CHALMERS
UNIVERSITY OF TECHNOLOGY

Urban morfologi och grönytor för att förbättra ljudmiljön

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

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Urban morfologi och grönytor för att förbättra ljudmiljön

- Bakgrund om buller
- Resultat från tidigare projekt HOSANNA, www.greener-cities.eu
- Pågående och framtida arbete

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Bakgrund om buller

...environmental noise leads to a disease burden that is second in magnitude only to that from air pollution, among environmental factors in Europe

HOSANNA – About

- 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

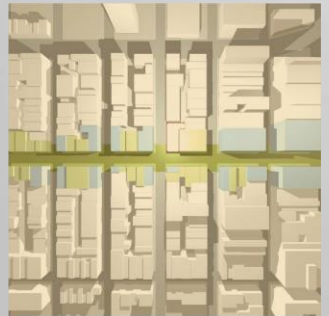
HOSANNA – Partners

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

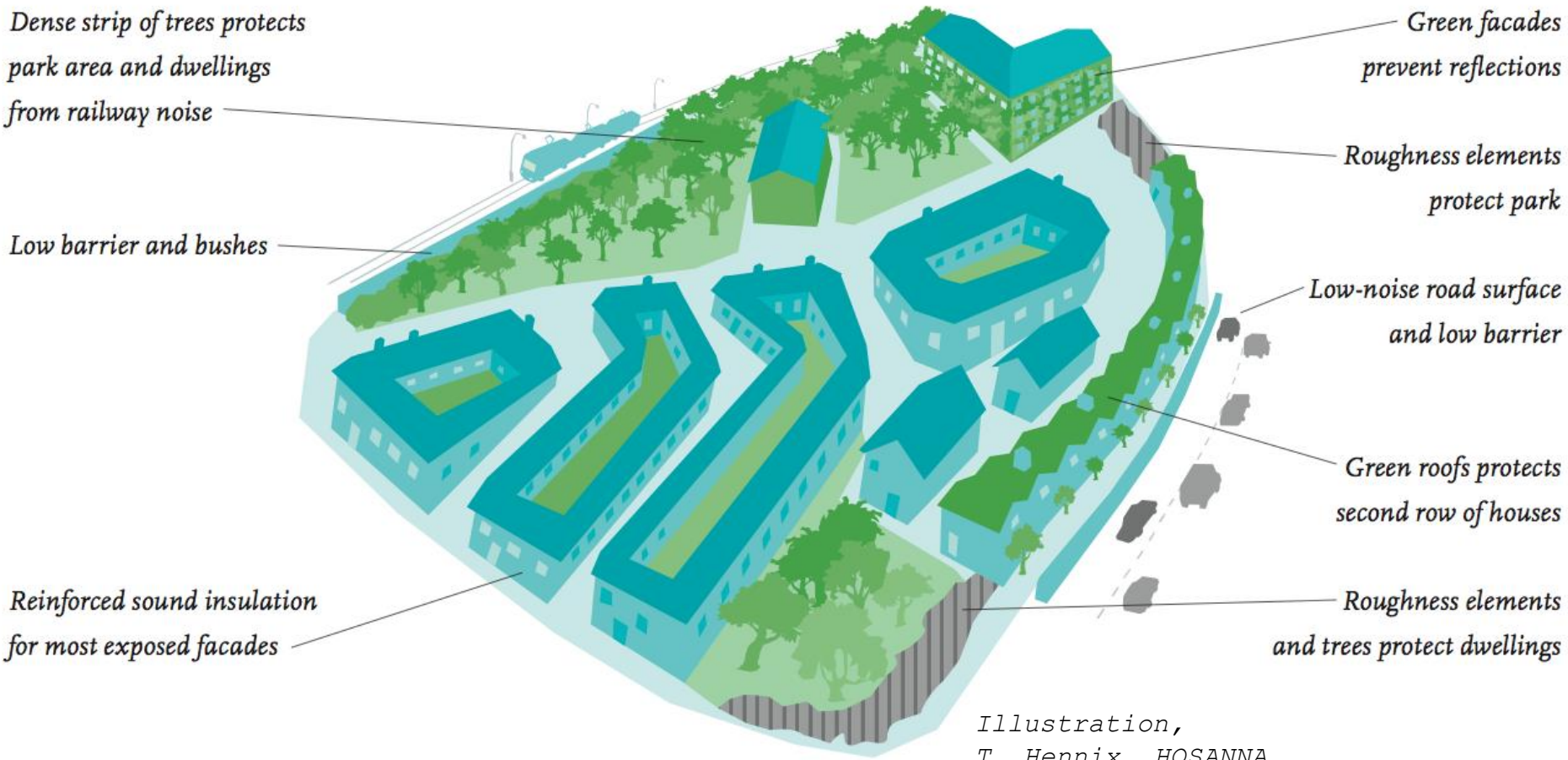
The main idea of our project is to optimize the use of green areas, green surfaces and other natural elements in combination with artificial elements in urban and rural environments for reducing the noise impact of road and rail traffic.



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

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

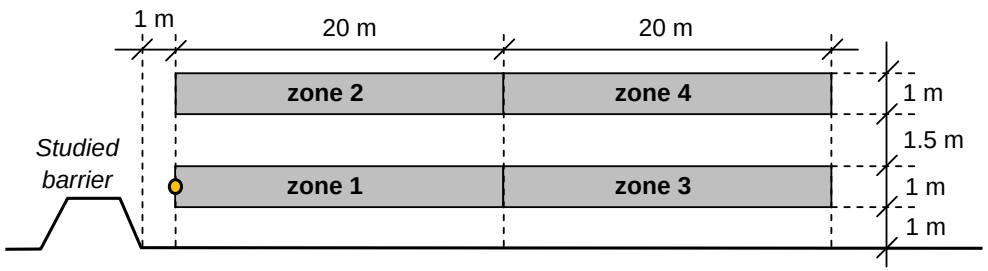
- Two-lane urban road
- 3.5 m between lanes
- Harmonoise/Imagine source model with source heights 0.01, 0.3 and 0.75 m
- 95% light vehicles and 5% heavy
- Speed 50 km/h
- Flow 27 500 vehicles per day (1146 vehicles per hour)
- Receiver height 1.5 m

Innovative barriers (CSTB)

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*



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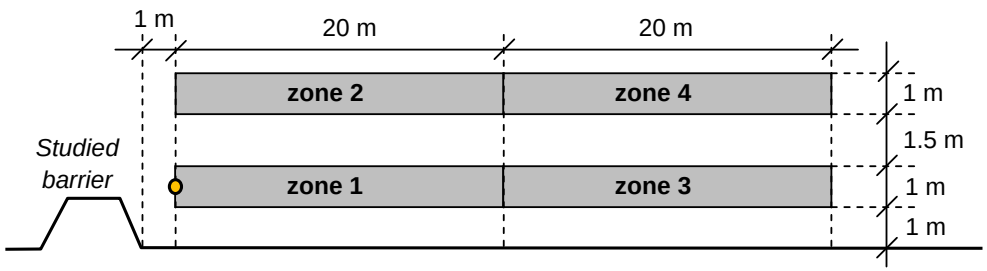
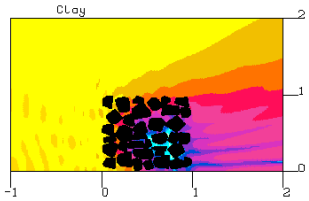


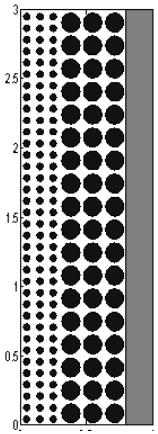
- **Many applications:**

Gabions

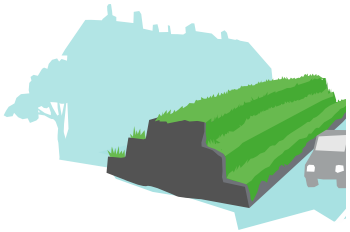


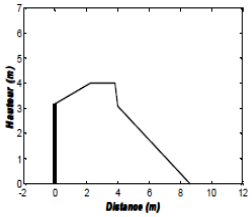
Low-height vegetated barriers

Sonic crystal assisted barriers

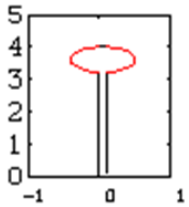


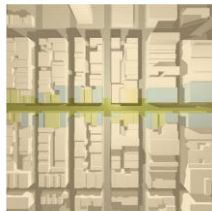
Complex shaped berms





Vegetated caps

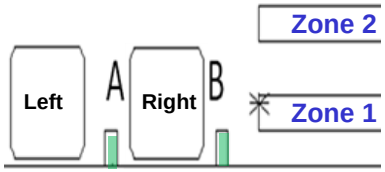




Low-height noise barriers

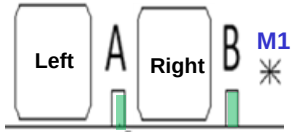
- **Inter-track low barriers (tram case)**

