Technical University of Delft
Faculty of Architecture and the Built Environment
Geomatics for the Built Environment

Master thesis

Testing and extension of a GIS-supported design tool for new urban development areas - Case study: Sloterdijk I, Amsterdam

22 June 2021

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Roberto Cavallo

Student: Doan Truc Quynh - 5025923

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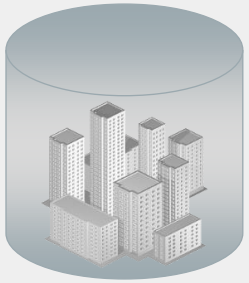
National datasets

BGT BRK AHN3 CBS (3D)BAG ...PDOK

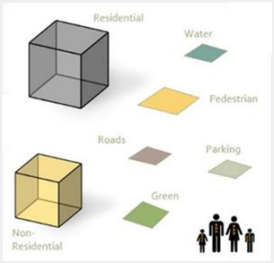
Local datasets

Amsterdam Maps data



Semantic 3D city model

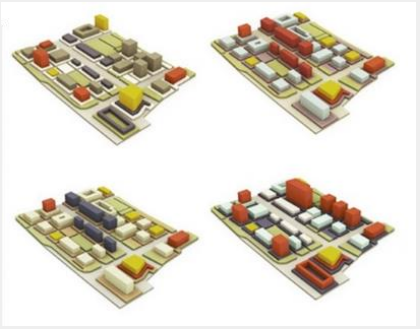
Spatial analysis
(KPIs & design parameters)



Choose "reference" neigbourhood(s)

Urban planning constraints

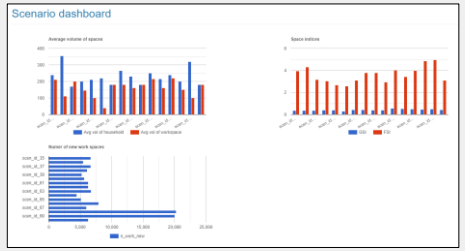
Design process and scenario generation



Provide feedback

Scenario evaluation
Integrate scenarios with the 3D city model

Share, compare, evaluate scenarios online



Choose scenario

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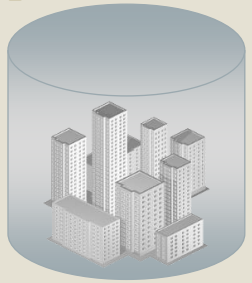
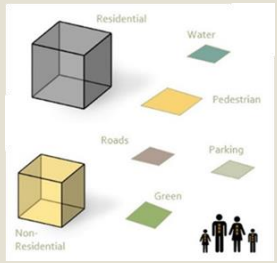
1



Semantic 3D city model

2

Spatial analysis
(KPIs & design parameters)



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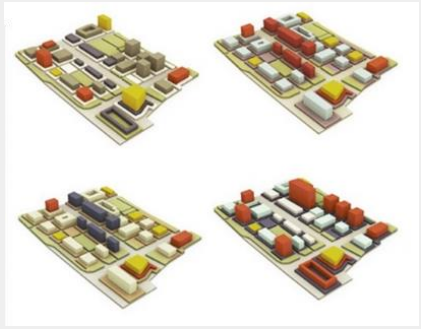

Provide feedback

3

Scenario evaluation
Integrate scenarios with the 3D city model

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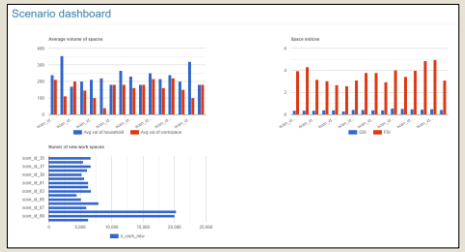


Choose scenario

Overview

Research questions

1. How accurate the 3D model is in estimating the residential and non-residential volumes within the city?

2. What key performance indices could be introduced as new inputs for the design stage of the tools? How to develop them in the pre-design stage?

3. In which aspects the developed scenarios could be evaluated in the post-design stage? How to utilize the 3D models of the scenarios, the 3D city models and other spatial data for the evaluation?

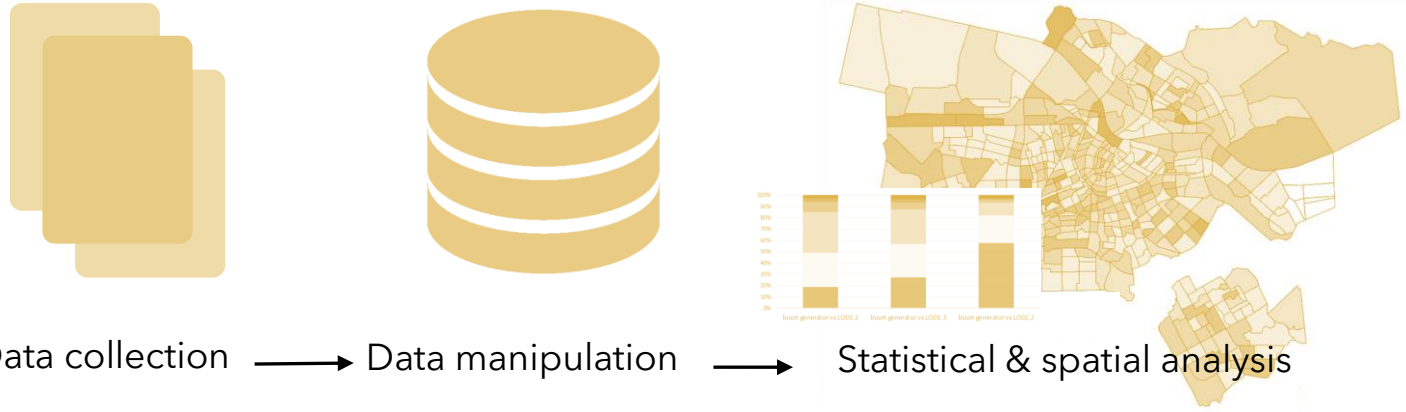
Overview

Research methodology

Approaches

1. Comparing volumes Buurt Generator vs. 3DBAG
2. Volumetric / Non-volumetric physical density + socio-economic data
3. Post-evaluation framework & implementation

Methods



Data collection → Data manipulation → Statistical & spatial analysis

Tools

PostgreSQL

The CityGML Database 3D City DB

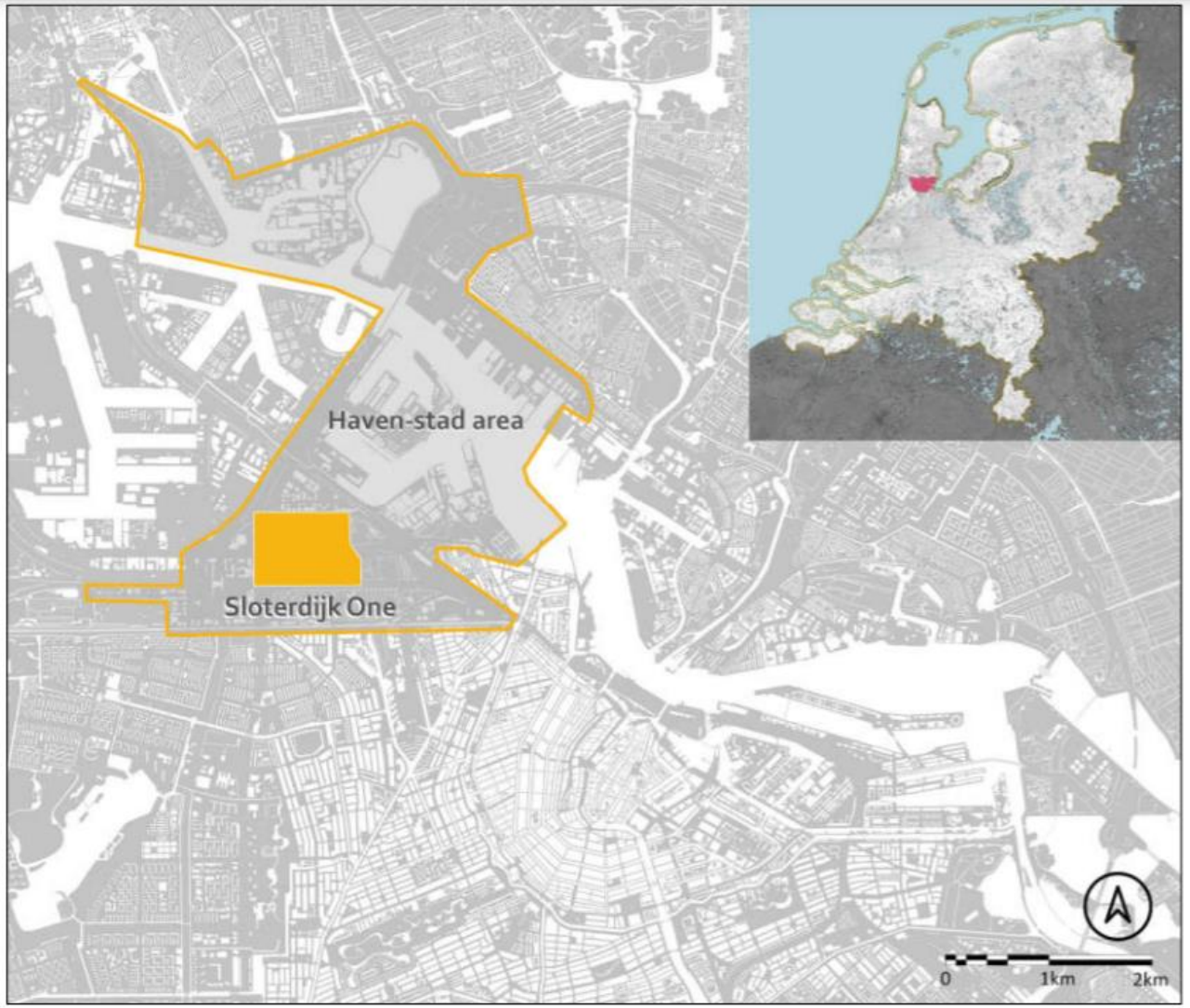
FME

QGIS

Rhinoceros NURBS modeling for Windows + grasshopper

Overview

Case study



Source: (Agugiaro et al., 2020)

Assessing the accuracy of the generated 3D City model

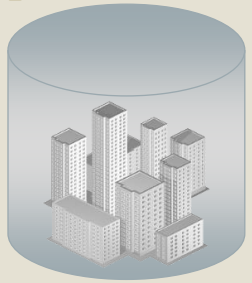
National datasets

BGT BRK AHN3 CBS (3D)BAG ...PDOK

Local datasets

Amsterdam Maps data

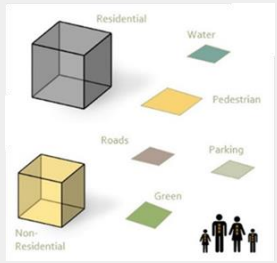
1



Semantic 3D city model

Check accuracy of building stock volume

Spatial analysis
(KPIs & design parameters)



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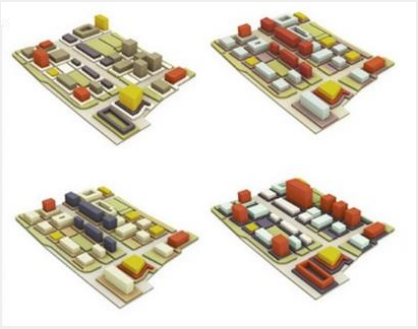

