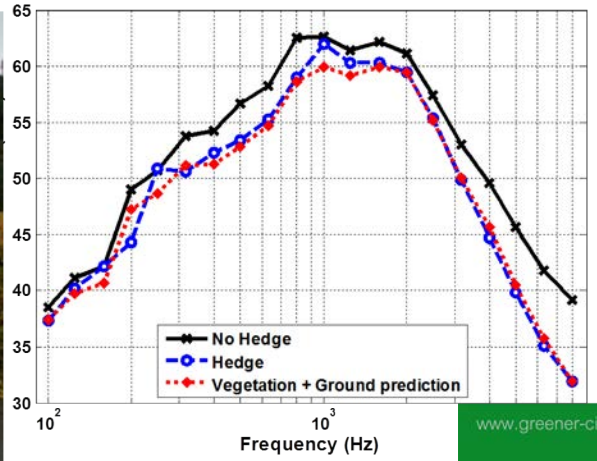


Soft ground and crops

Surface description	2-Lane road Insertion Loss (dB)
sports field (high flow resistivity)	5.5
Arable ground only (low flow resistivity)	8.4
Arable ground + dense corn	13.7



Hedges – Drive by Test



Hedge attenuation
1–2 dB

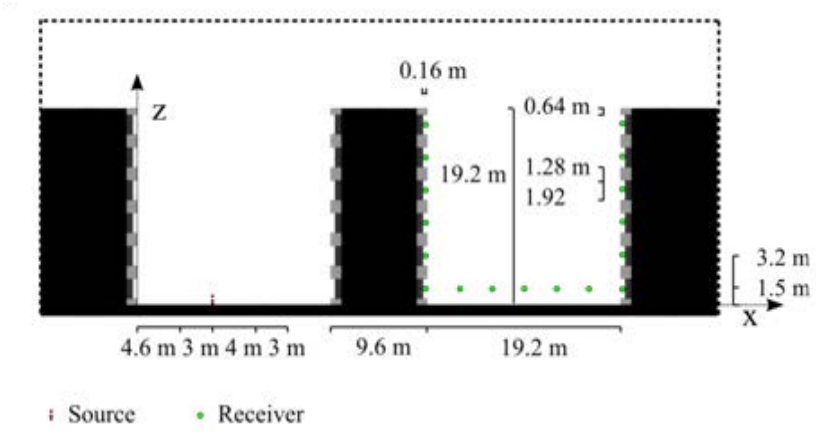
(of which half is due to soft ground)

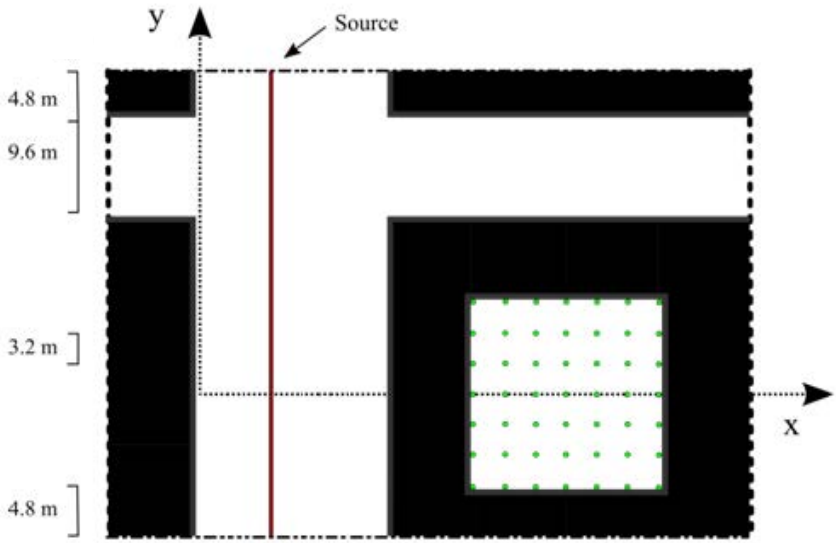
Greening buildings

(USFD, iMinds/UGent, Chalmers)

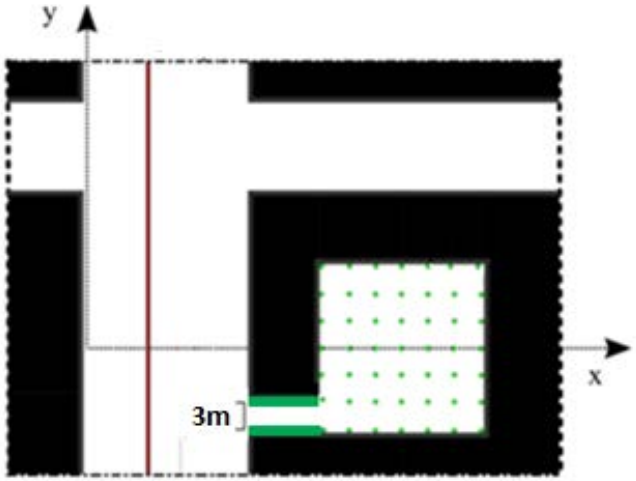
Vegetated façades of courtyard next to street canyon

Noise reduction: 3–4 dBA (driving speeds 30–70 km/h)