  Barrier= Vegetation substrate with inner rigid core



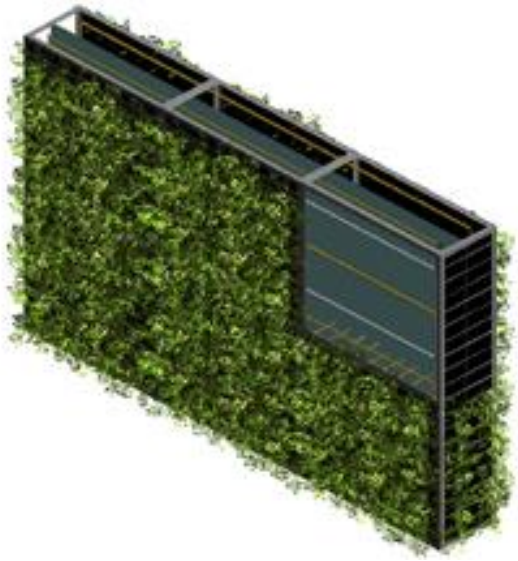
No building

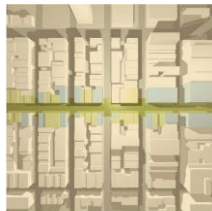
Config.	Pedest.	Zone 1	Zone 2
Left B	**2.7**	**10.3**	**3.5**
Right B	**17.1**	**20.4**	**17.8**
L+R B	**7.9**	**13.4**	**6.6**
L+R A&B	**16.7**	**20.4**	**15.7**



Street canyon

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

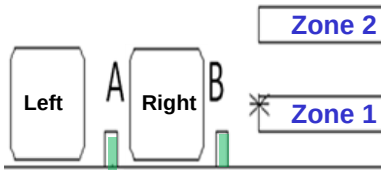




Low-height noise barriers

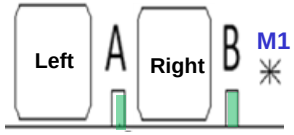
- **Inter-track low barriers (tram case)**

  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

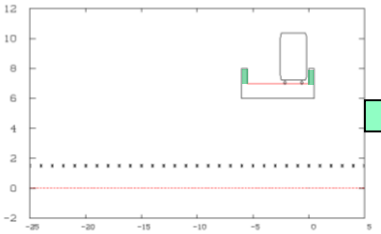


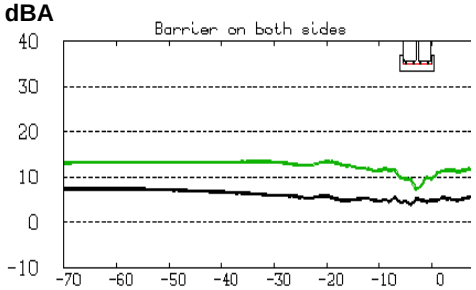
Street canyon

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

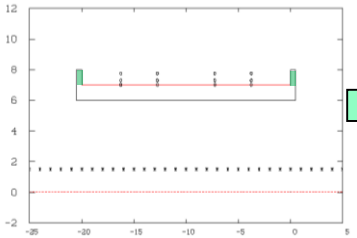
- **Lightweight vegetated barriers at bridges**

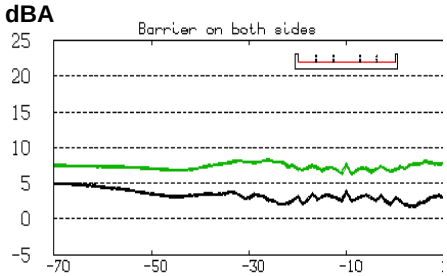
Tramway





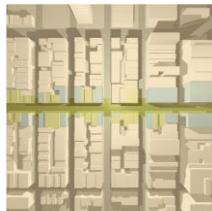
4-lane road



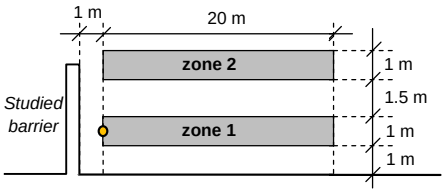


— ***absorbing barrier***

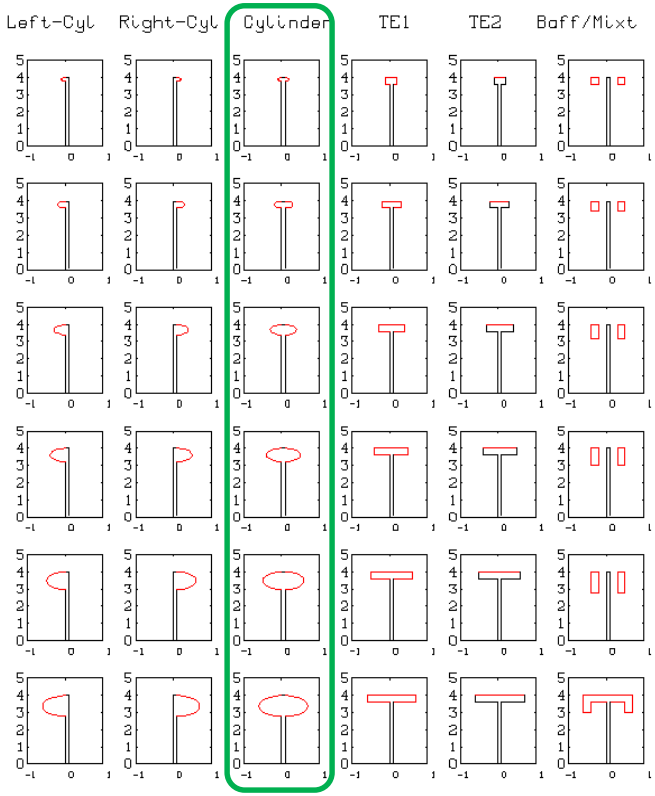
— ***rigid barrier***



Vegetated caps



Studied shapes (motorway)



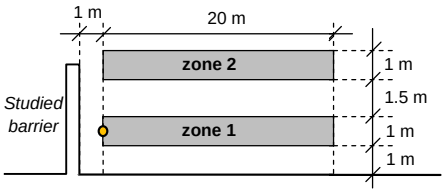
Red: vegetation substrate with inner rigid core

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



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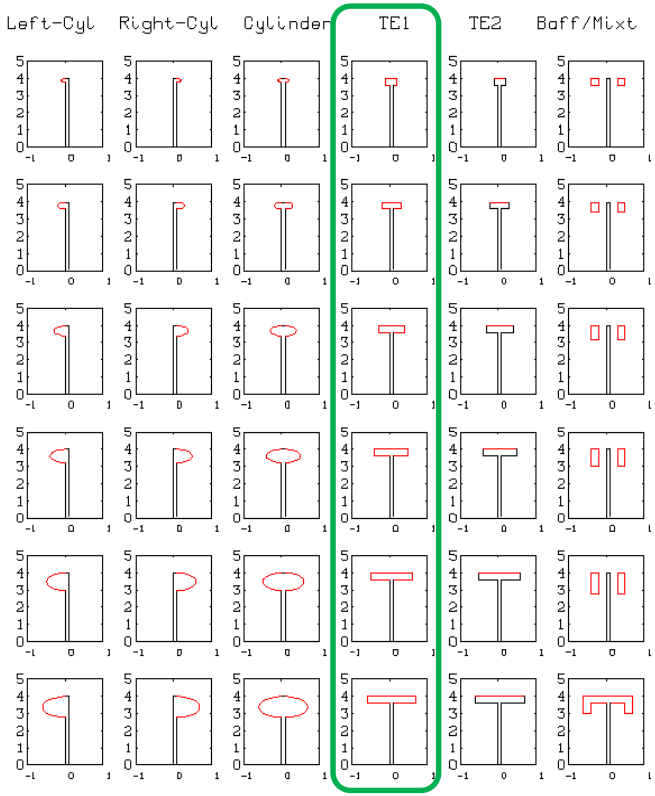


Red: vegetation substrate with inner rigid core

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**

Recycled materials
(University of Bradford)

Combining green and recycled products

(i) Sound absorbing

mixed soil and granulated waste

(ii) Sound absorbing and soil retention

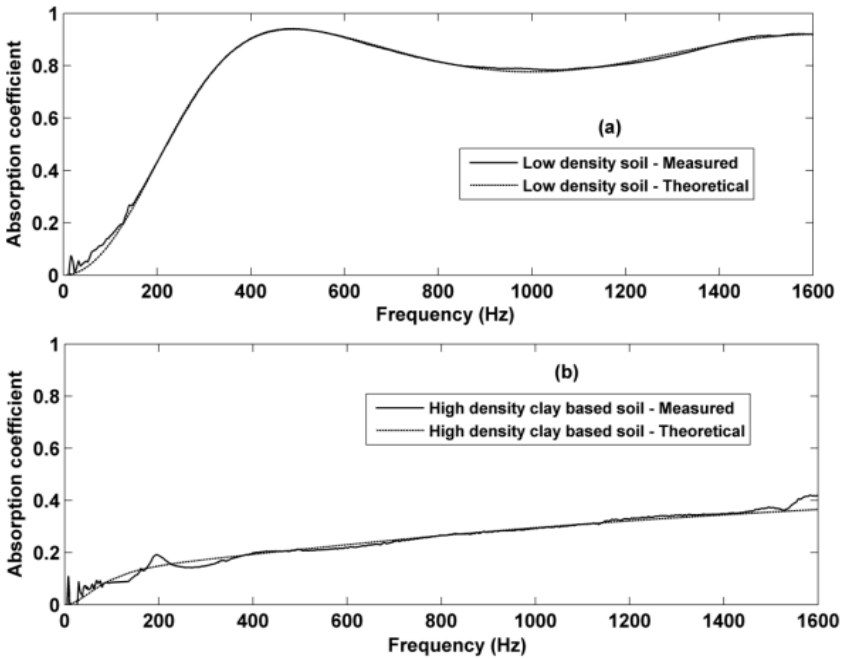
soil with a front layer of lightly consolidated waste