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Scenario evaluation
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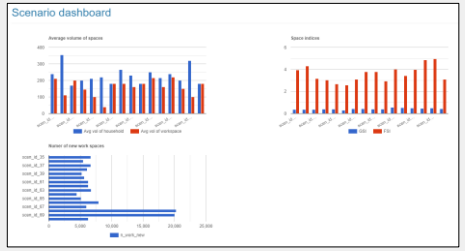


Choose scenario

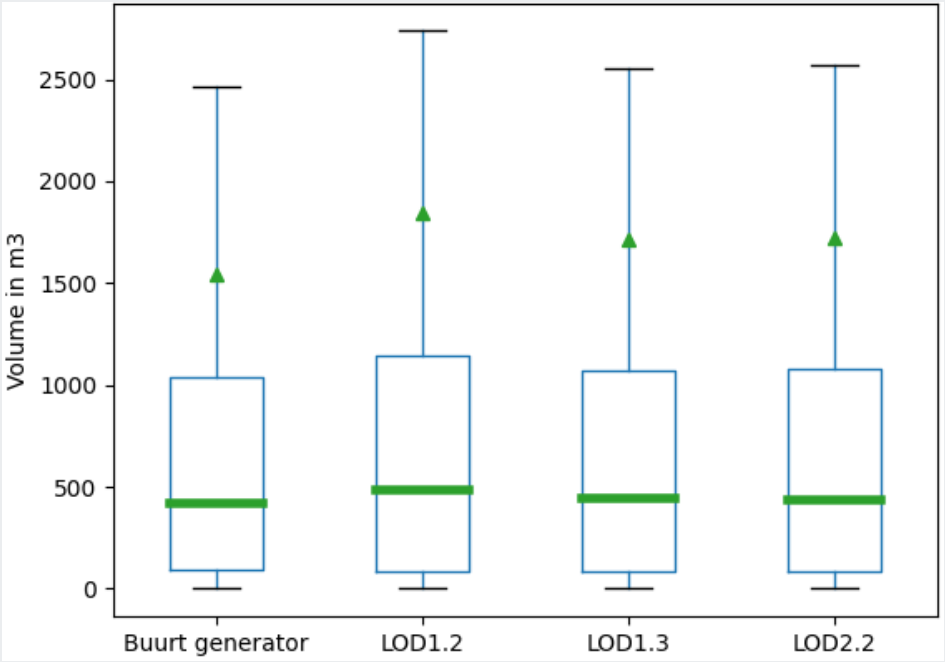
Assessing the accuracy of the generated 3D City model

Comparison approach

Building volumes
BAG 3D 2.0
(LOD12, LOD13, LOD22)

><

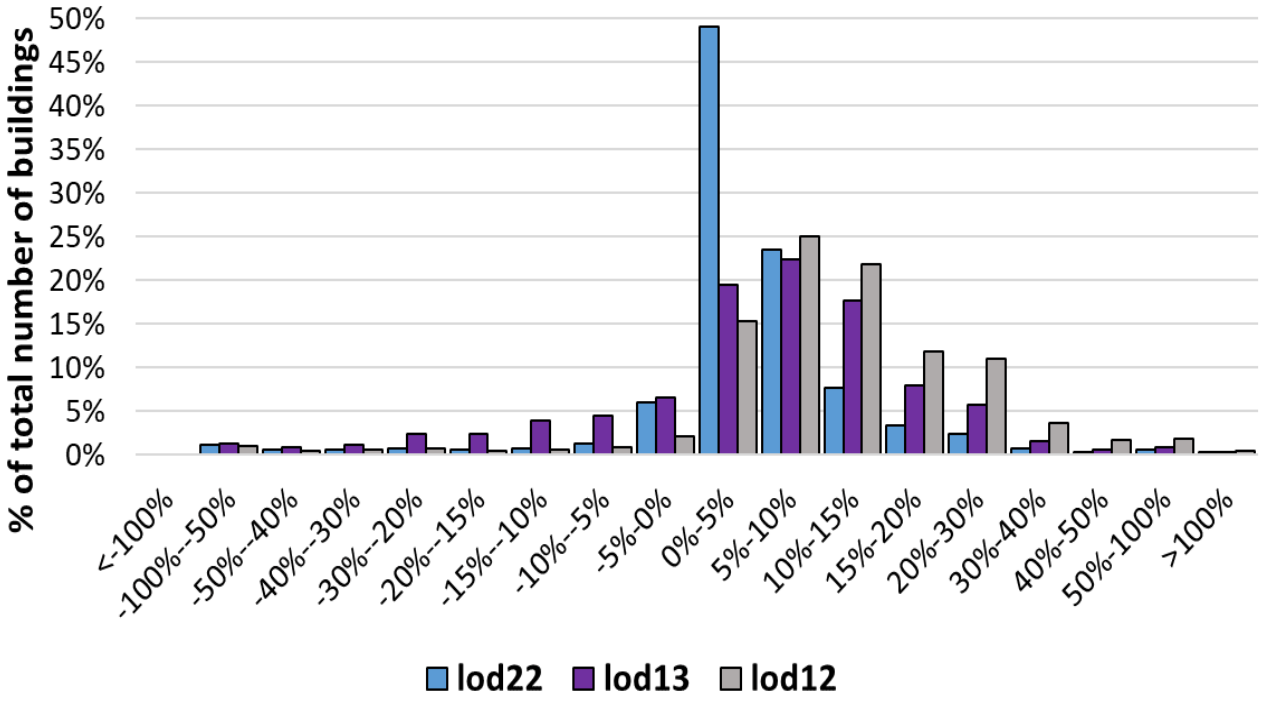
Building volumes
BUURT GENERATOR
(DSM-derived model)

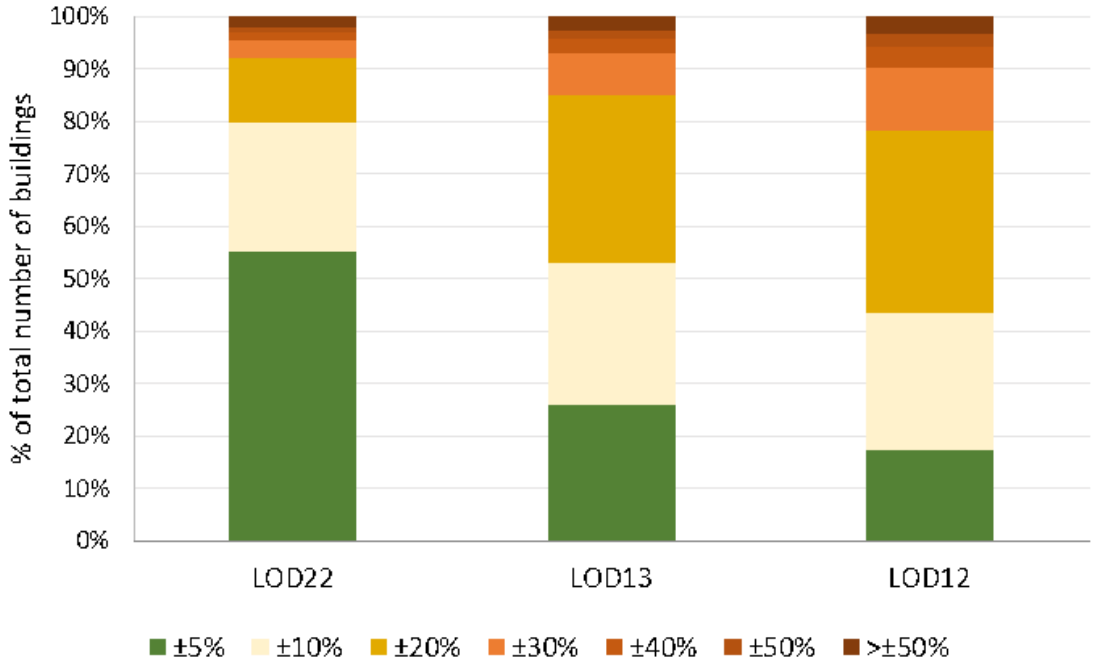


	"Buurt Generator" (m^3)	LOD1.2 (m^3)	LOD1.3 (m^3)	LOD2.2 (m^3)
mean	1545.27	1848.58	1716.94	1724.43
std	10697.46	13554.68	17035.02	16915.04
min	0.18	2.14	1.44	0.88
25%	89.56	85.32	84.6875	82.52
50%	416.92	485.25	447.23	436.79
75%	1038.29	1146.51	1072.675	1076.15
max	1642195.57	2205115	4256801	4226450

Assessing the accuracy of the generated 3D City model

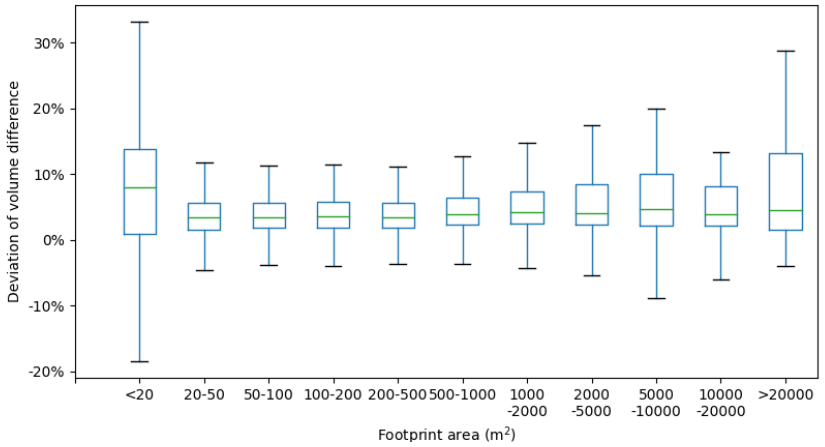
Distribution of normalized volume differences between the “Buurt Generator” and LODs