Vegetated entrance to the courtyard



Opening height	Reduction
3 m	4–5 dBA
9 m	4 dBA

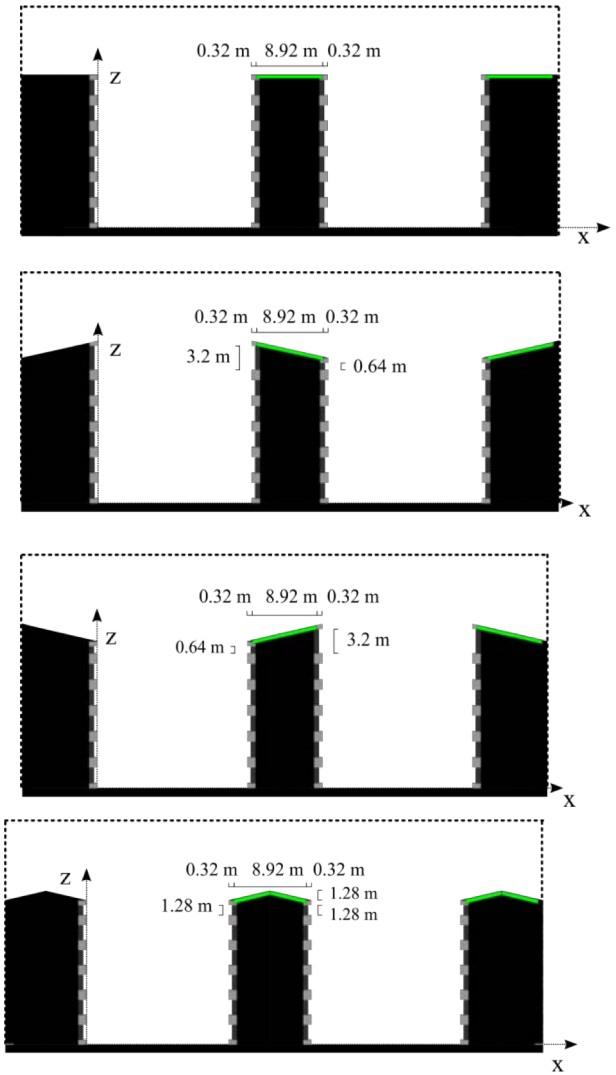
Vegetated roofs

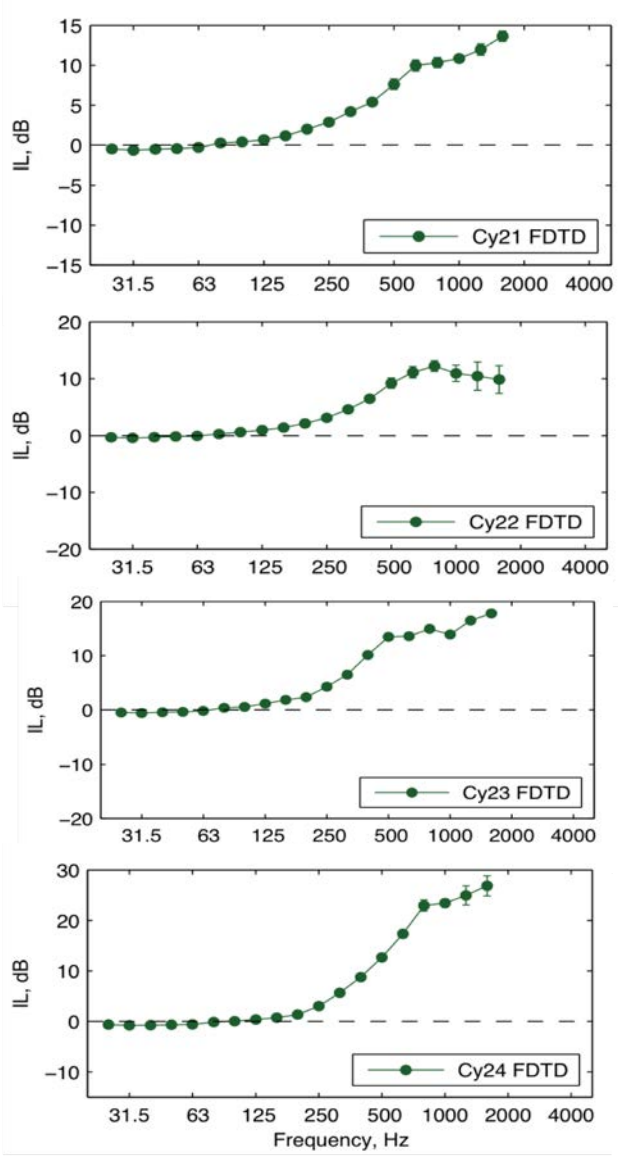
Noise reduction:

3–7 dBA depending on geometry

Example

Calculated examples





Noise reductio

3 dBA

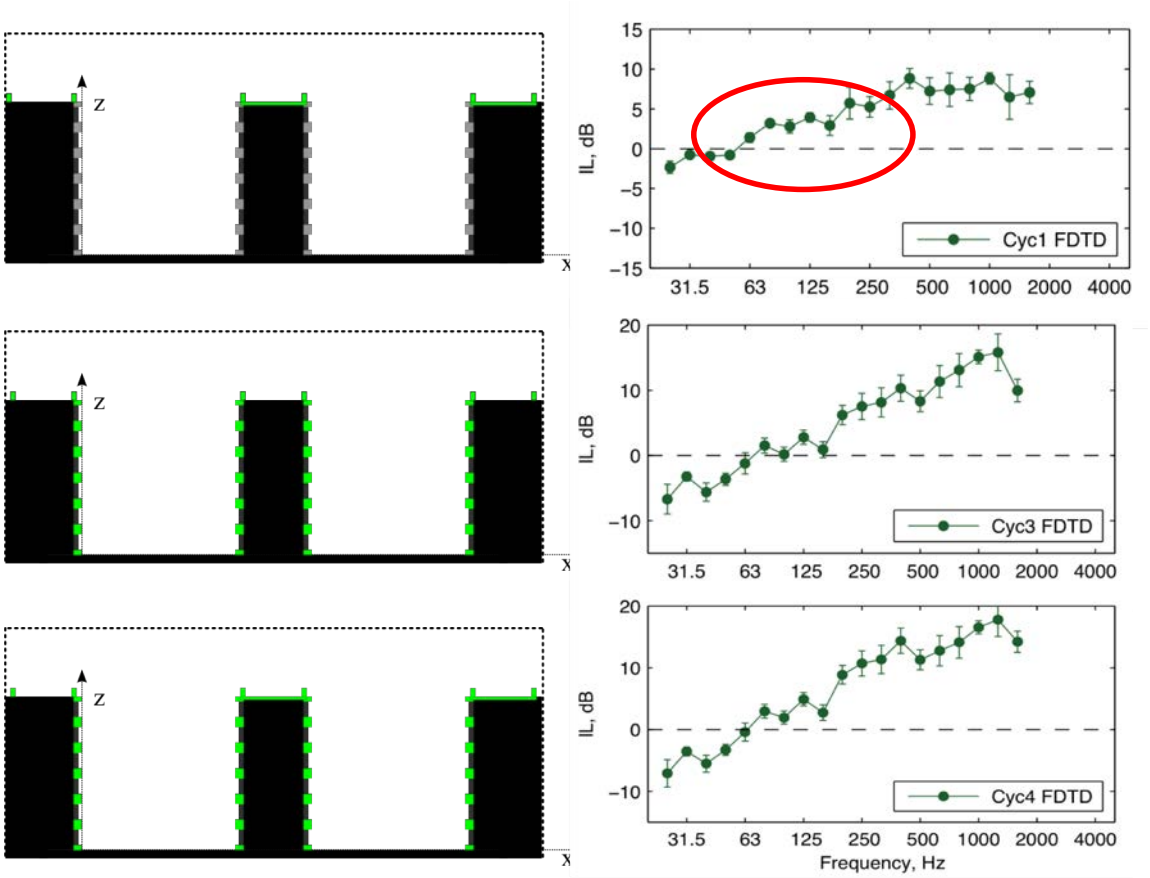
7.4 dBA

7 dBA

8 dBA

Flat roof performs better without vegetation

Vegetated façades, roofs and roof barriers



Noise reduction:

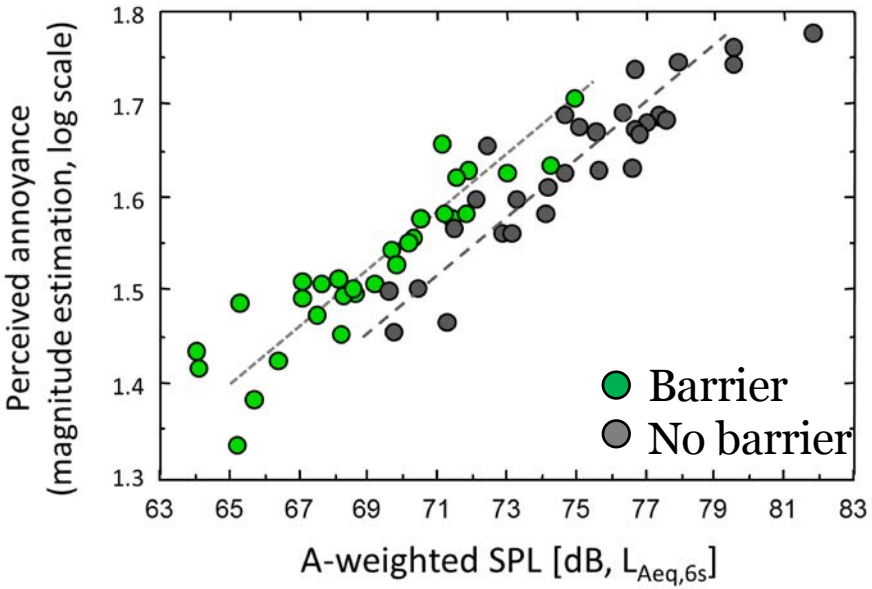
4.4 dBA

3.3 dBA

4.6 dBA

1. Noise perception before and after mitigation
(Stockholm University)

Road traffic noise (Lyon)