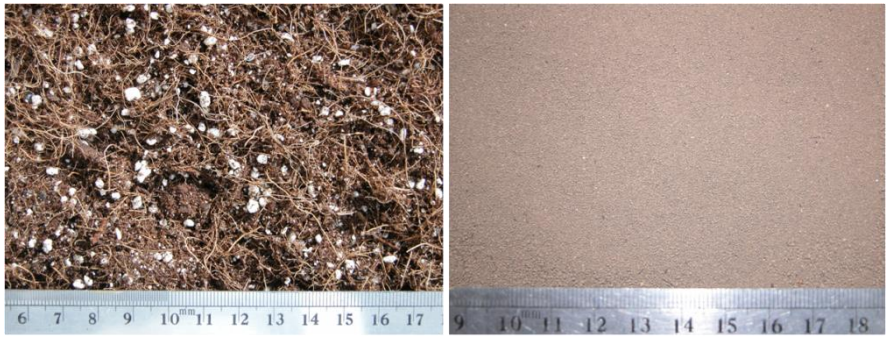
(iii) Sound absorption and transmission

soil with a back layer of densely consolidated waste

Acoustic absorption and transmission loss applications

Low maintenance high performance low density soil – acoustic models





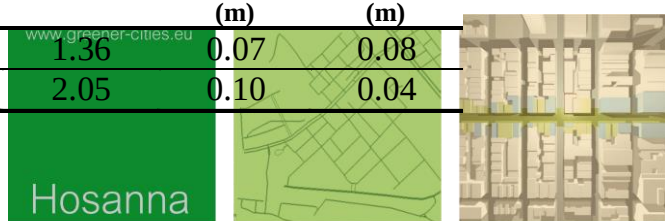
(a) Low density soil

(b) Normal garden soil – Clay based

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

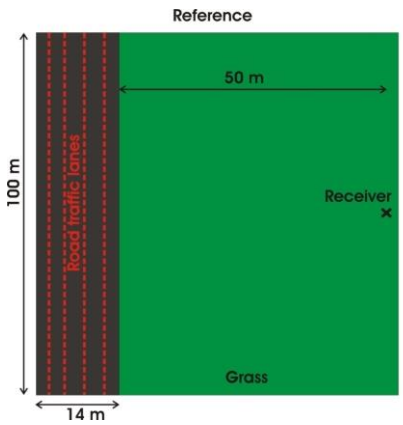
Summary of soil properties

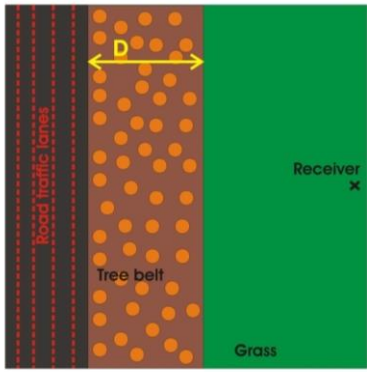
Soil type	Flow resistivity (exp.) (Pa.s/m^2)	Flow resistivity (theor.) (Pa.s/m^2)	Porosity (exp.)	Porosity (theo.)	Tortuosity (exp.)	Tortuosity (theo.)	Thickness (exp.) (m)	Thickness (theo.) (m)
Substratum	7,600	7,218	0.76	0.76	-	1.36	0.07	0.08
Clay based	566,350	620,650	0.39	0.39	-	2.05	0.10	0.04

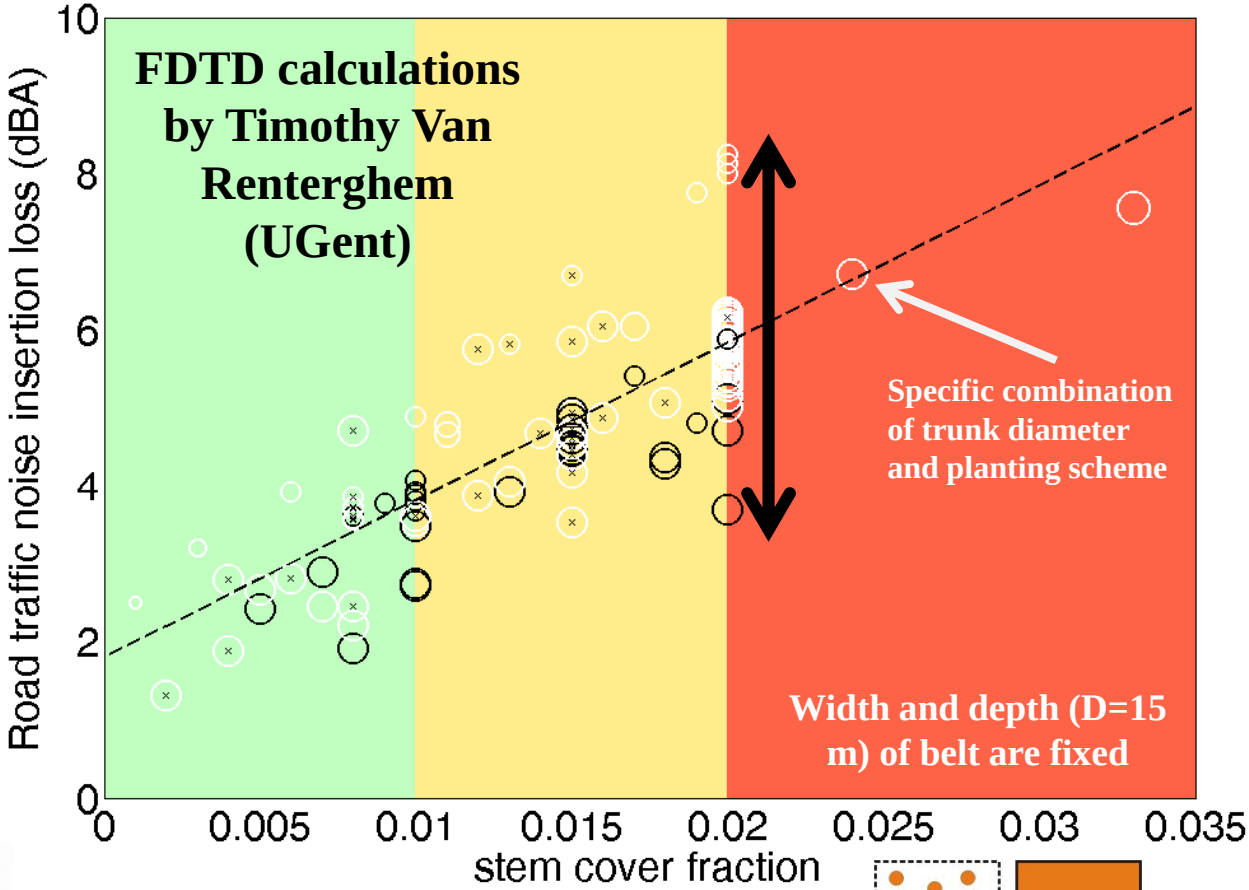


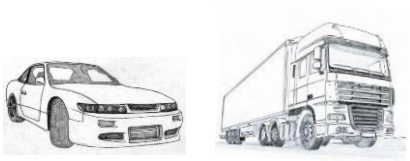
Trees (iMinds/UGent)