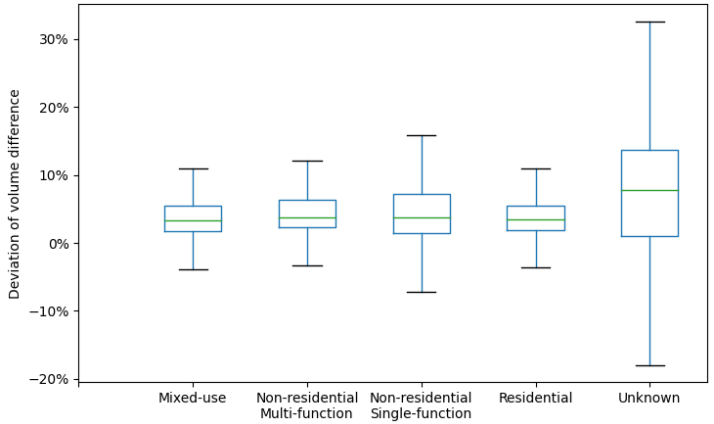


Assessing the accuracy of the generated 3D City model

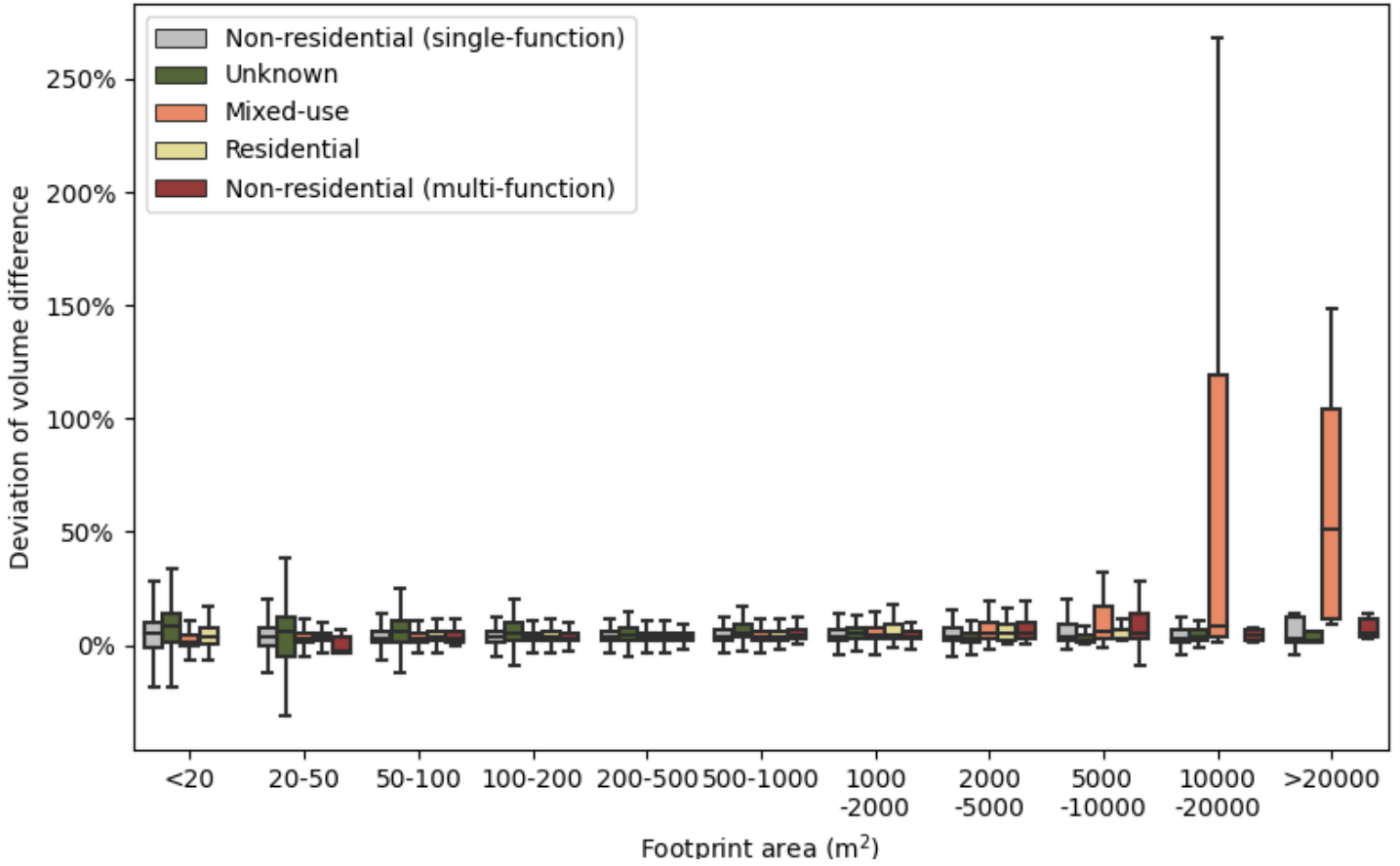
Building's characteristics and volume difference



Distribution of volume difference ratio according to building's footprint area



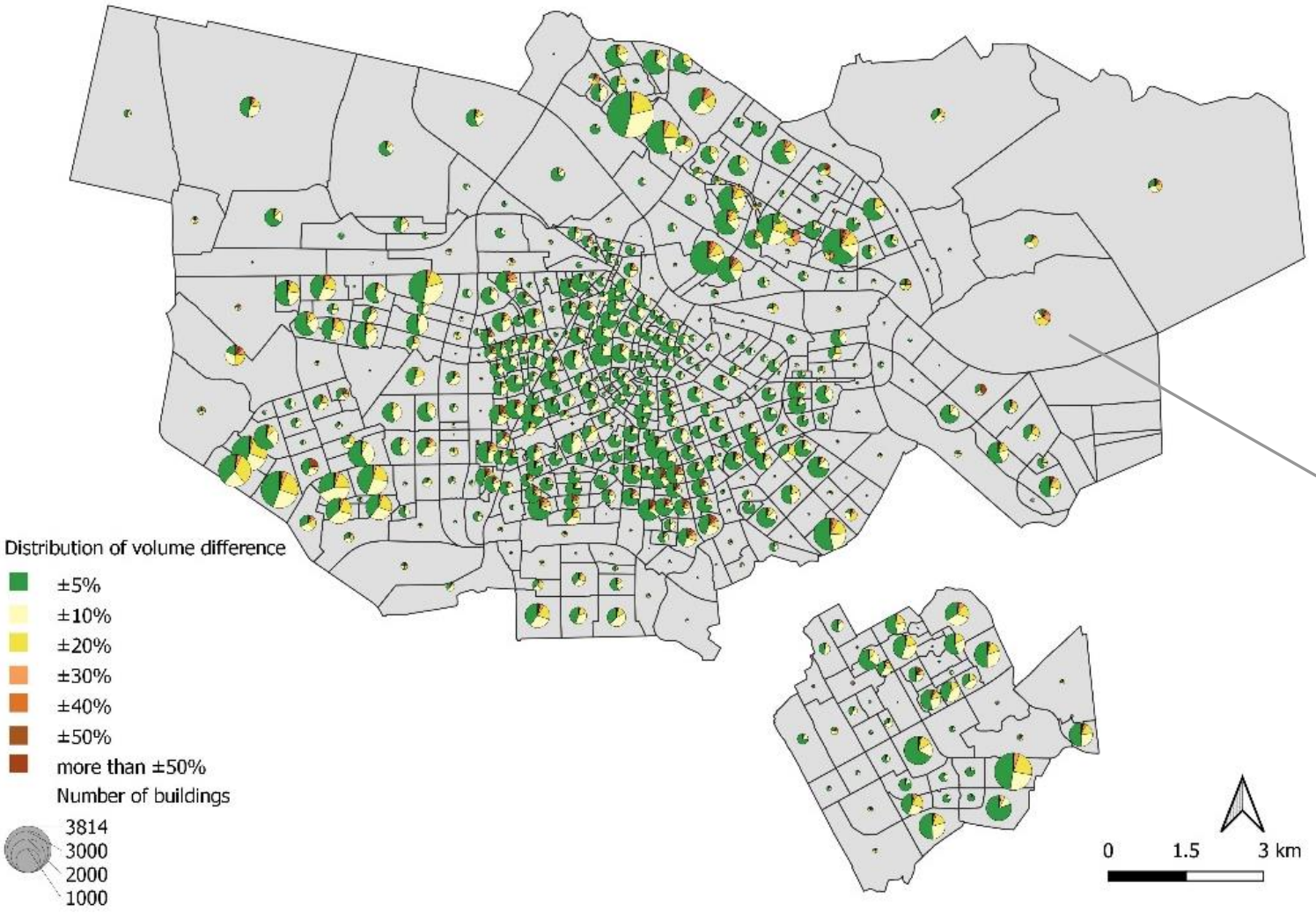
Distribution of volume difference according to building's class

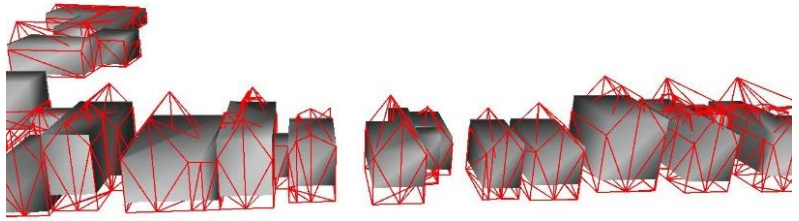


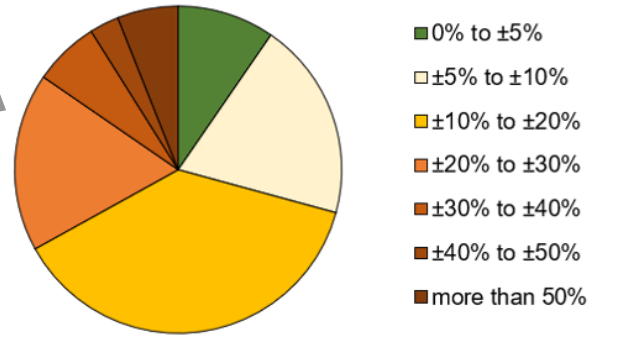
Distribution of volume difference according to building's class and footprint area