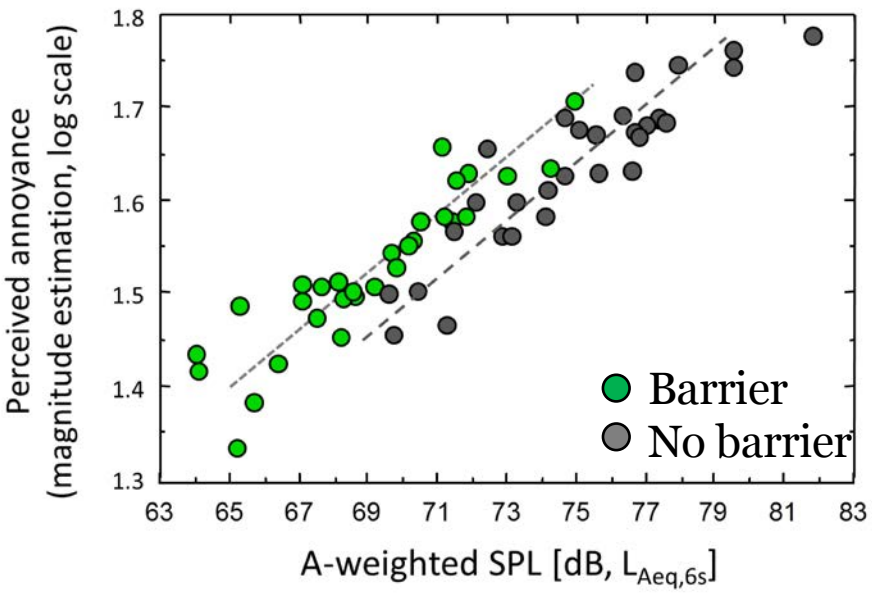


Annoyance reduction:
1-2 dB *less* than expected from dBA-reduction

1. Noise perception before and after mitigation

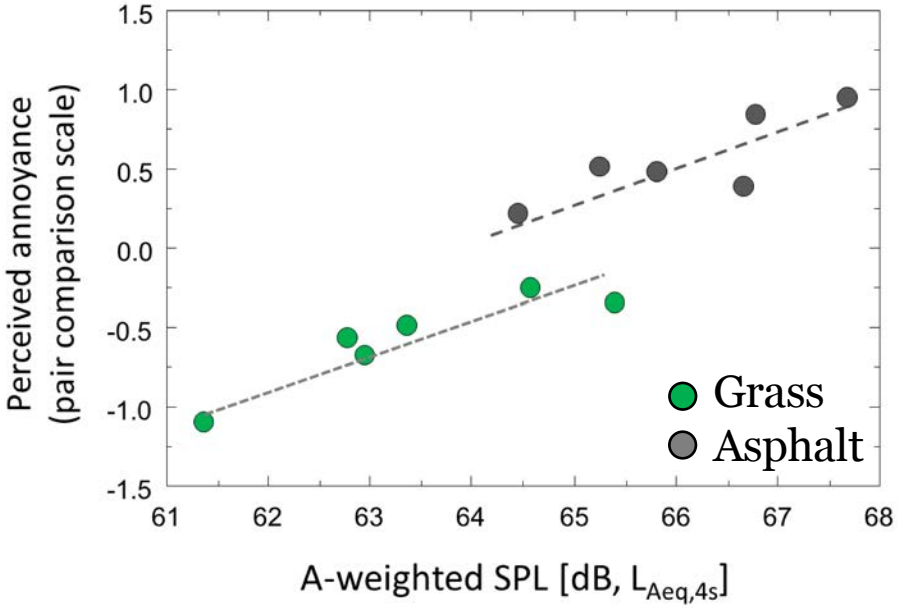
(Stockholm University)

Road traffic noise (Lyon)



Annoyance reduction:
1-2 dB *less* than expected from dBA-reduction

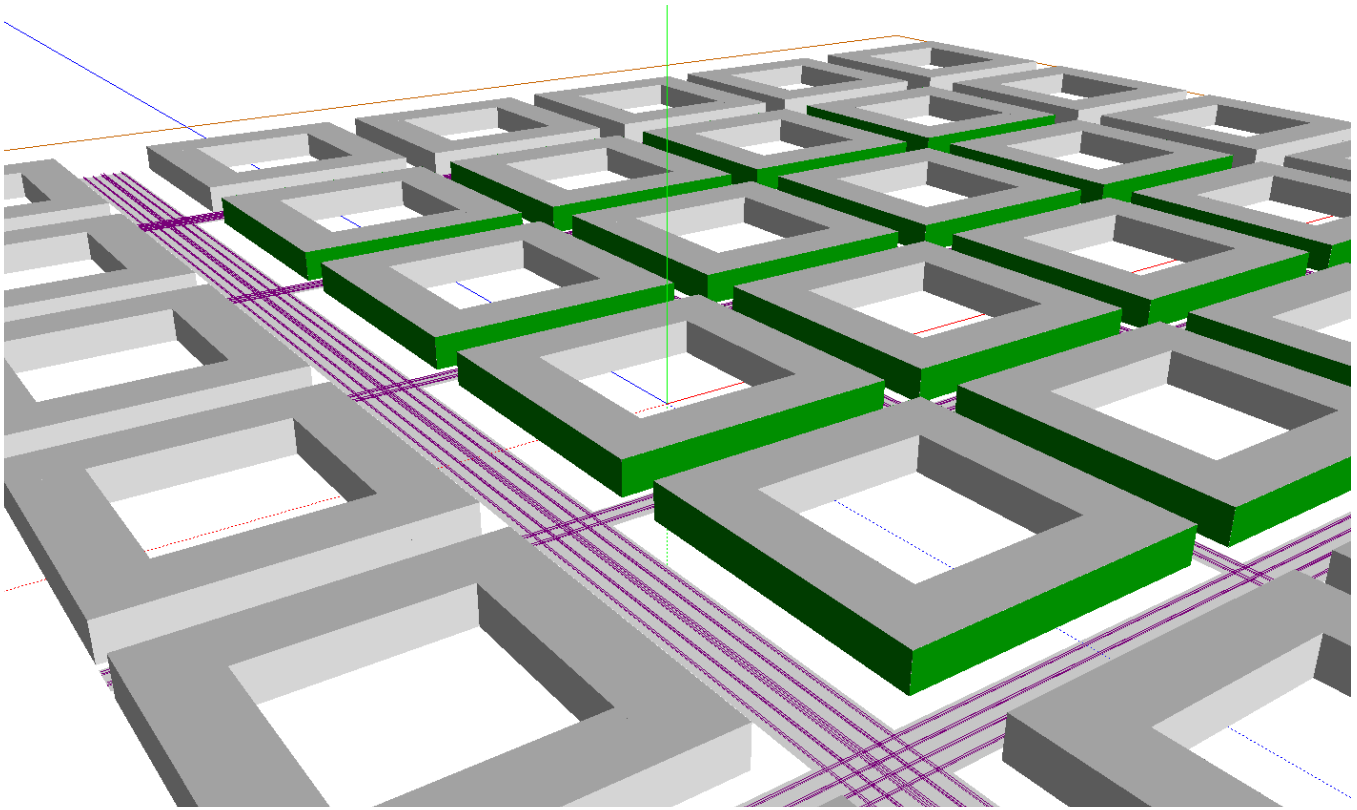
Tram noise (Grenoble)