Tree belts along roads: planting schemes matter



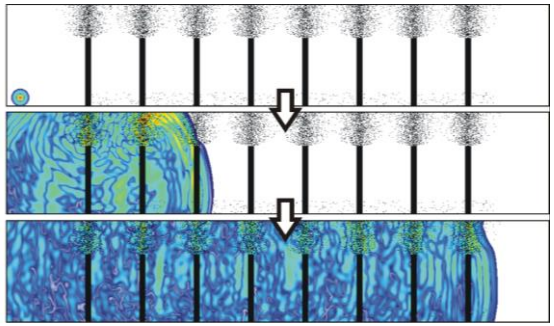


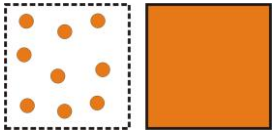




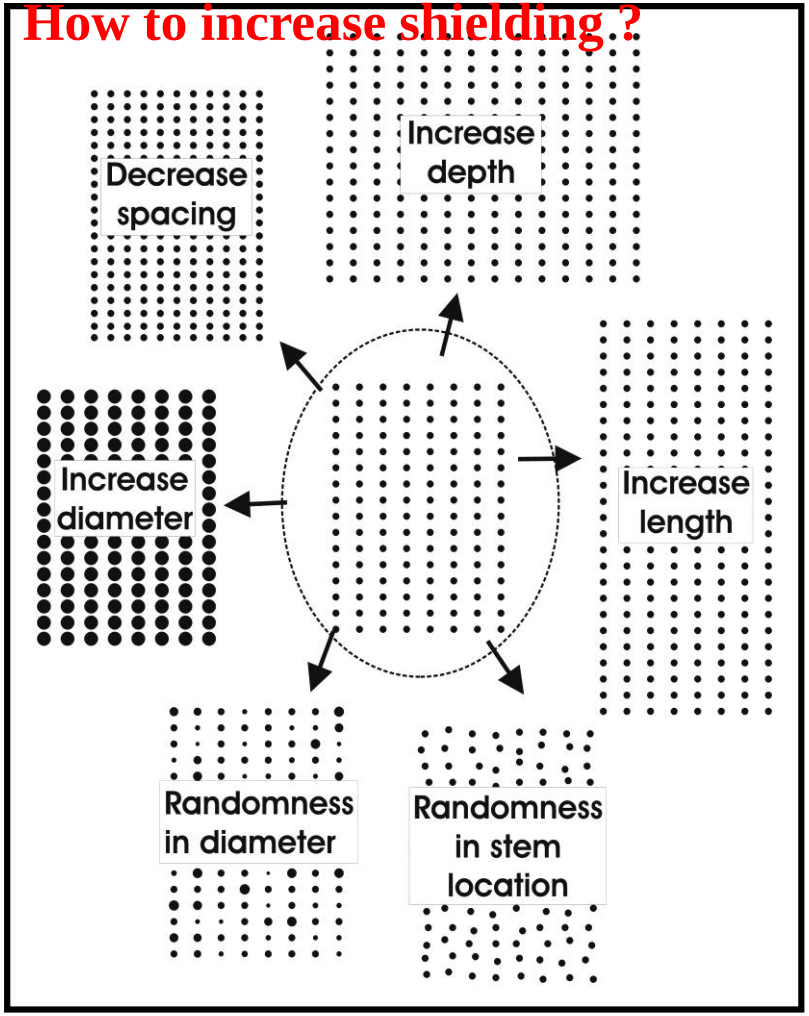
85 % 15 %

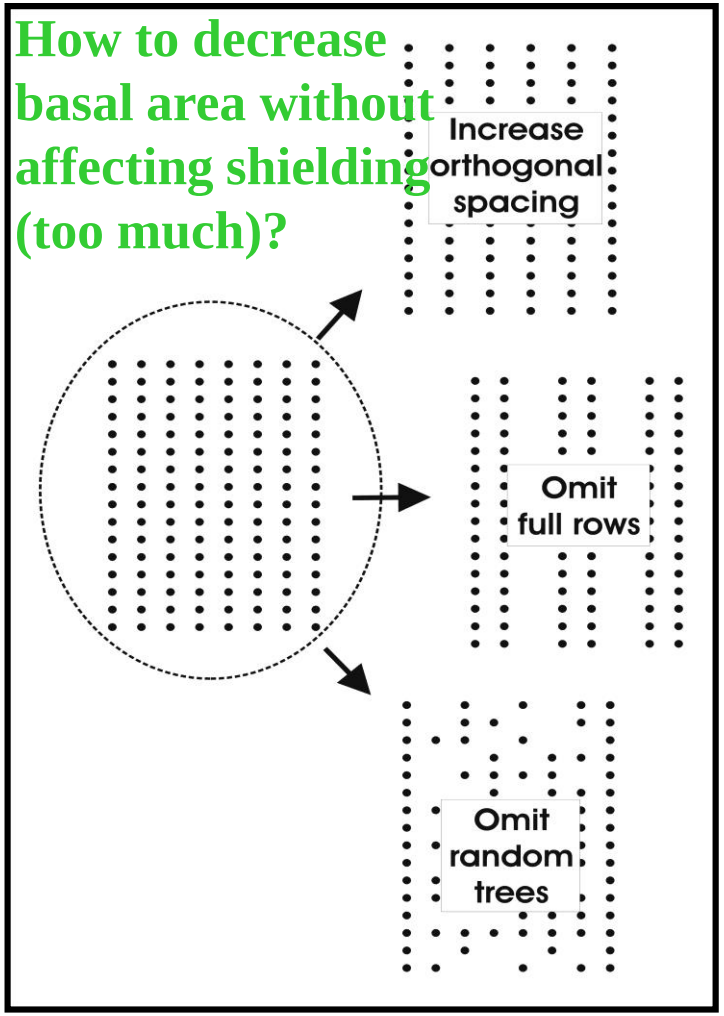
70 km/h

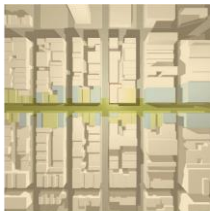




Tree belts along roads: guidelines



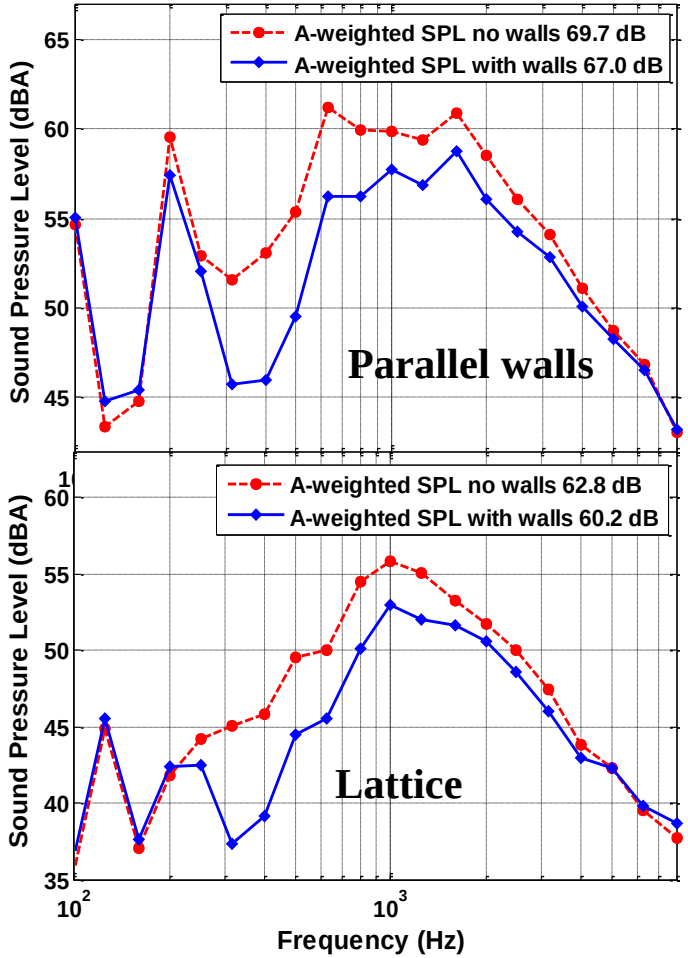




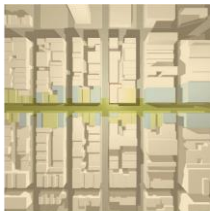
Ground treatments (OPU, CSTB)

Roughness-based treatments-Drive by test

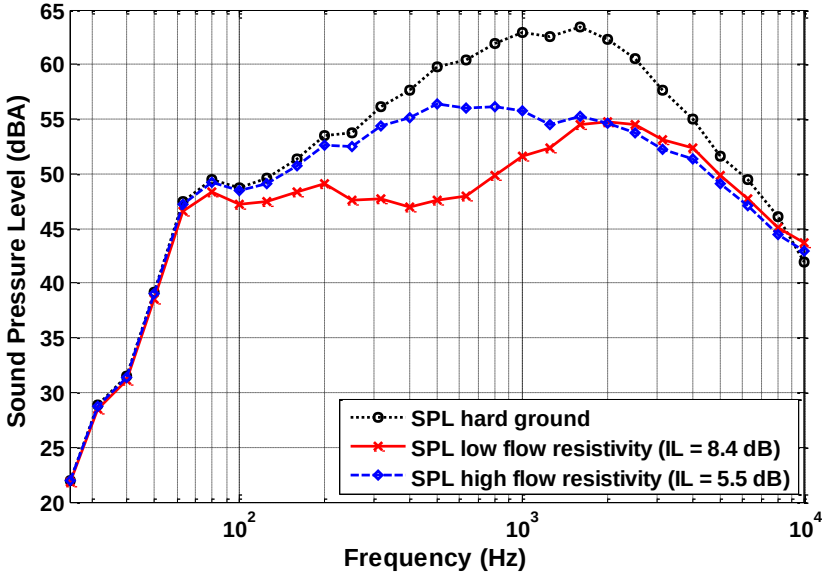
- Parallel walls: 2.3 m wide and 0.2 m high
- Insertion loss **2.7 dB** at 35.4 km/h



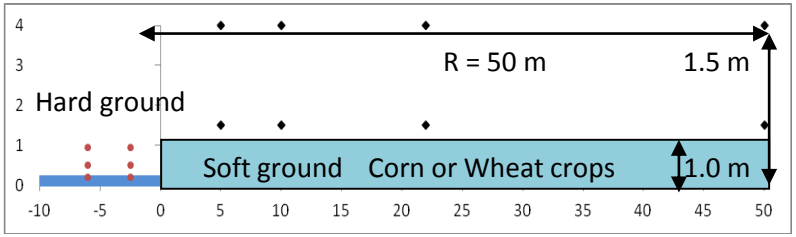
- Lattice: 1.18 m wide and 0.2 m high
- Insertion loss **2.6 dB** at 38 km/h