Assessing the accuracy of the generated 3D City model

Spatial distribution of volume differences



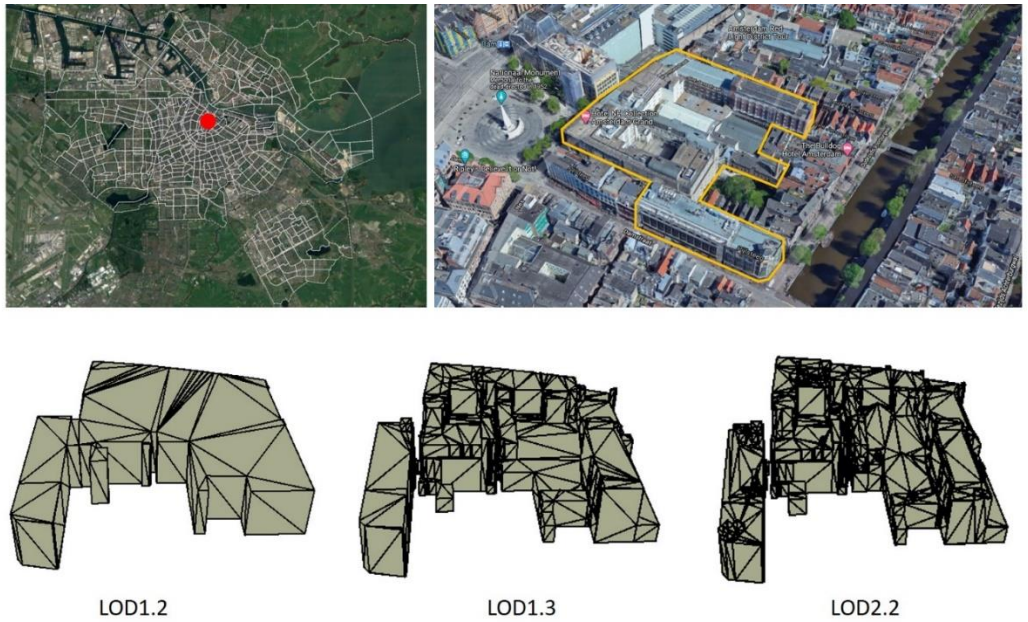




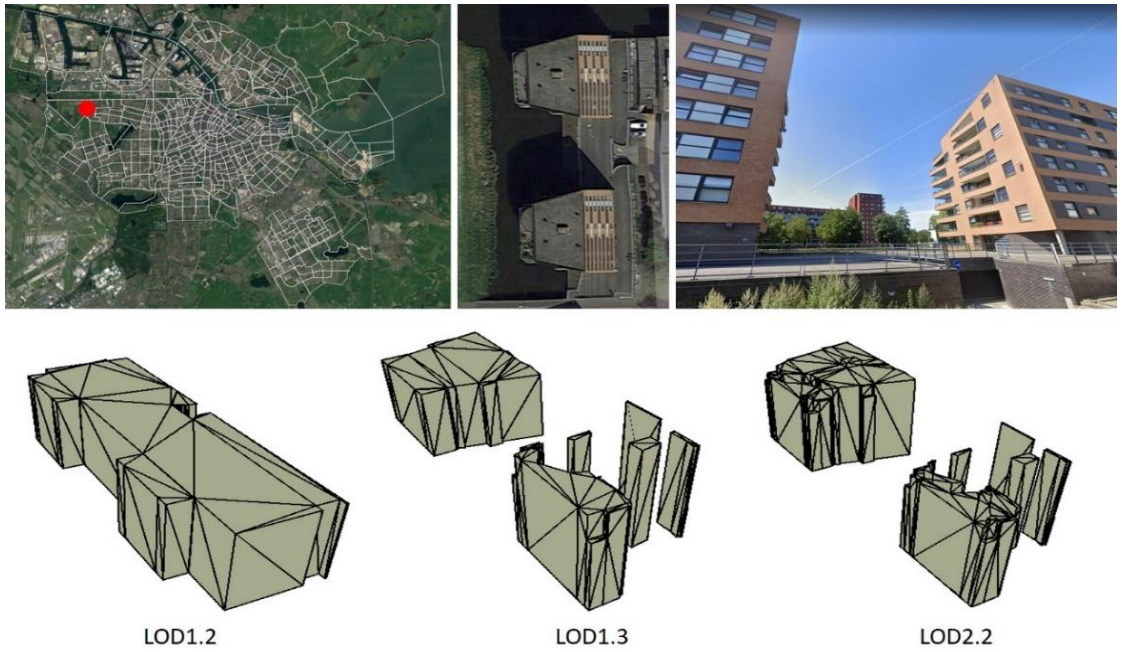
Assessing the accuracy of the generated 3D City model

Special cases

Multi-parts buildings



Example of multi-parts building



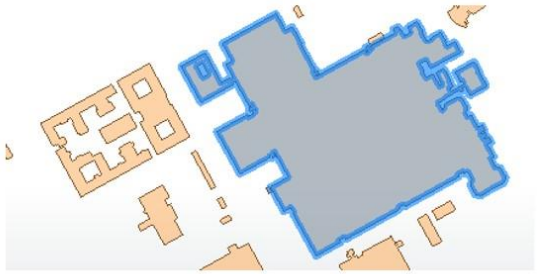
Example of error in the 3D reconstruction process

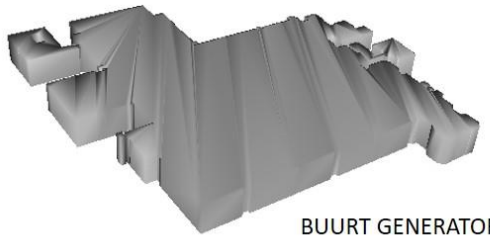
Assessing the accuracy of the generated 3D City model

Special cases

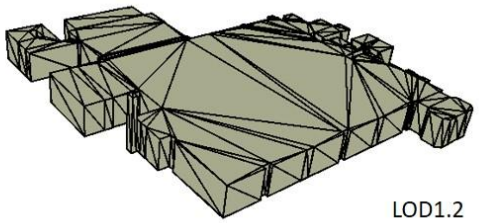
Buurt generator and LODs – extreme cases

	identificatie character varying	vol_ahn double precision	vol_lod12 double precision	vol_lod13 double precision	vol_lod22 double precision
1	0363100012073816	1355403.18	1441219.97	4256801.31	4226450.05

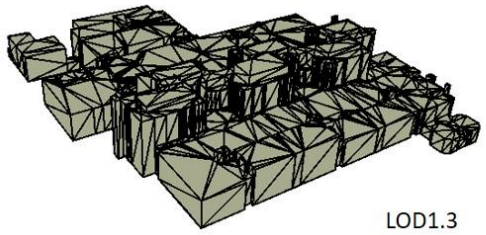




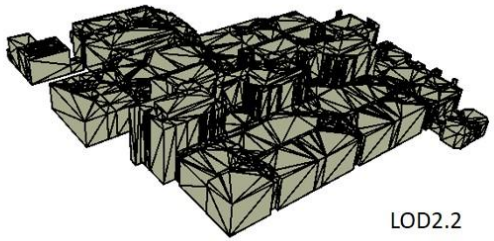
BUURT GENERATOR



LOD1.2

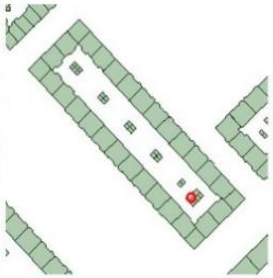


LOD1.3

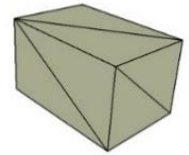


LOD2.2

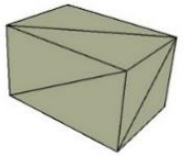
	identificatie character varying	vol_ahn double precision	vol_lod12 double precision	vol_lod13 double precision
1	0363100012184135	54.98	26.34	26.33



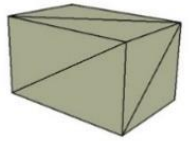
BUURT GENERATOR



LOD1.2



LOD1.3



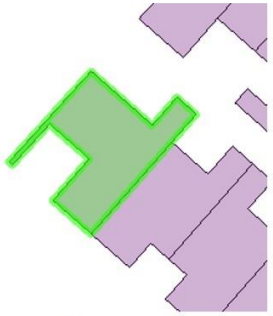
LOD2.2

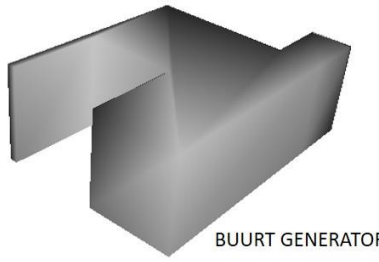
Assessing the accuracy of the generated 3D City model

Special cases

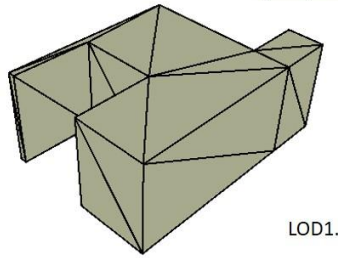
LOD1.3 and LOD2.2 – extreme cases

	identificatie character varying	vol_ahn double precision	vol_lod12 double precision	vol_lod13 double precision	vol_lod22 double precision
1	0363100012155528	471.46	542.38	15.62	512.81

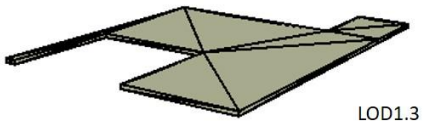




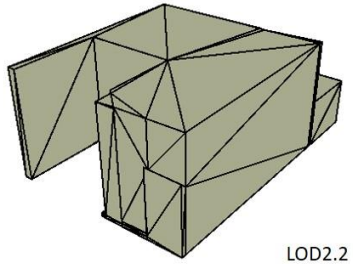
BUURT GENERATOR



LOD1.2

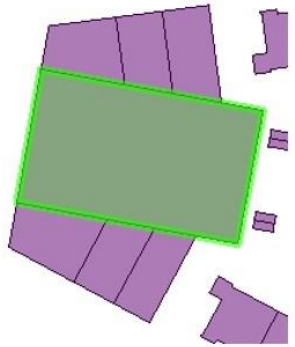


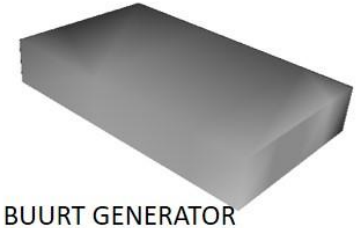
LOD1.3



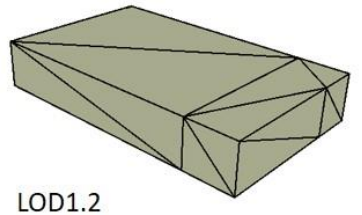
LOD2.2

identificatie character varying	vol_ahn double precision	vol_lod12 double precision	vol_lod13 double precision	vol_lod22 double precision
0363100012146941	3759.13	3809.02	6258.75	3857.38

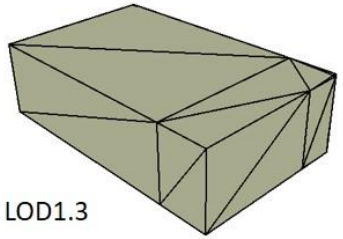




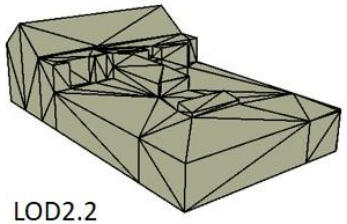
BUURT GENERATOR



LOD1.2



LOD1.3



LOD2.2

Assessing the accuracy of the generated 3D City model

Conclusion

nDSM model is quite similar to LOD2.2 model regarding volume

→ The nDSM model could be used as an replacement for its efficiency and reliability

Some drawbacks of the nDSM:

- Volume overestimation of buildings with tiny footprints
- Volume underestimating of buildings with very large footprints and large height variation

→

- Tiny footprints buildings are mostly unknown buildings and are not used in deriving urban KPIs
- For large footprints buildings, further investigation is needed for a better choice of height value to extrude the footprint

The developed method detects errors from the nDSM model and the 3D BAG 2.0 models and quickly identifies major volume deviations

→ The method could be further used to quickly identify problematic buildings from different 3D reconstruction approaches.

- For the details:

Volume comparison of automatically reconstructed multi-LoD building models for urban planning applications
Truc Quynh Doan, Camilo León Sánchez, Ravi Peters, Giorgio Agugiaro, Jantien Stoter, 2021
Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences

Urban KPIs for the pre-design stage

National datasets

BGT

BRK

AHN3

CBS

(3D)BAG

...PDOK

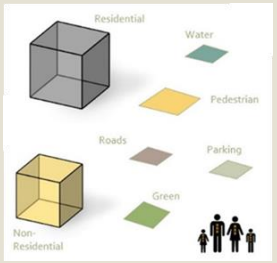
Local datasets

Amsterdam Maps data

Semantic 3D city model

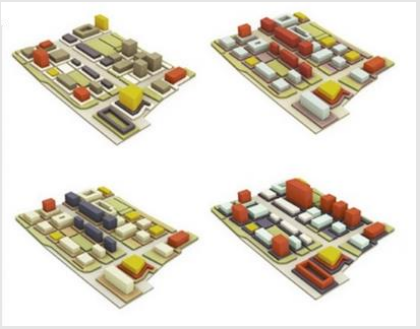
Expand urban KPIs

Spatial analysis
(KPIs & design parameters)