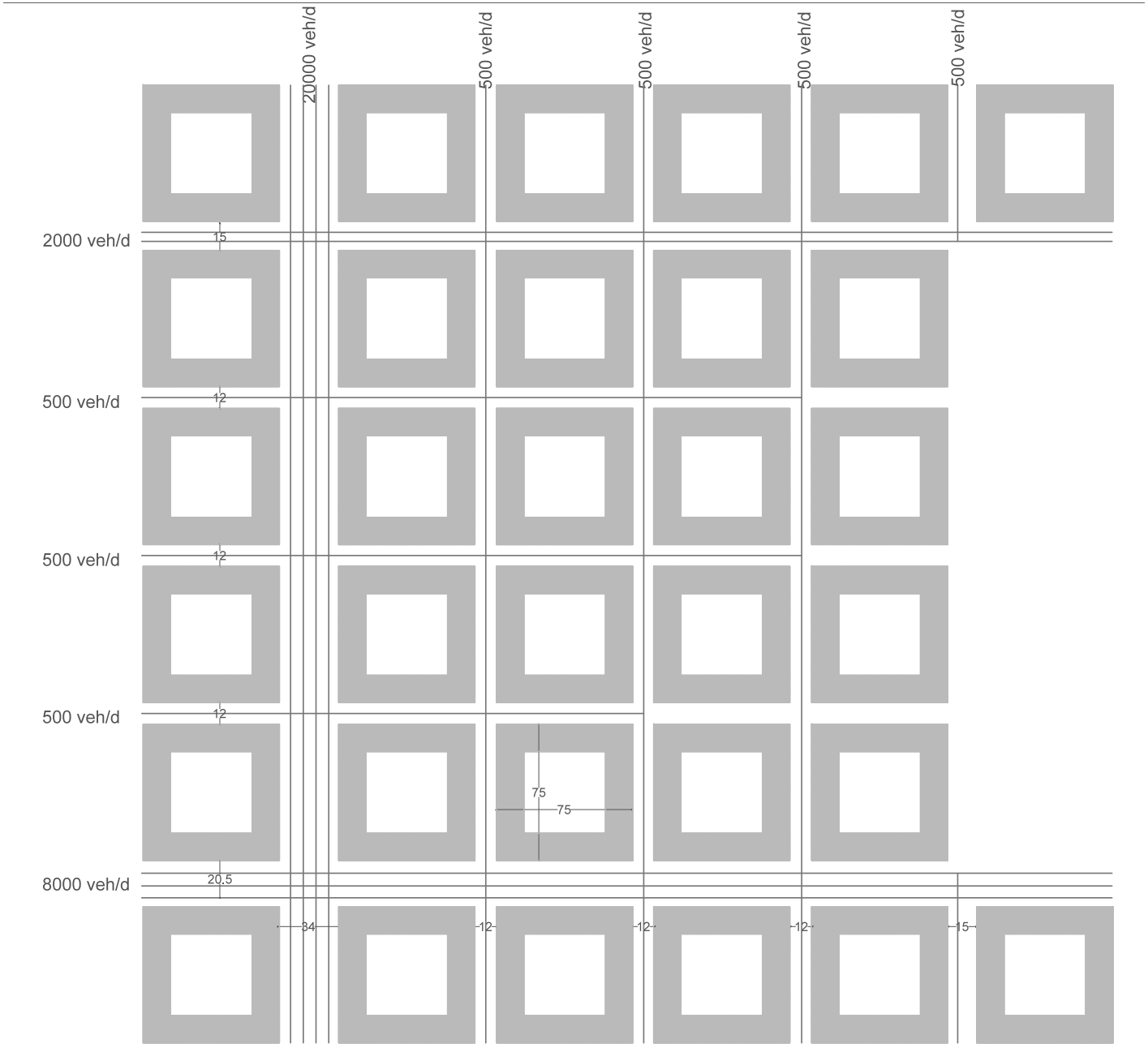
Annoyance reduction:
1-2 dB *more* than expected from dBA-reduction

Projekt C/O City: piloter och modellstudier

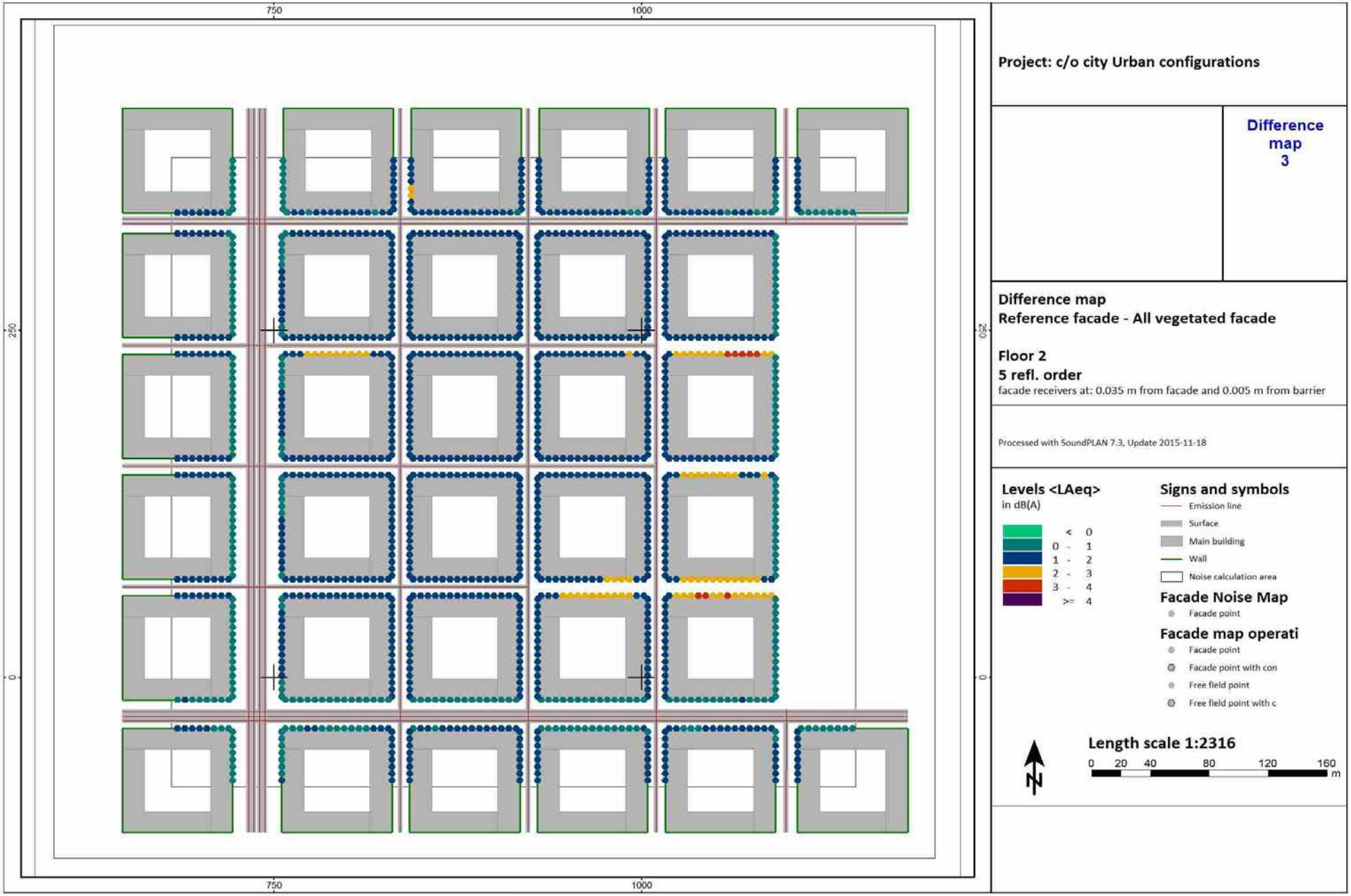
C/O City Project: model study with vegetated facades