Soft ground and vegetation



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



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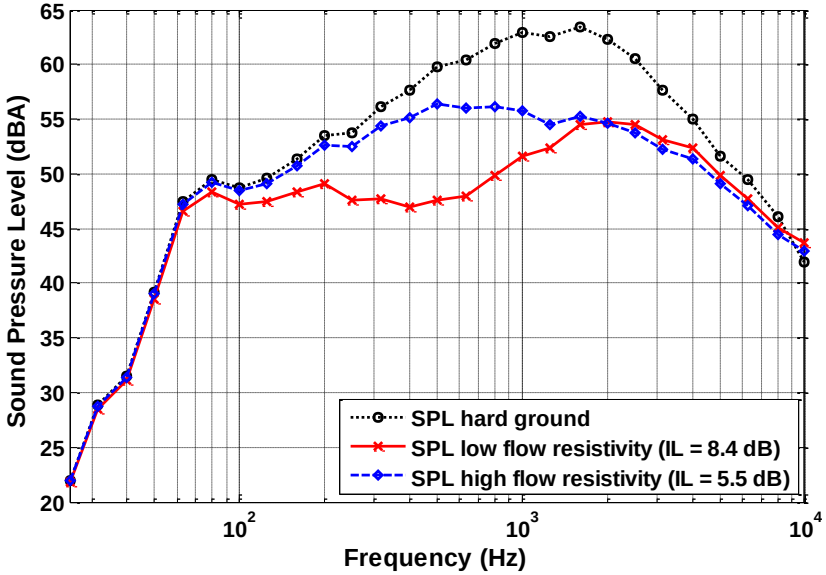

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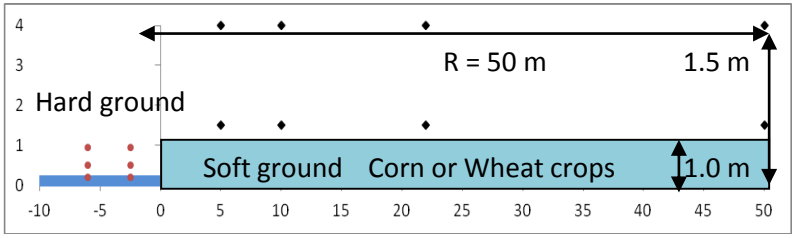
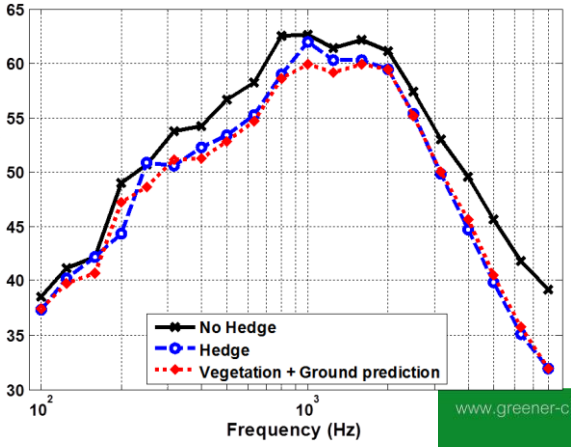


Hedges – Drive by Test



Hedge attenuation
1–2 dB

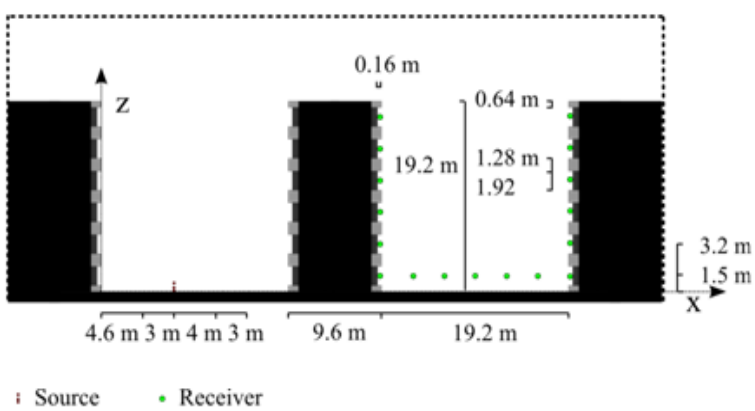
(of which half is due to soft ground)

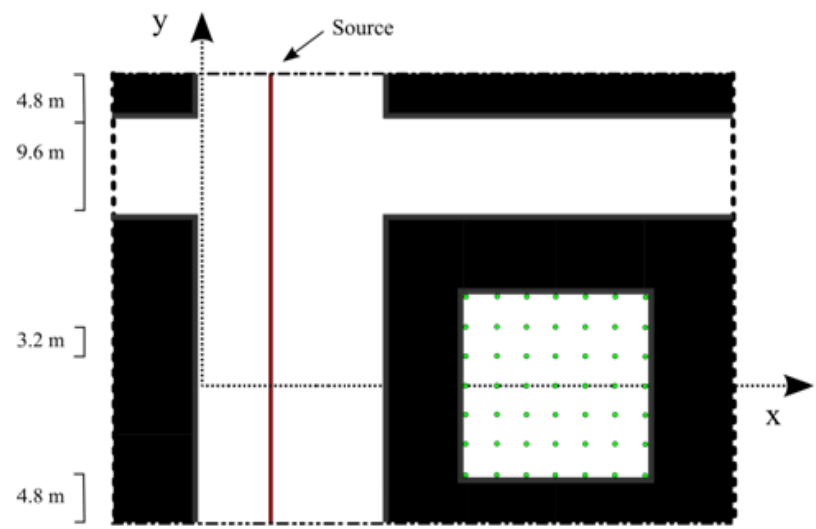
Greening buildings

(USFD, iMinds/UGent, Chalmers)

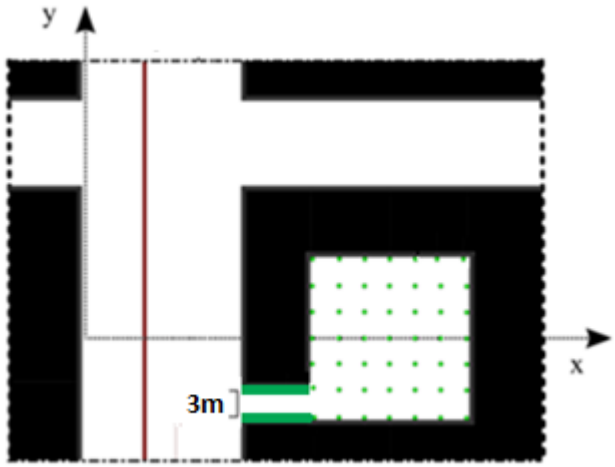
Vegetated façades of courtyard next to street canyon

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

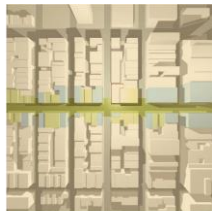




Vegetated entrance to the courtyard



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

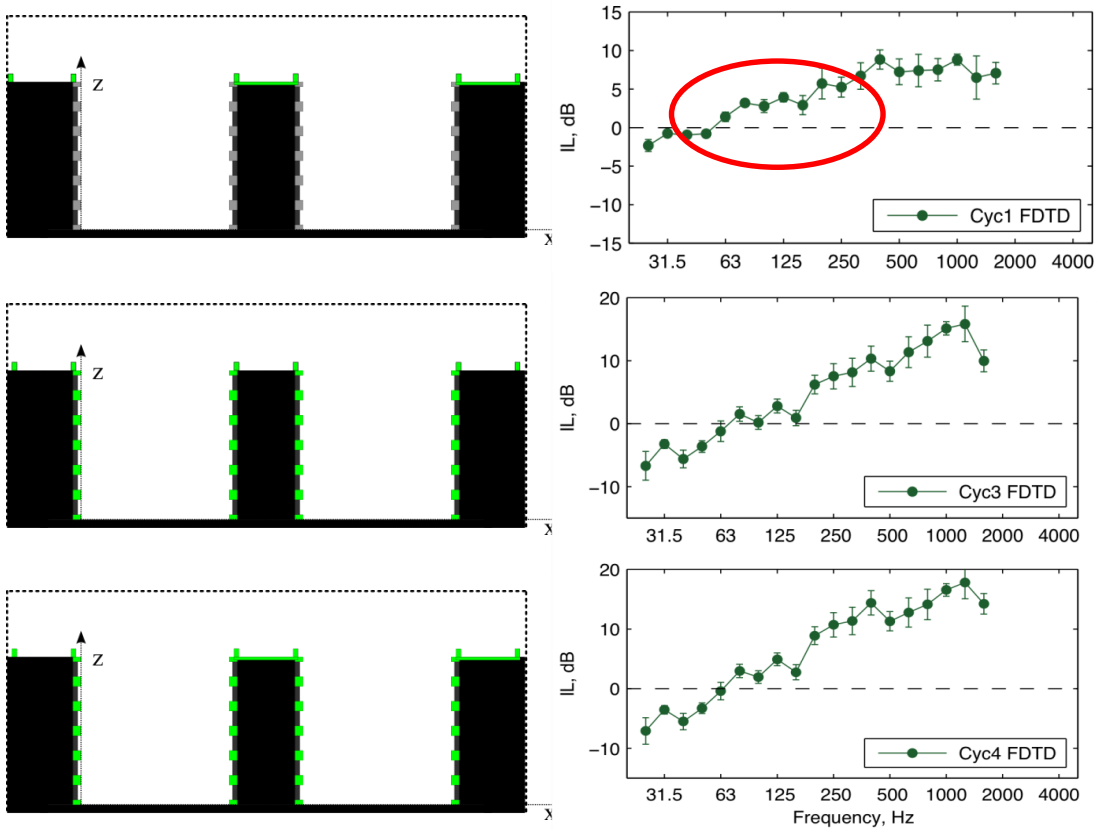


Vegetated roofs

Noise reduction:

3–7 dBA depending on geometry

Vegetated façades, roofs and roof barriers



Noise reduction:

4.4 dBA

3.3 dBA

4.6 dBA

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1:10 urban scale model (Hanyang University)