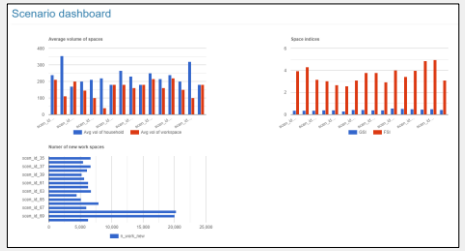
Urban planning constraints

Design process and scenario generation



Scenario evaluation
Integrate scenarios with the 3D city model

Share, compare, evaluate scenarios online



Provide feedback

Choose scenario

Urban KPIs for the pre-design stage

Current approach

Urban KPIs → Template neighborhoods

Proposed approach

Urban KPIs and Interpretation of City Context

Expand the list of KPIs

Comprehensively and comparatively understand the city context

Ready to use urban parameters to be query in many fields and at any site

→

Design KPIs

Focus on the development site

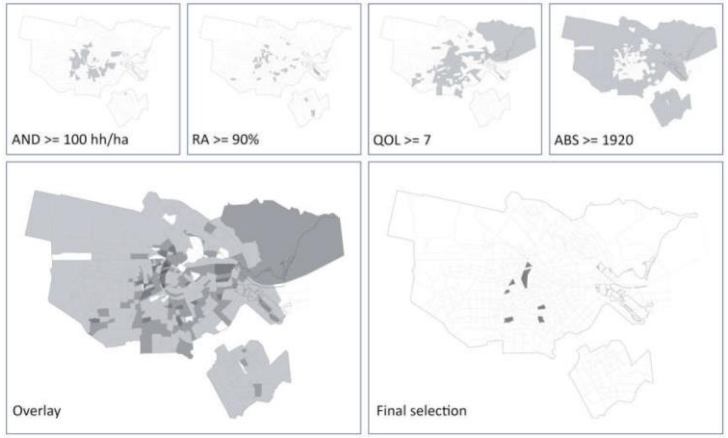
Query necessary data for the reasoning process

Deriving design KPIs

Urban KPIs for the pre-design stage

Expand the list of KPIs

Current KPIs



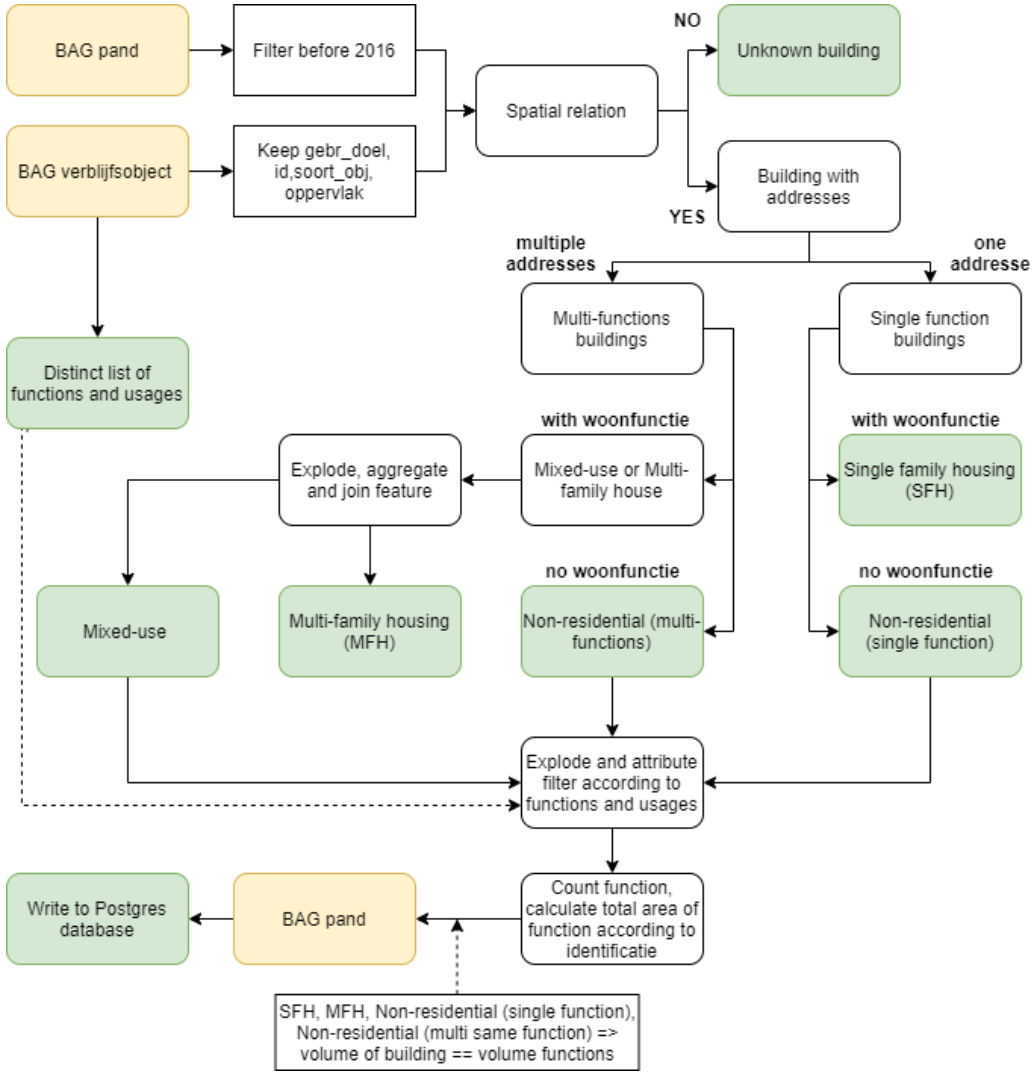
- AND: Average Neighborhood density (base on number of households)
- RA: Percentage of Residential Area
- QOL: Quality of Life
- ABS: Age of the building stocks

Proposed urban aspects and criteria

Urban aspects	Criteria
Demographic	Distribution of population according to size and age classes
	Distribution of household according to size and types
Built environment	Distribution of volumetric density
	Distribution of footprint density
	Distribution of buildings according to functions
Housing	Distribution of dwelling types and dwelling sizes
Indoor amenities	Distribution of built infrastructure/amenities according to types and total volume
Outdoor amenities	Distribution of road types (regional and local street, pedestrian, bicycle lanes)
	Distribution of natural amenities (greeneries, watershed)
Development period	Distribution of building according to the development period
Quality of life	Overall indicator and categorical indicators (housing, amenities, safety, and security)

Urban KPIs for the pre-design stage

Data preparation and calculation



Building classification workflow in FME

Six building types:

- Unknown (mostly having footprint < 20 m2)
- Single address housing
- Multi-addresses housing
- Non-residential (Single function)
- Non-residential (Multi-functions)
- Mixed-use

With attributes on:

- Functions / Number of of Functions
- Floor areas of the functions

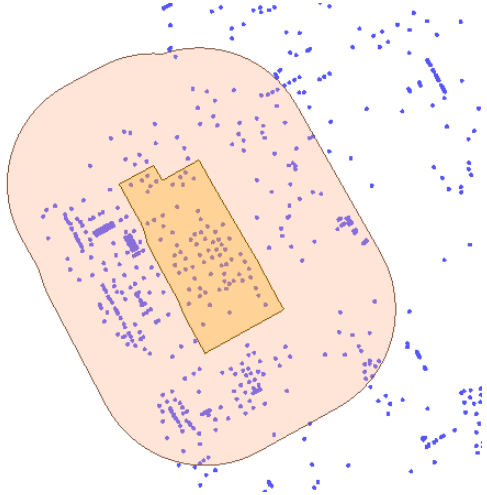
Table “Building_info”:

- Record according to building id (identificatie)
- Volume of each functions of the records
- Average size of dwelling unit and number of dwelling units of residential building

Urban KPIs for the pre-design stage

Data preparation and calculation

Volumetric urban parameters at the buurt level



KPIs: total volume of cafeteria/restaurant per neighborhoods, volume of cafeteria/restaurant per dwelling per neighborhood, etc.

The buffer zone of 800 meters from the neighborhood boundary that covers the indoor urban amenities of the surrounding areas

Outdoor urban parameters at the buurt level

KPIs: total area of green landscape per neighborhoods, volume of green landscape per dwelling per neighborhood, etc.

The buffer zone of 400 meters from the neighborhood boundary that covers the outdoor urban amenities of the surrounding areas