Geometry and traffic flows



Results


750
1000
250
0
Project: c/o city Urban configurations
Difference map 3
Difference map
Reference facade - All vegetated facade
Floor 2
5 refl. order
facade receivers at: 0.035 m from facade and 0.005 m from barrier
Processed with SoundPLAN 7.3, Update 2015-11-18
Levels <LAeq>
in dB(A)
< 0
0 - 1
1 - 2
2 - 3
3 - 4
>= 4
Signs and symbols
Emission line
Surface
Main building
Wall
Noise calculation area
Facade Noise Map
Facade point
Facade map operati
Facade point
Facade point with con
Free field point
Free field point with c
N
Length scale 1:2316
0 20 40 80 120 160
m
C:\Users\STAFF\Documents\Soundplan_all\Laura soundplan projects\c_o_city\urban configurations\3_diff_ref_allveg_F2.sgs

Urbana akustikskärmar
Urban Acoustic Screens

VINNOVA-finansierat projekt, 2014-2017

Partners

Chalmers

Stockholms universitet

Stockholms stad, Miljöförvaltningen

Stockholms stad, Trafikkontoret

Konstfack + Mikael Pauli

Stockholm konst

Tyréns AB

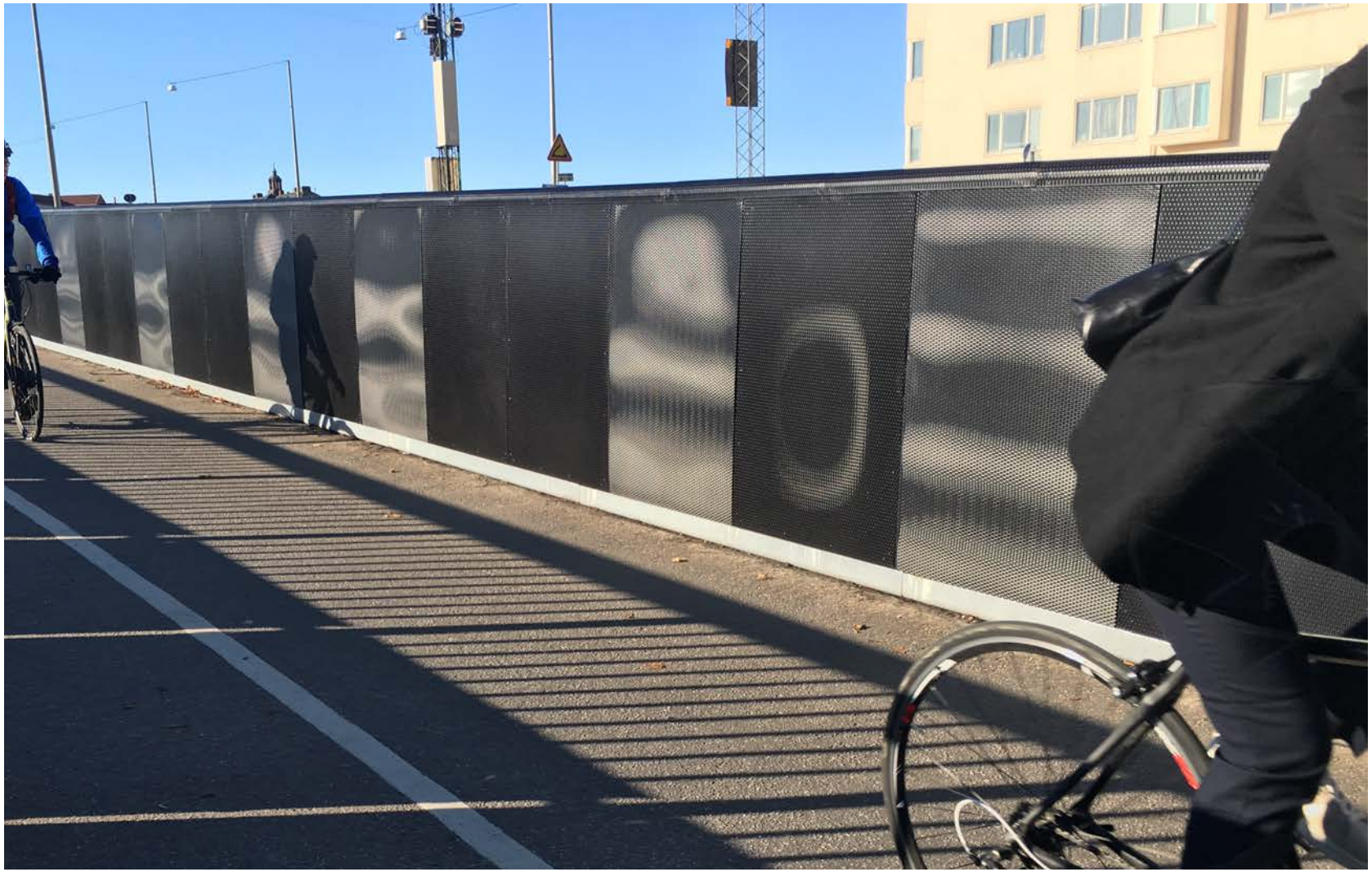
Z-bloc Norden AB

CSTB, Frankrike (underkontrakterade)

Kontakt: Jens Forssén, Teknisk akustik, Chalmers
jens.forssen@chalmers.se

Inspirationsbilder...