References

Rigid façade street

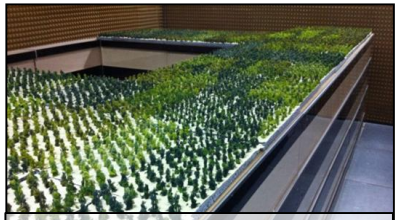
Rigid façade Courtyard

Noise abatements

Vegetated facades (530 m²/1,200 m²)

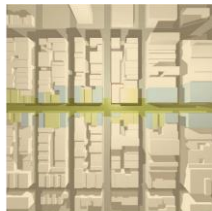
Shrubs (30 m²/600 m²)

Trees (H 7.7m, W 6.9 m) at 9.6 m intervals



Green roofs (Approx. 1,000 m²)

	Noise abatements	Insertion loss [dBA]	
		Street	Courtyard
Single	Vegetated façades	1.6	2.2
	Shrubs	0.4	0.2
	Trees	-0.5	0.4
	Green roofs	-	1.7
Combined	Vegetated façades + Shrubs	1.6	2.5
	Vegetated façades + Trees	0.4	2.4
	Vegetated façades + Shrubs + Trees	0.8	2.6
	Vegetated façades + Shrubs + Trees + Green roofs	0.8	3.4



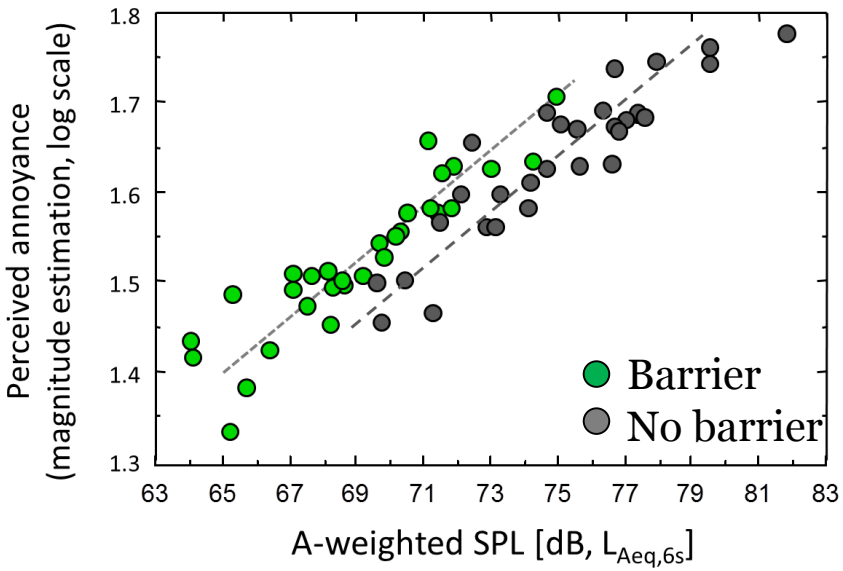
Perceptual effects of noise mitigation

Perceptual effects studied in the HOSANNA project

1. **Noise perception (annoyance, etc.)**
2. **Perception of other sounds (masking, attention)**
3. **Perception of overall environment (audio-visual effects)**

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

Road traffic noise (Lyon)



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

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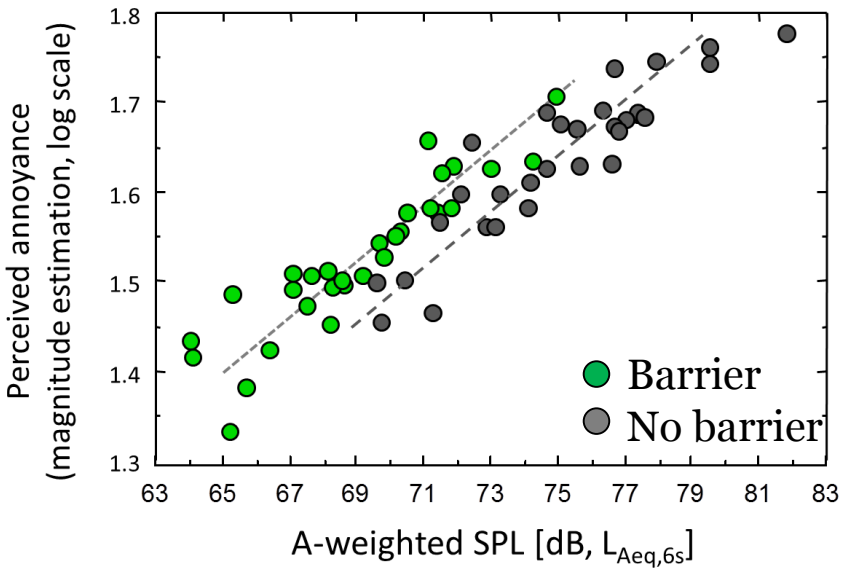
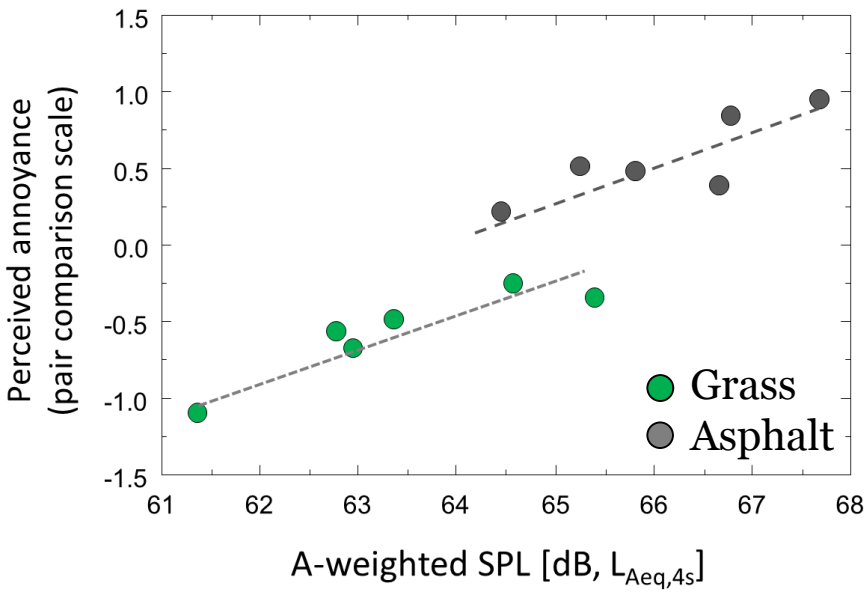


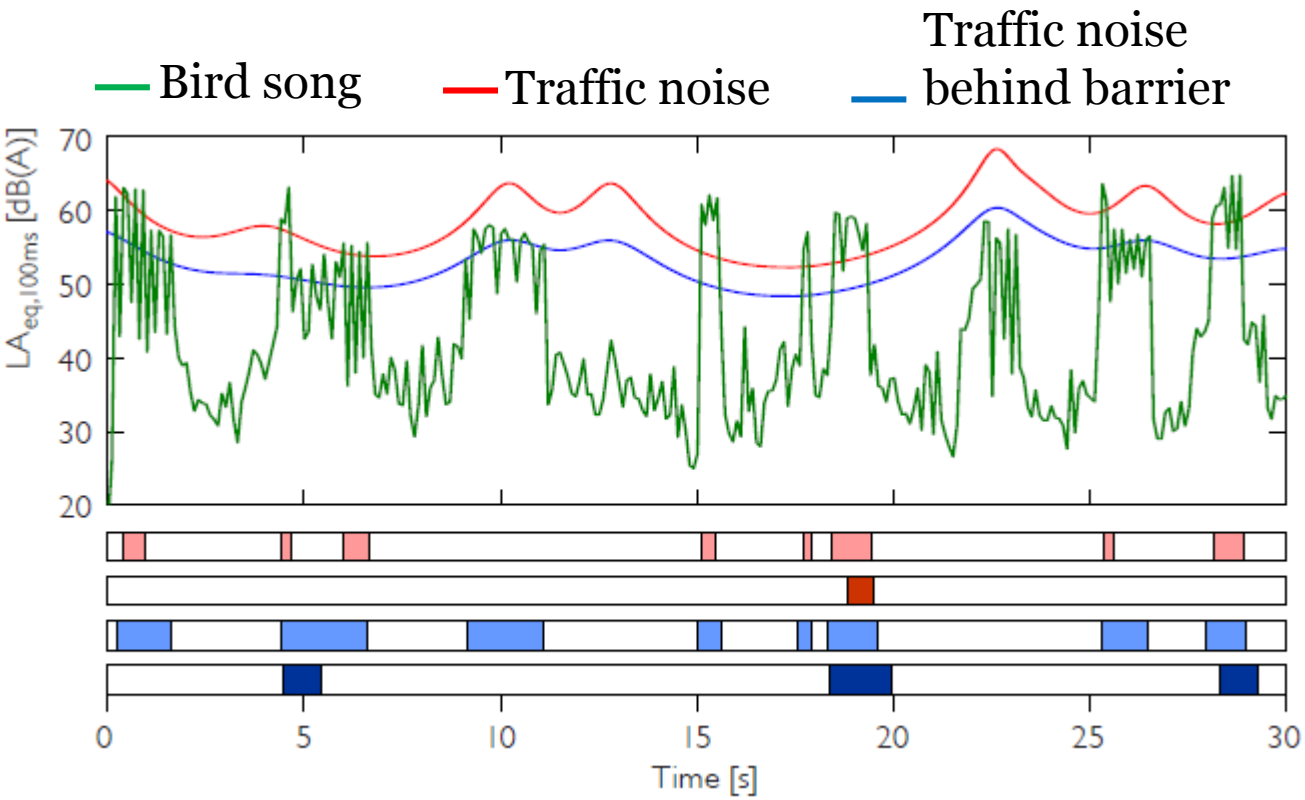
Annoyance reduction:
1-2 dB *less* than expected from dBA-reduction