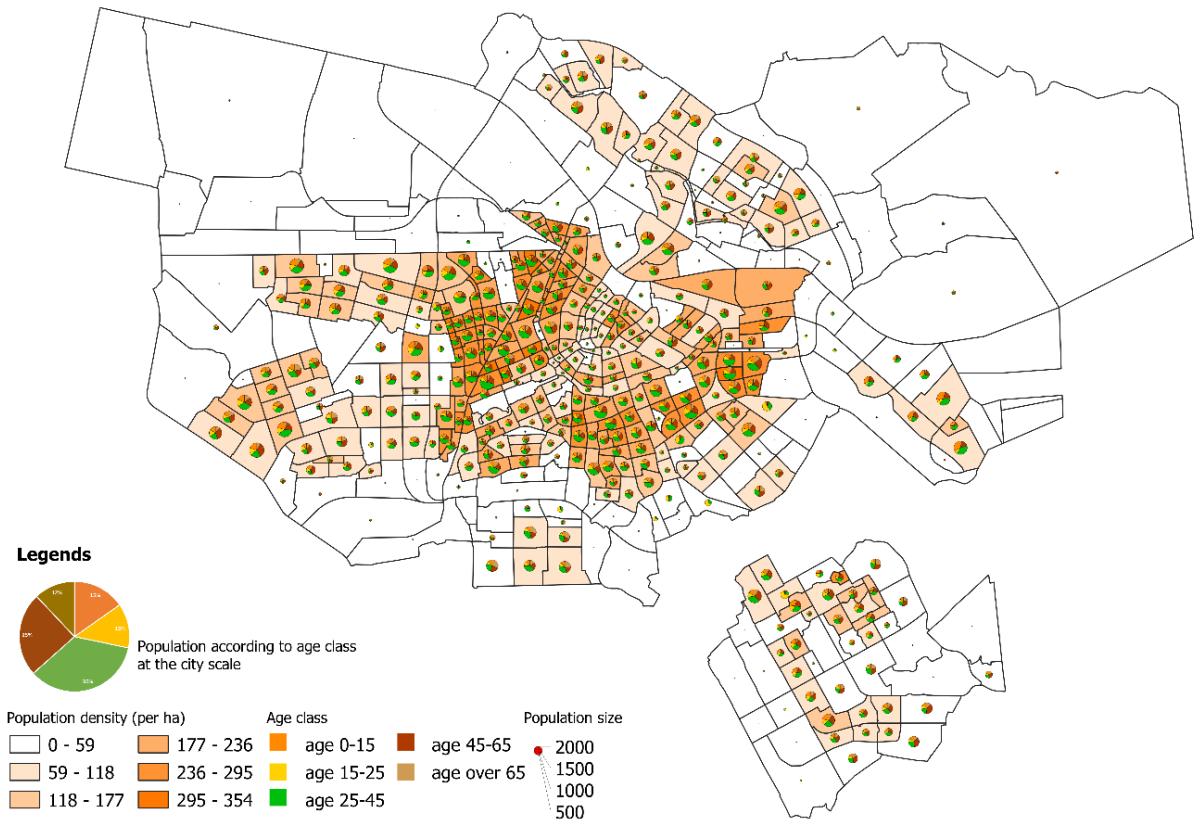
Urban KPIs for the pre-design stage

The extented database for the Urban KPIs

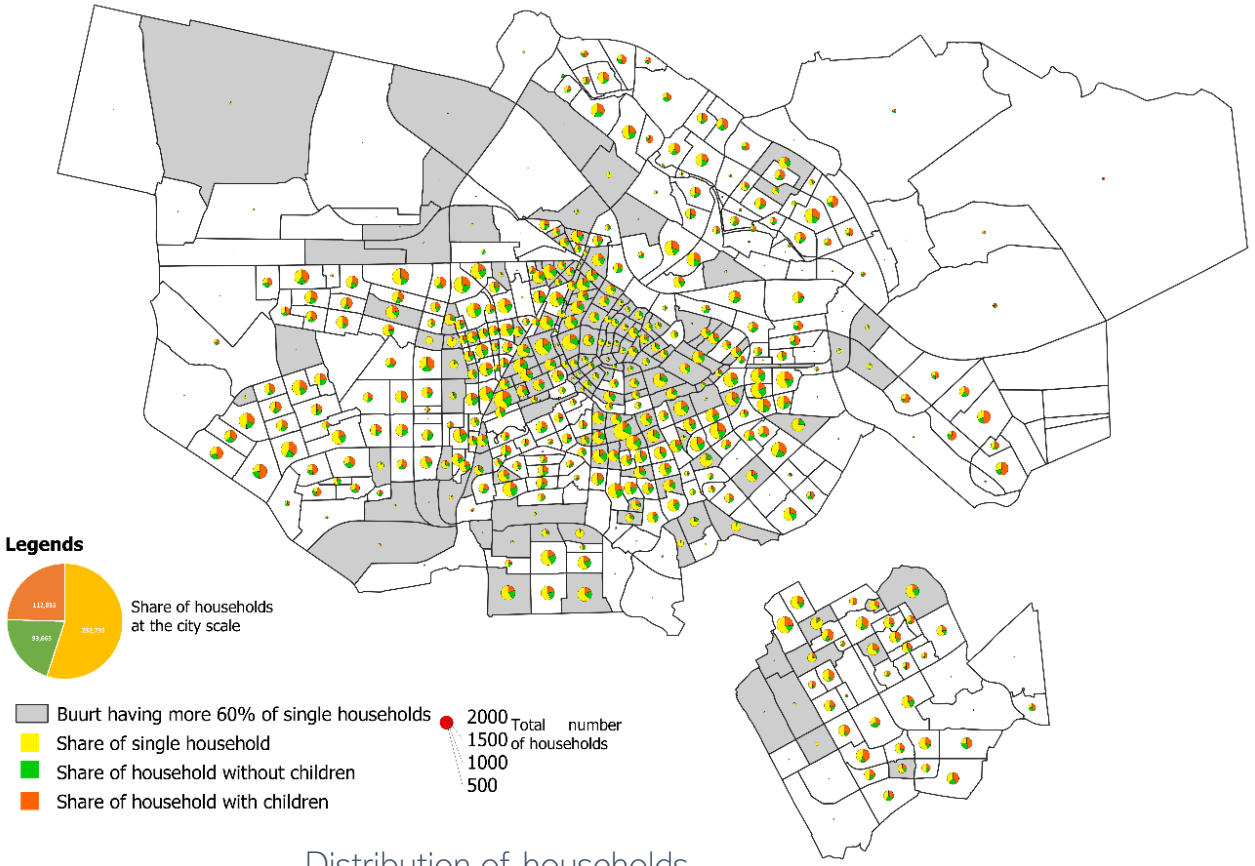
Name of the table	Urban KPIs
Building_info	number of dwellings, usages (per type), net floor area of usages (per type), and volume of usages (per type), age class, and price range.
Buurt_building	number of buildings, number of building per development period, number of buildings per building type, volume of building per building type, number of buildings per development period, total building footprint, total building volume, footprint density and volume density.
Buurt_housing	the number of dwelling units, number of dwelling units per building type, total, average, and median dwelling volume per building type, indoor amenities volume per dwelling, and outdoor amenities area per dwelling.
Buurt_indoor_amenties	total volume per function per buurt.
Buurt_indoor_amenites_buffer	the volume of indoor amenities from the surrounding buurt (800 meters of buffer zone)
Buurt_outdoor_amenities	water surface, foot path, bike path, local street, regional street and green landscape.
Buurt_outdoor_amenities_buffer	outdoor amenities from the surrounding buurt (400 meters of buffer zone)
Buurt_population	total population, population per age class, population density, dwelling volume per people, indoor amenities (800 meters buffer) per people, and outdoor amenities (400 meters buffer) per people.
Buurt_household	number of households, number of households per household type, household density, dwelling volume per household, indoor amenities (800 meters buffer) per household, and outdoor amenities (400 meters buffer) per household.
Buurt_liveability	Livability index at the buurt level.