Foto av uppförd skärm på Liljeholmsbron 2017



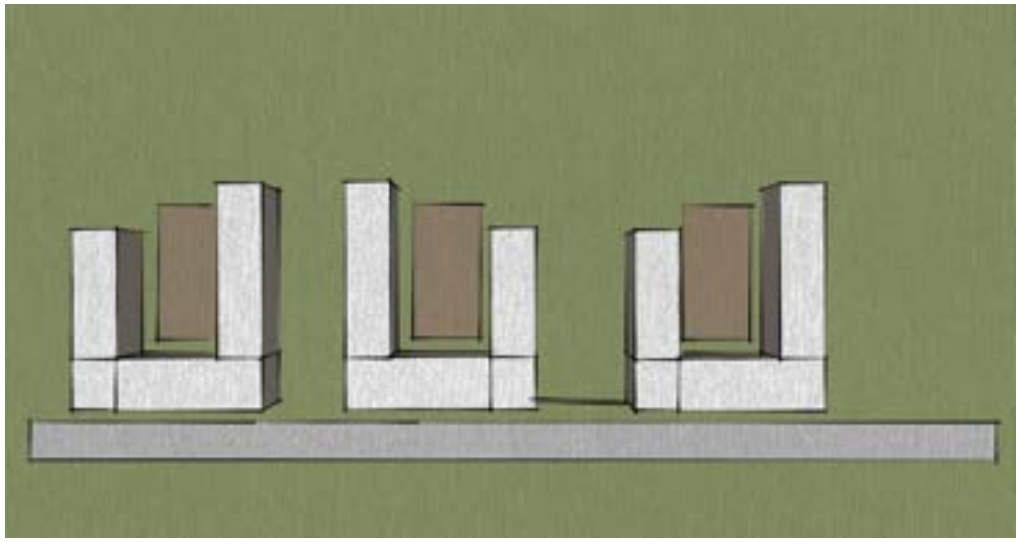
Året efter


ÅHLÉNS

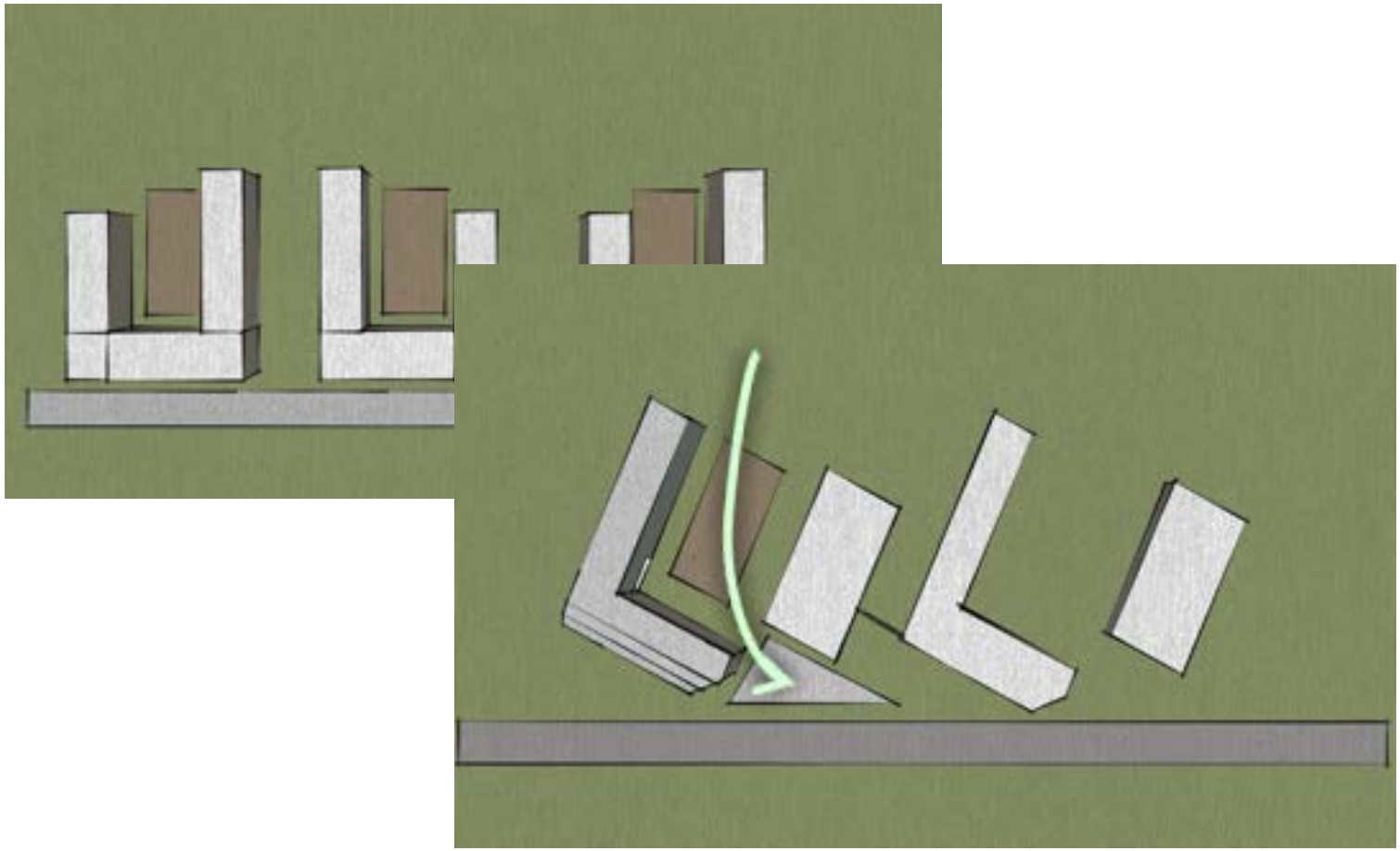
Pågående projekt

- DemoVirPEN – en demonstrator av ett planeringsverktyg med ljud
- God ljudmiljö i stationssamhällen
- Kombination av buller och luft