Tram noise (Grenoble)



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

2. Modelling of notice events (iMinds/UGent)



Notice-Event Model
Model devopled that predicts the time of noticed pleasant sounds in the soundscape

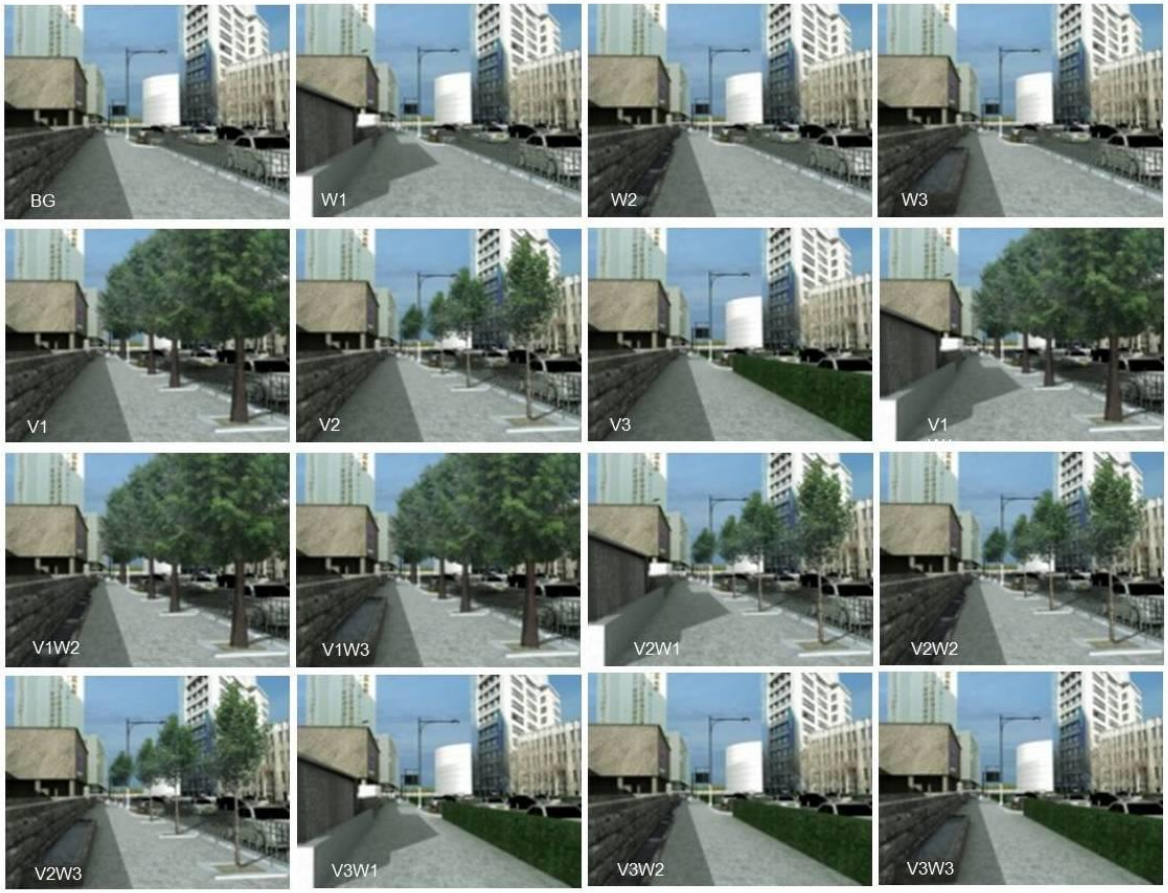
Bird song inaudible (masked)

Bird song noticed

Bird song audible

3. Audio-visual effects (Hanyang University)

Visual stimuli ('streetscapes') combined with noise and pleasant sounds



Results:

- Urban streets planted with greenery perceived as more pleasant and quieter than streets with no greenery.
- Vegetation planted on barriers make the sidewalk more visually attractive.

Economic analyses

(TOI, The Institute of Transport Economics, Norway)

Cost-Benefit Analyses (CBA)

- Developed web-based tool for rapid CBA. Calculations are transparent/easy to check
- Discounted benefits over several decades are accumulated
- Allows us to assess whether benefits outweigh the cost of measures (context dependent)
- Monte-Carlo module allows sensitivity analyses and visualises spread in economic performance.

Example: Simple extensive green roof

Component	Q*M*C*B	Annuity	Cost	Benefits	ΣΣCosts	ΣΣBenefits	B/C Ratio
Simple vegetated flat roof concave corner sloped							
SVFRCV1S Simple vegetated flat roof concave corner							
Investment SVFRCCS	688	2.57	1,767.72				
Maintenance SVFRCCS	688	0.78	536.23				
CO2 removal grass	688	0.04		27.14			
PM10 removal	688	0.73		502.15			
NO2 removal grass	688	0.36		250.72			
Noise_SVFRCV1S	34.5	119.59		4,125.74	2,303.94	4,905.76	213%

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Above: Winter and Spring views of a living wall installation benefiting from a careful selection of plant varieties. Source: Randy Sharp

The following montage of photos shows a variety of green walls in different seasons, illustrating a wide range of color and texture.

Green facades are visually pleasing.

However, aesthetic benefits are excluded from CBA and assigned zero value.

In economic analyses all benefits should be counted (if possible) also air-quality, CO_2, aesthetics etc.

In HOSANNA economic valuations of trees and green facades were synthesized to provide unit values.

The inclusion of non-acoustic effects can improve the economic performance of green acoustic measures.

When do the new measures perform well economically?

- When they do not cost much – brick lattices, low barriers, tree belts
- When lifetime, time between replacement, is longer + not too expensive to maintain
- When relatively many benefit from the measures
- When measures have good acoustic performance
- When non-acoustic benefits «subsidize» the cost of the acoustic measures

Conclusion

- We suggest: Tools to reduce noise from surface transport with main focus on vegetation

- Results include
  - Noise insertion losses (spectra and dBA)
  - Perceived improvements
  - Economic analyses

Pågående och framtida arbete

- Projekt C/O City: piloter och modellstudier

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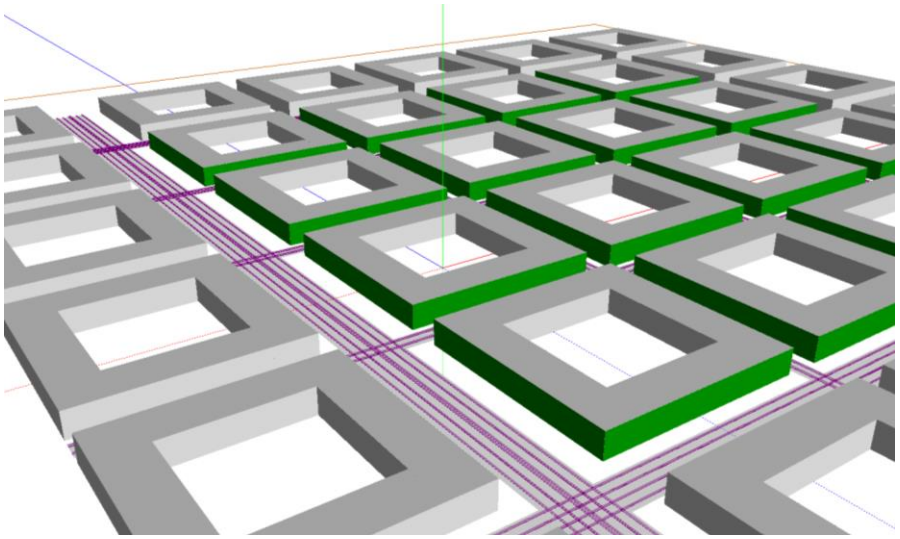
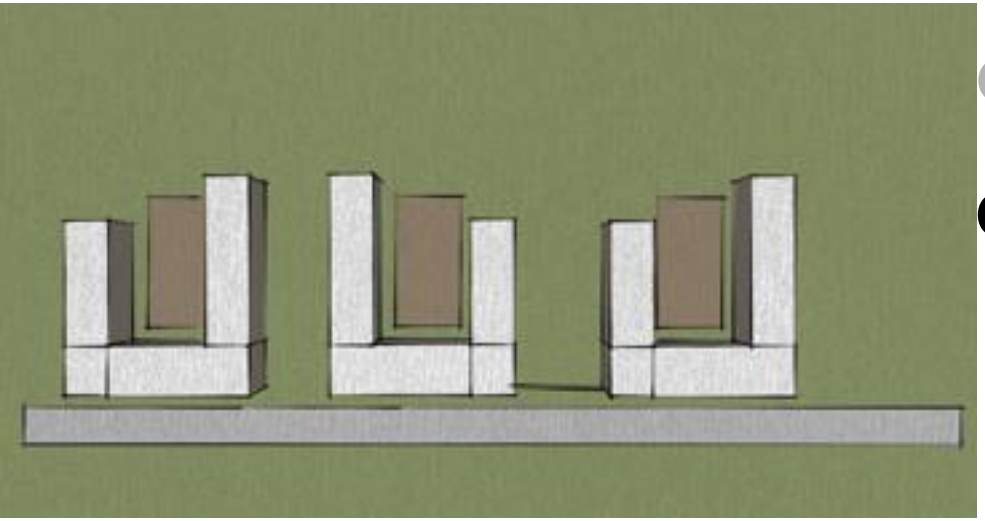