Urban KPIs for the pre-design stage

The city context



Distribution of population

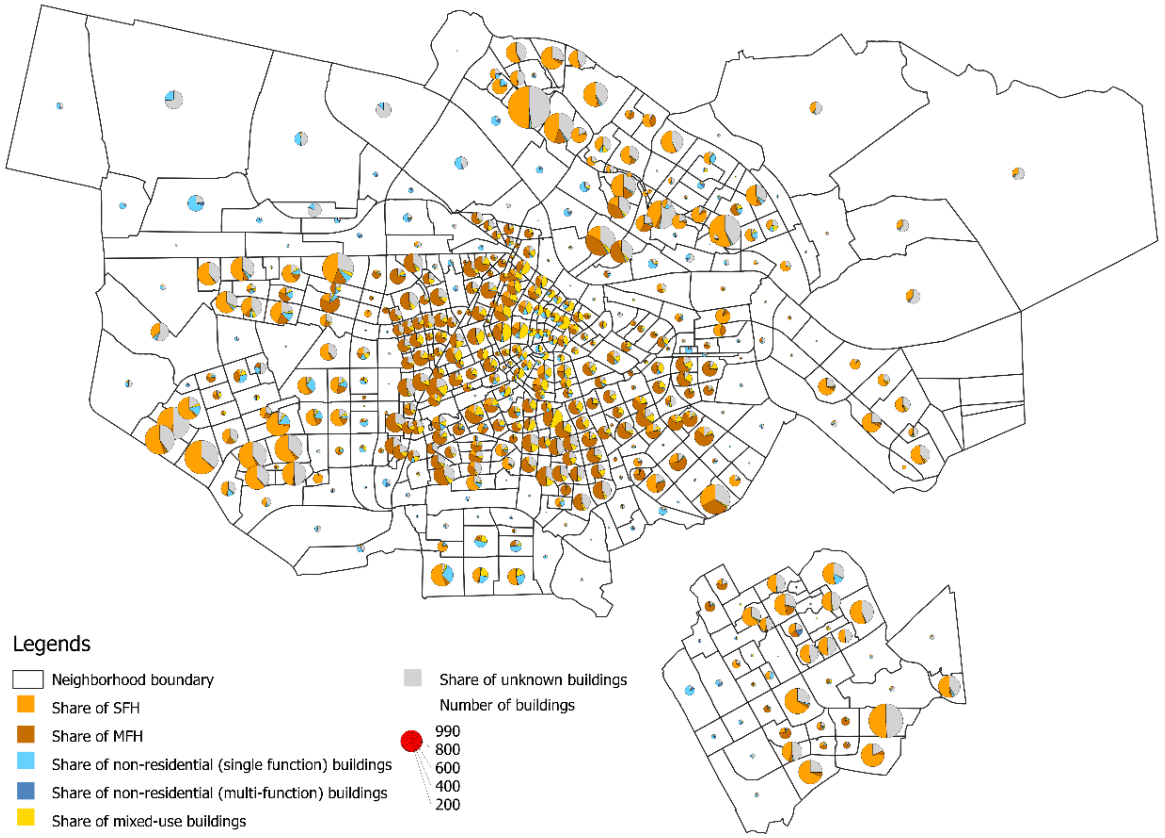


Distribution of households

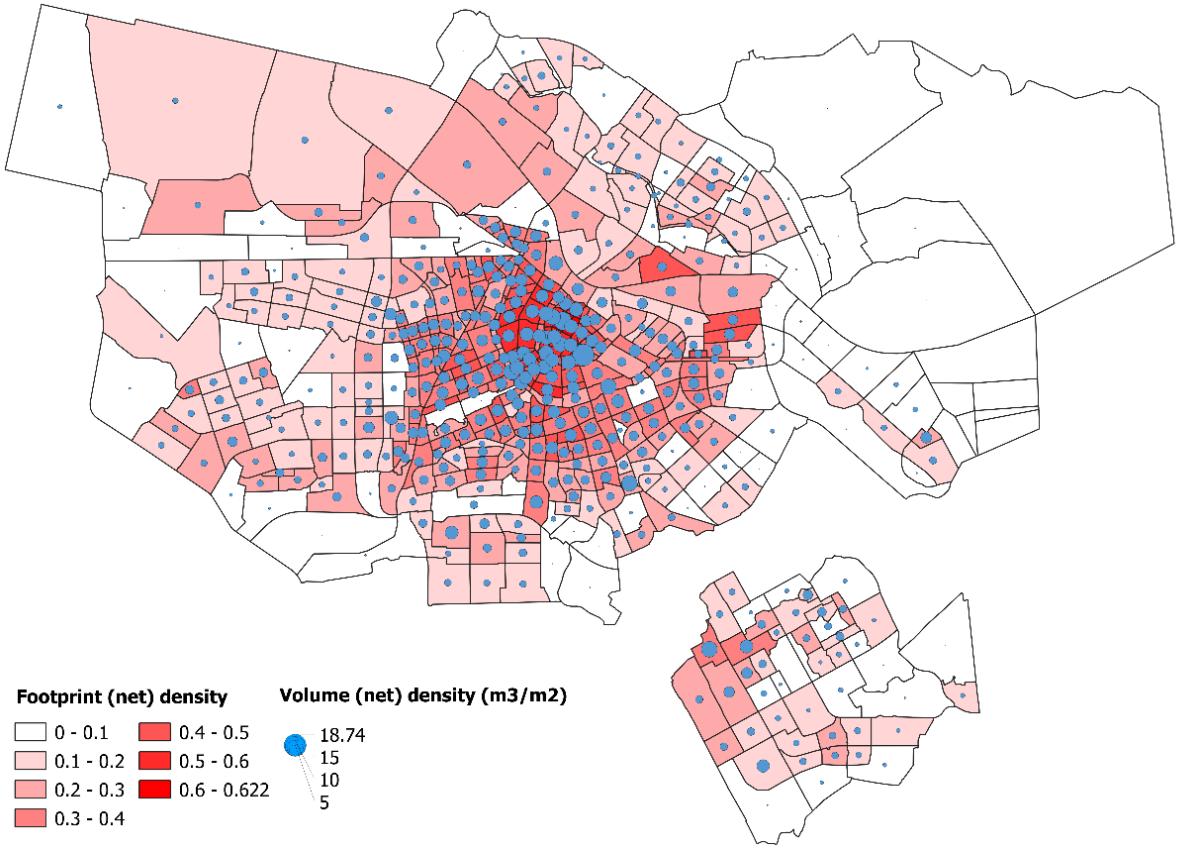
Demographic context

Urban KPIs for the pre-design stage

The city context



Distribution of number of buildings according to building types

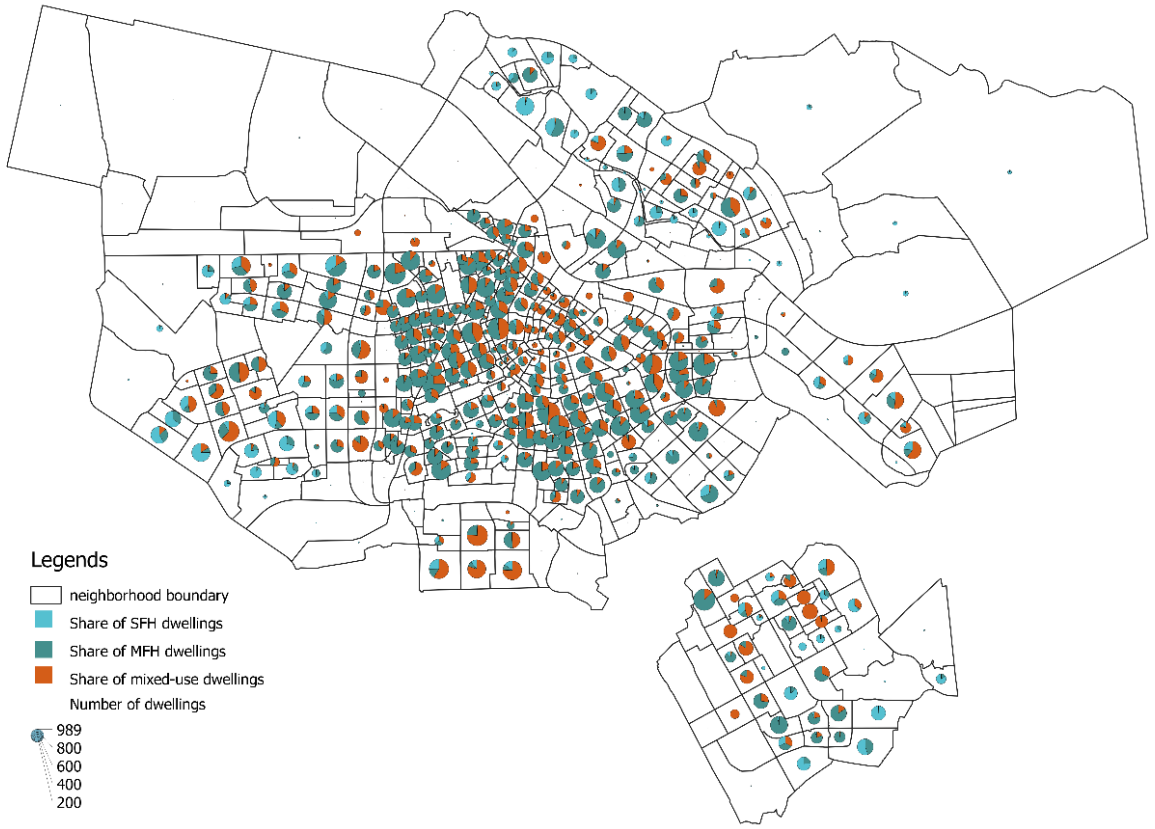


Building density according to building footprint and building volume

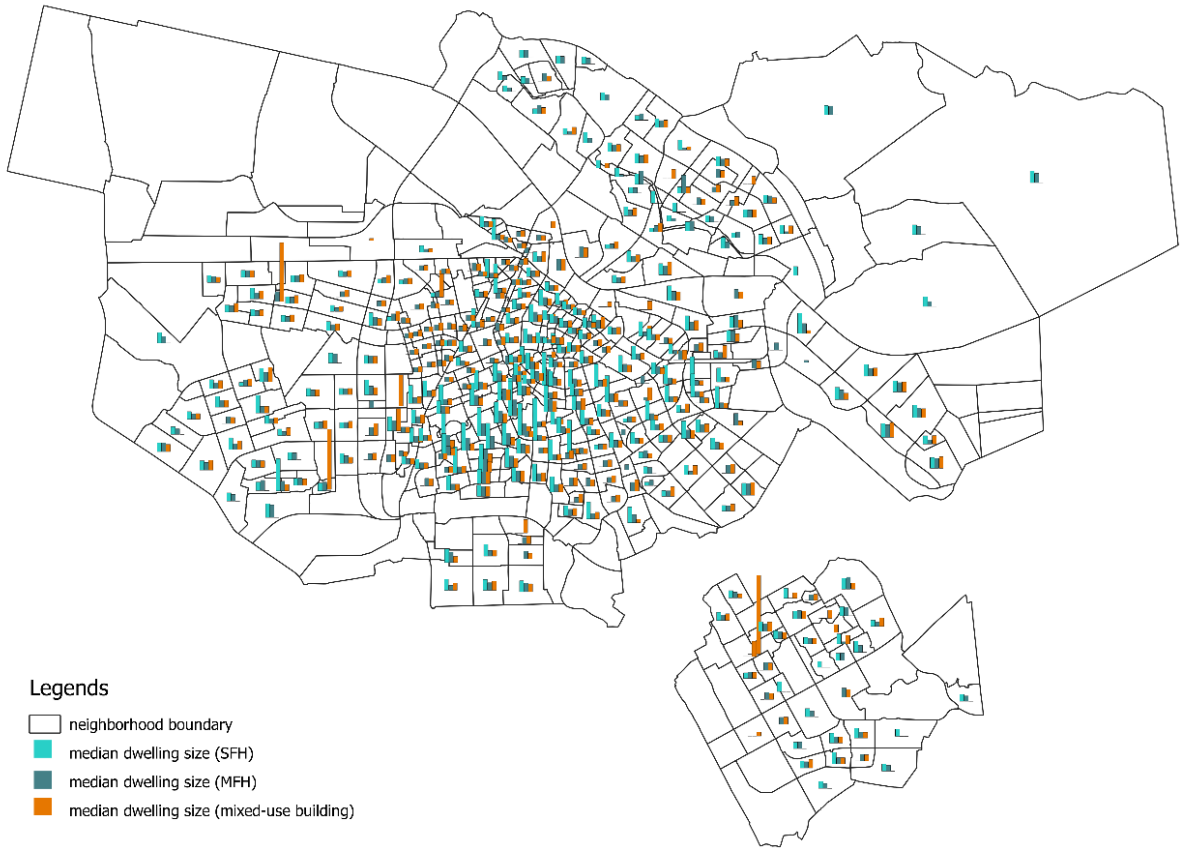
Building context

Urban KPIs for the pre-design stage

The city context



Distribution of dwelling types and number of dwellings