  MaGNA – Morphology and Greening for Noise and Air quality. Formas

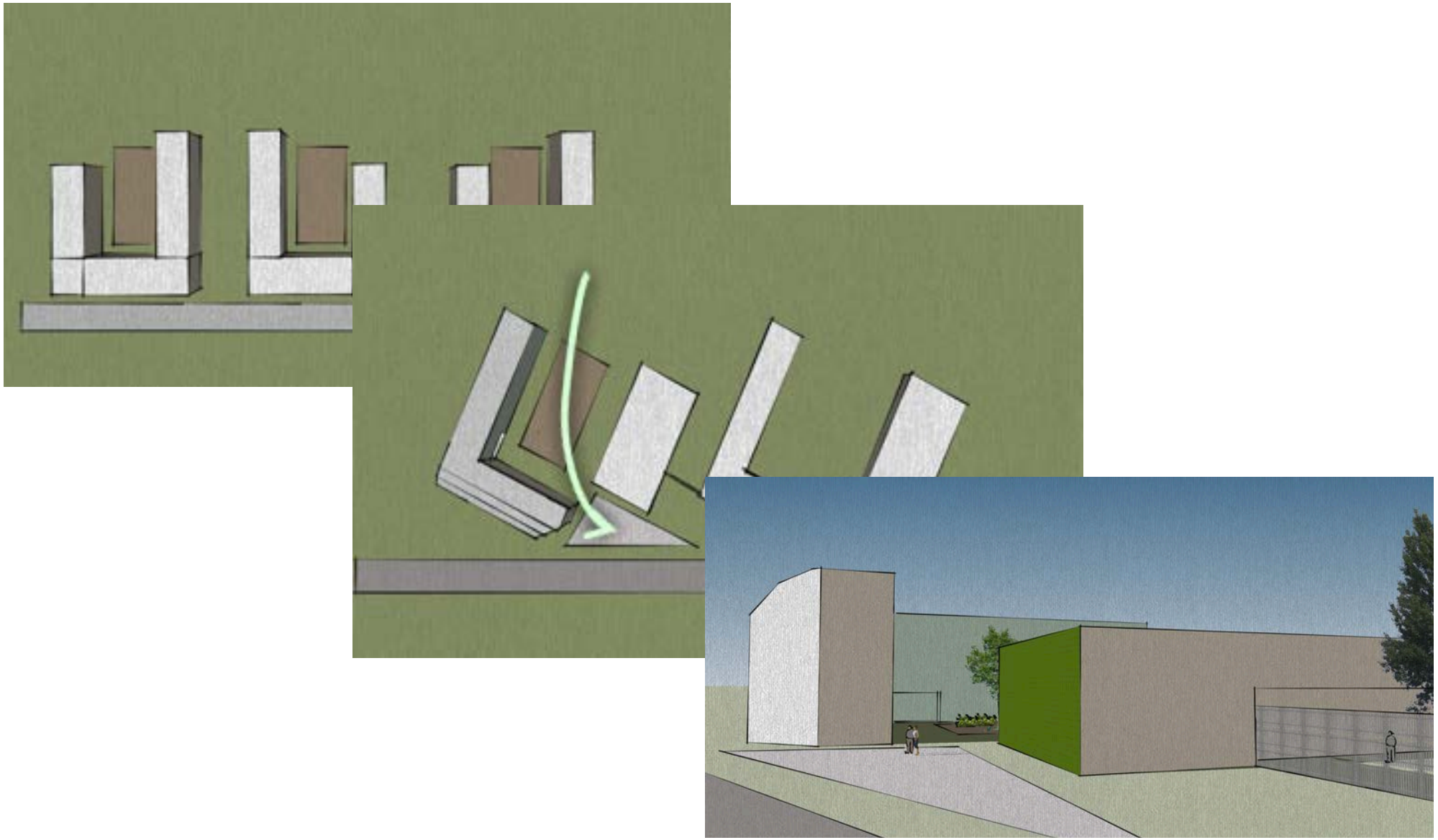
MaGNA



MaGNA



MaGNA



CHALMERS
UNIVERSITY OF TECHNOLOGY

Sammanfattning

- Var med tidigt i processen
- Beakta alla verktyg

Jens Forssén, Avd. Teknisk akustik
jens.forssen@chalmers.se