Pågående och framtida arbete

- Projekt C/O City: piloter och modellstudier
- Kombination av buller och luft (och andra ekosystemtjänster)

Pågående och framtida arbete



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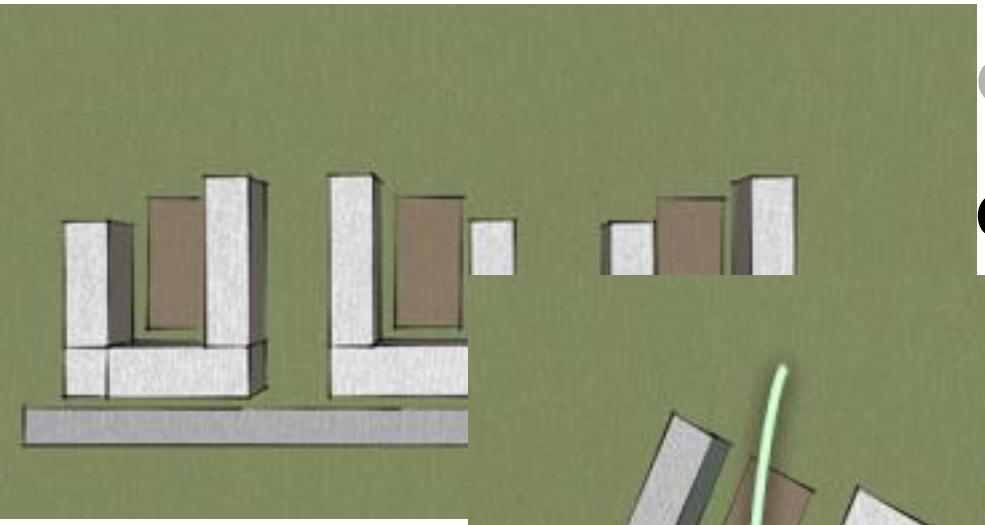

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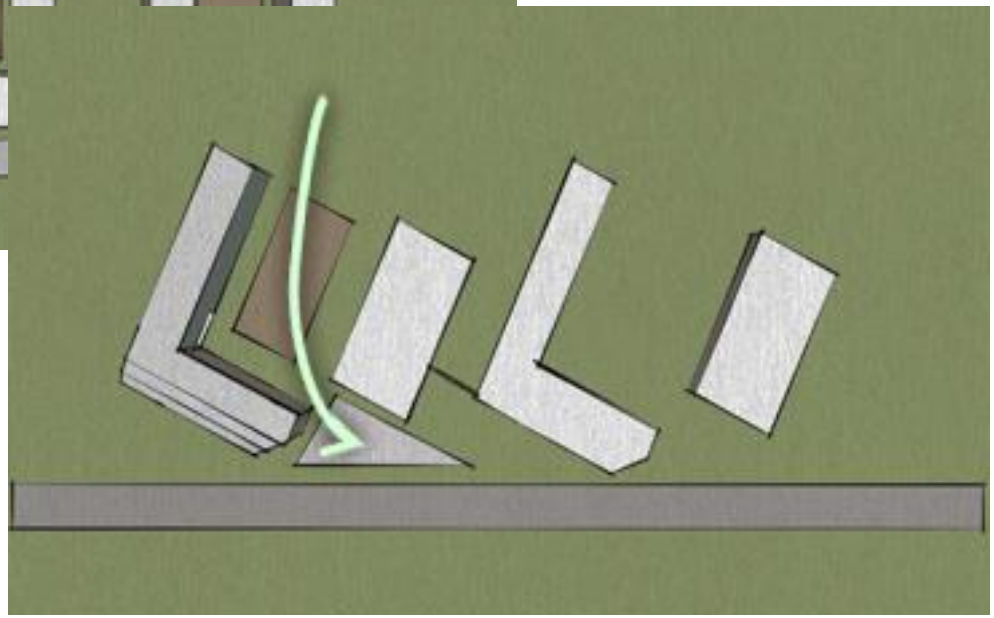

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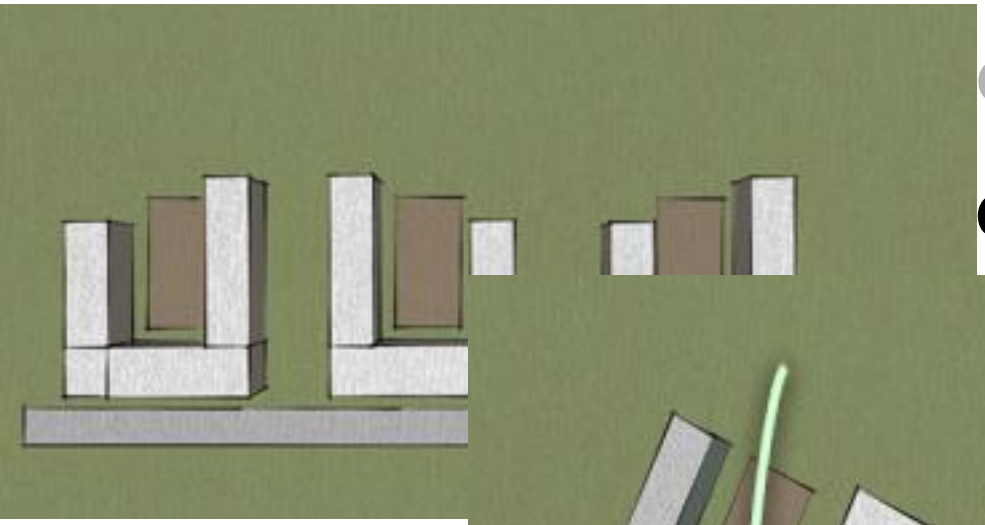

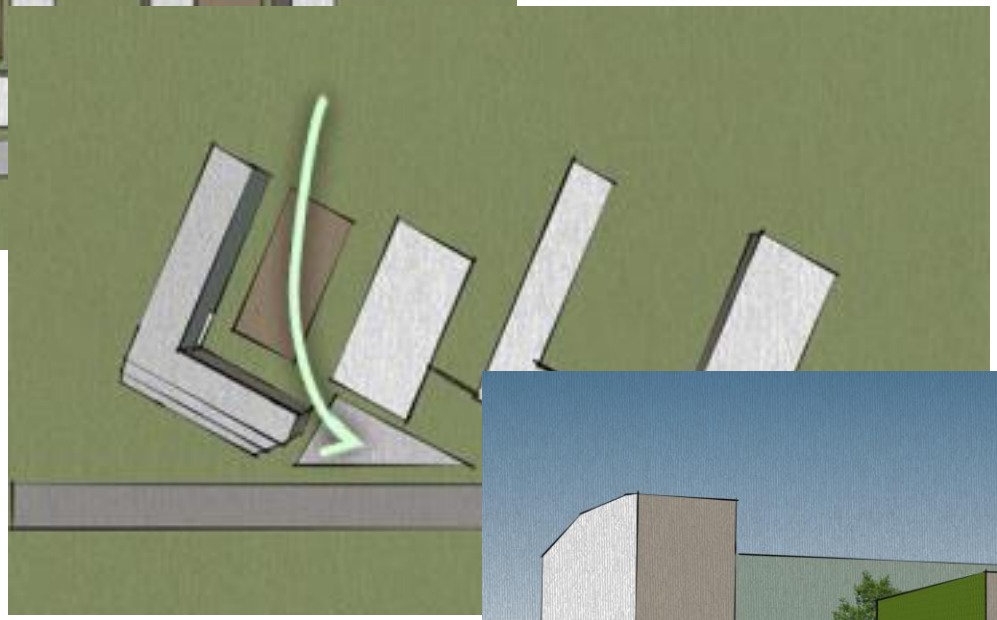

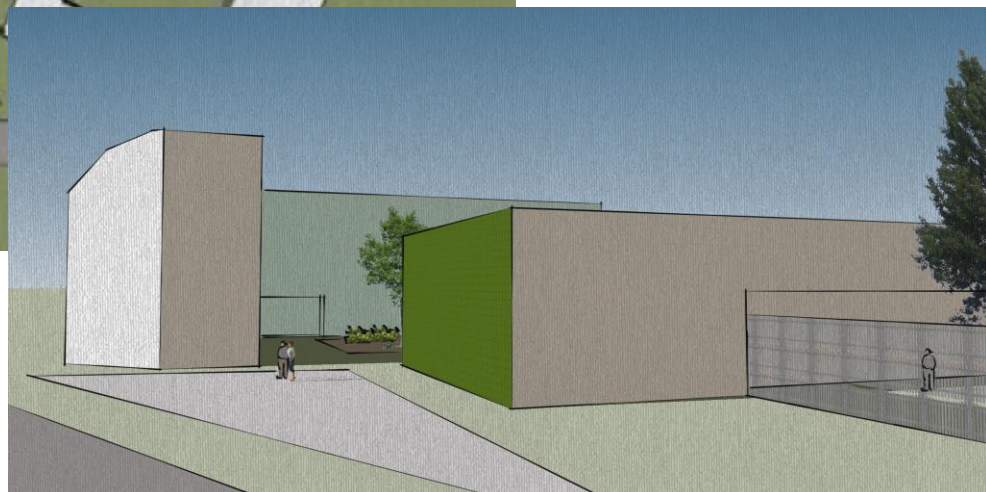

Tack!