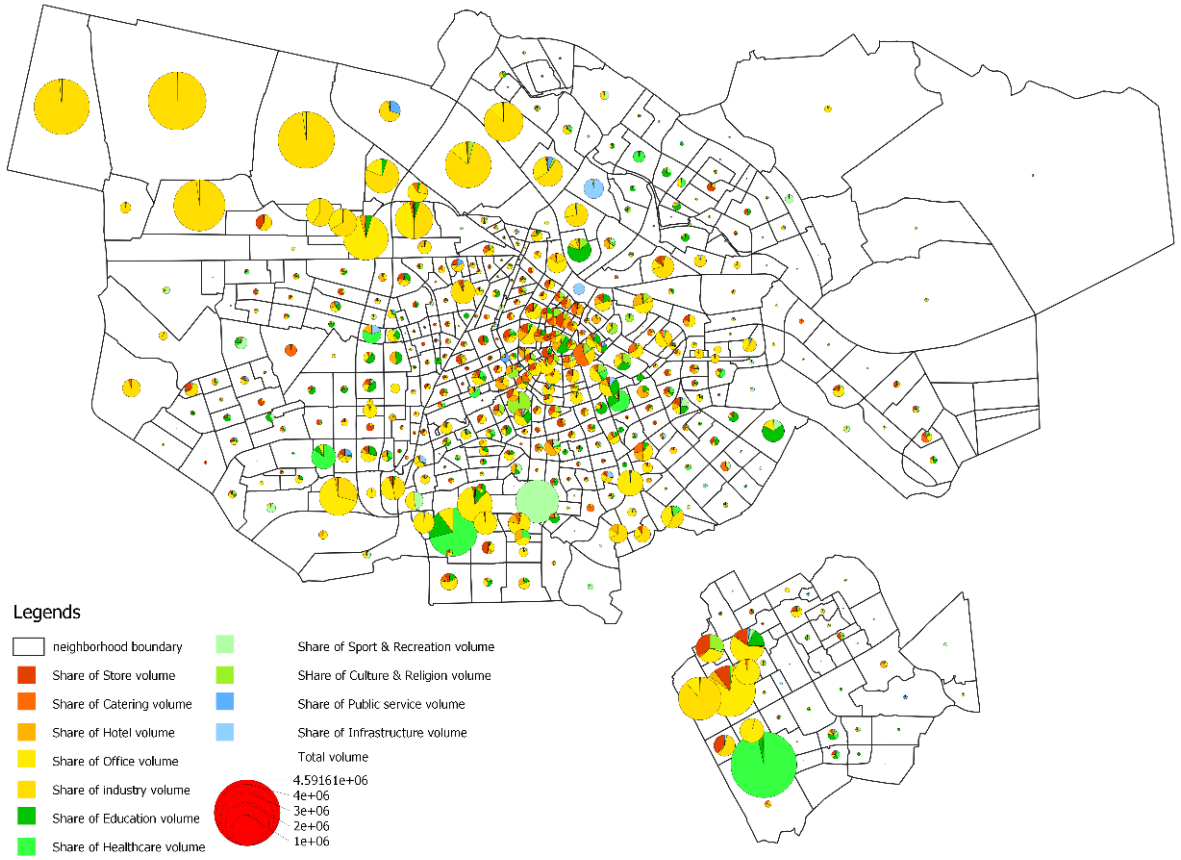


Distribution of dwelling size in volume

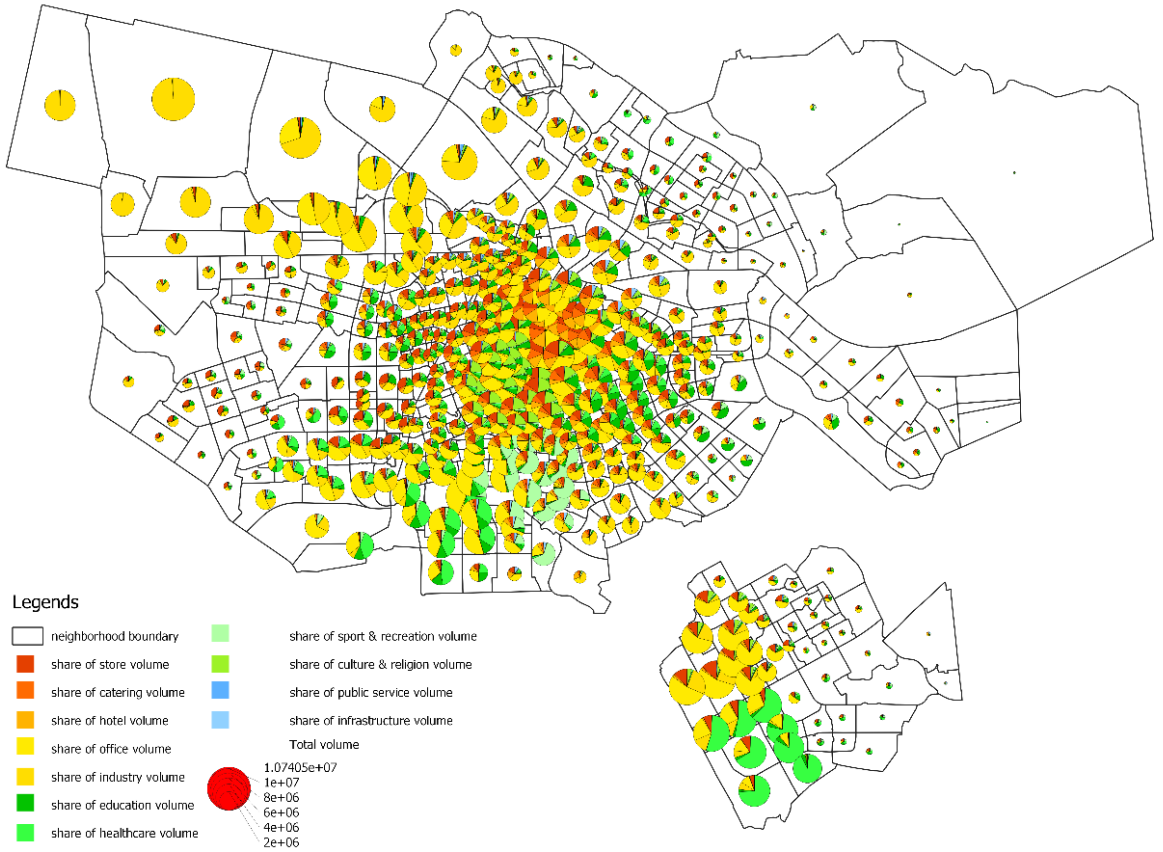
Housing context

Urban KPIs for the pre-design stage

The city context



Distribution of indoor amenities



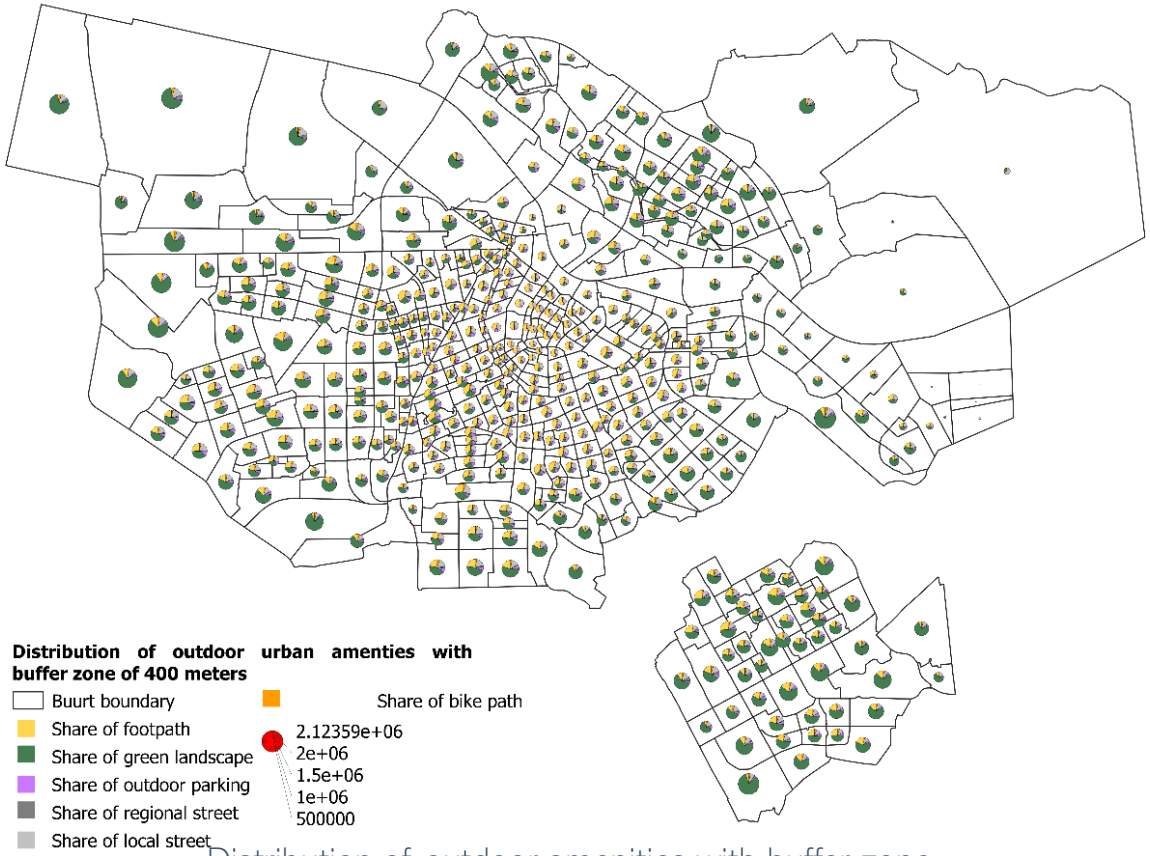
Distribution of indoor amenities with buffer zone

Indoor Urban amenties

Urban KPIs for the pre-design stage

The city context

Distribution of outdoor amenities

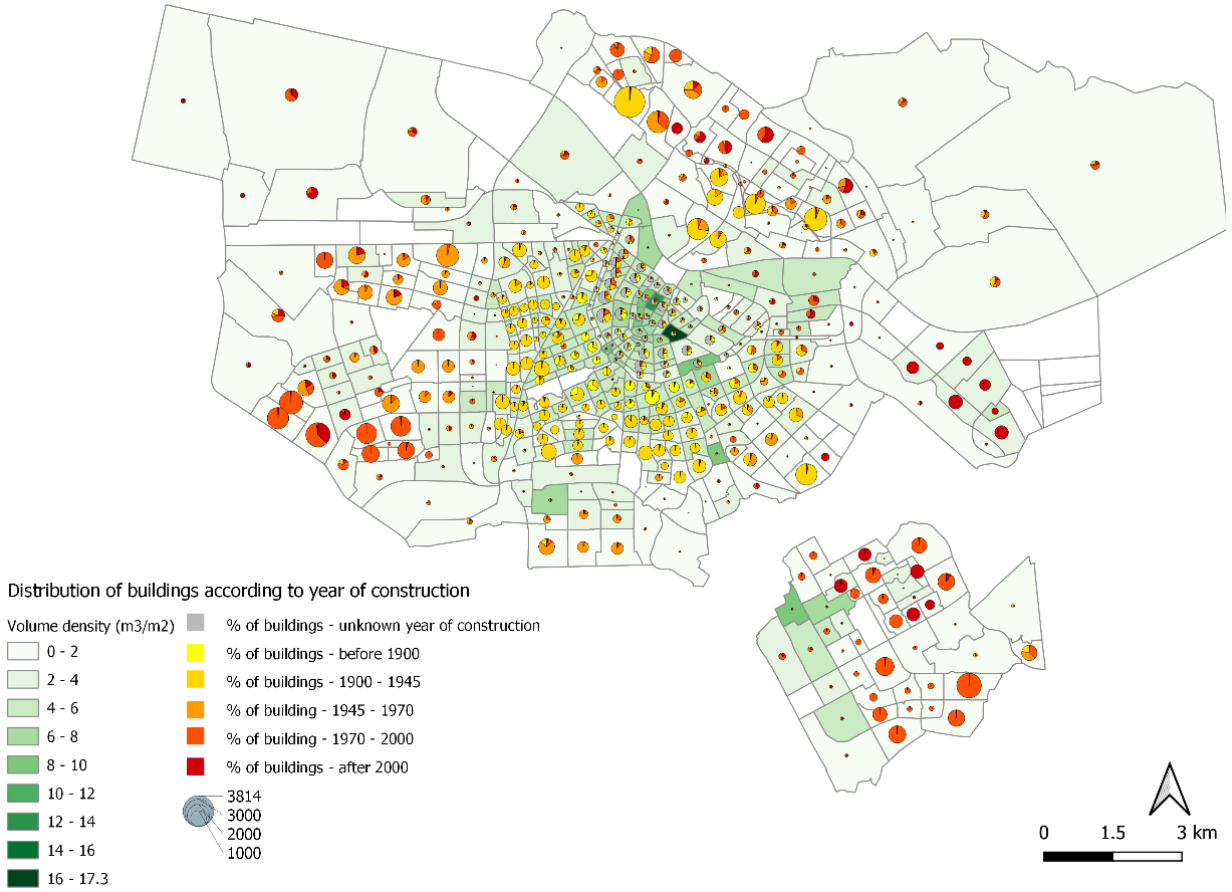


Distribution of outdoor amenities with buffer zone

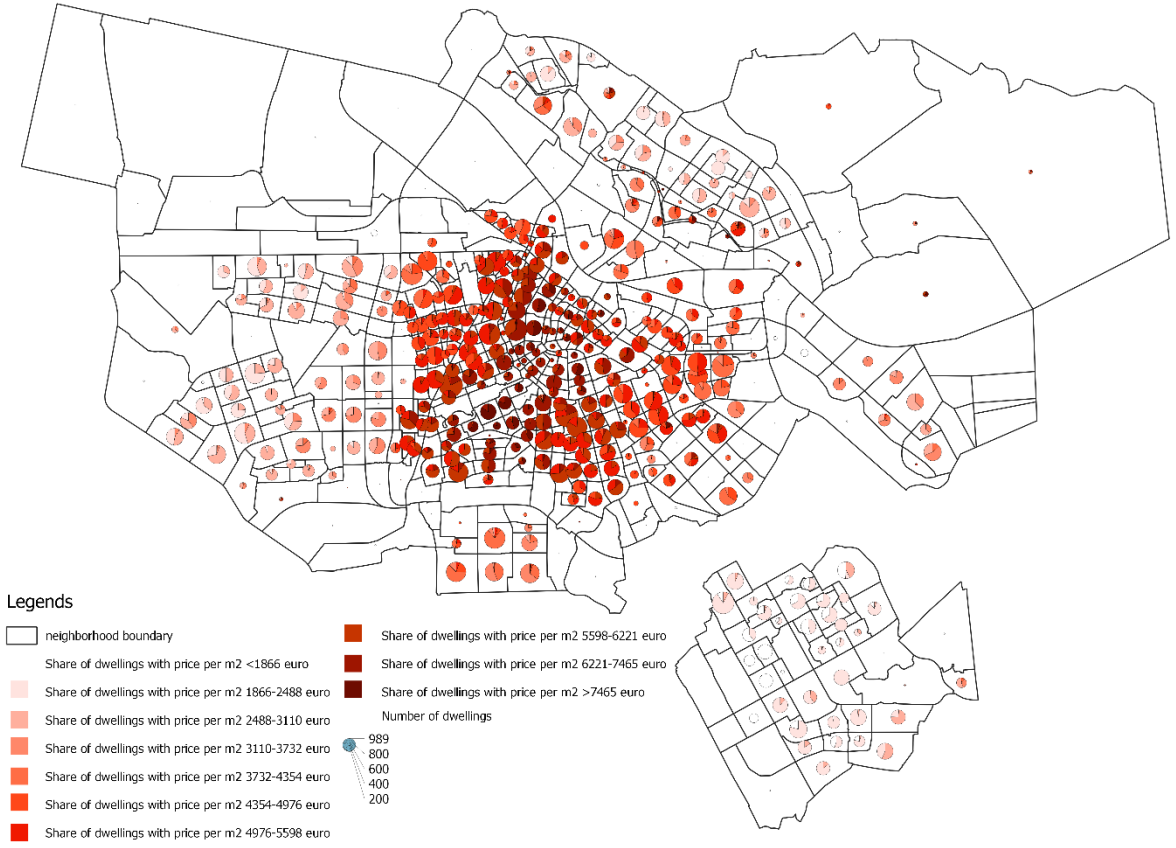
Outdoor Urban amenties

Urban KPIs for the pre-design stage

The city context



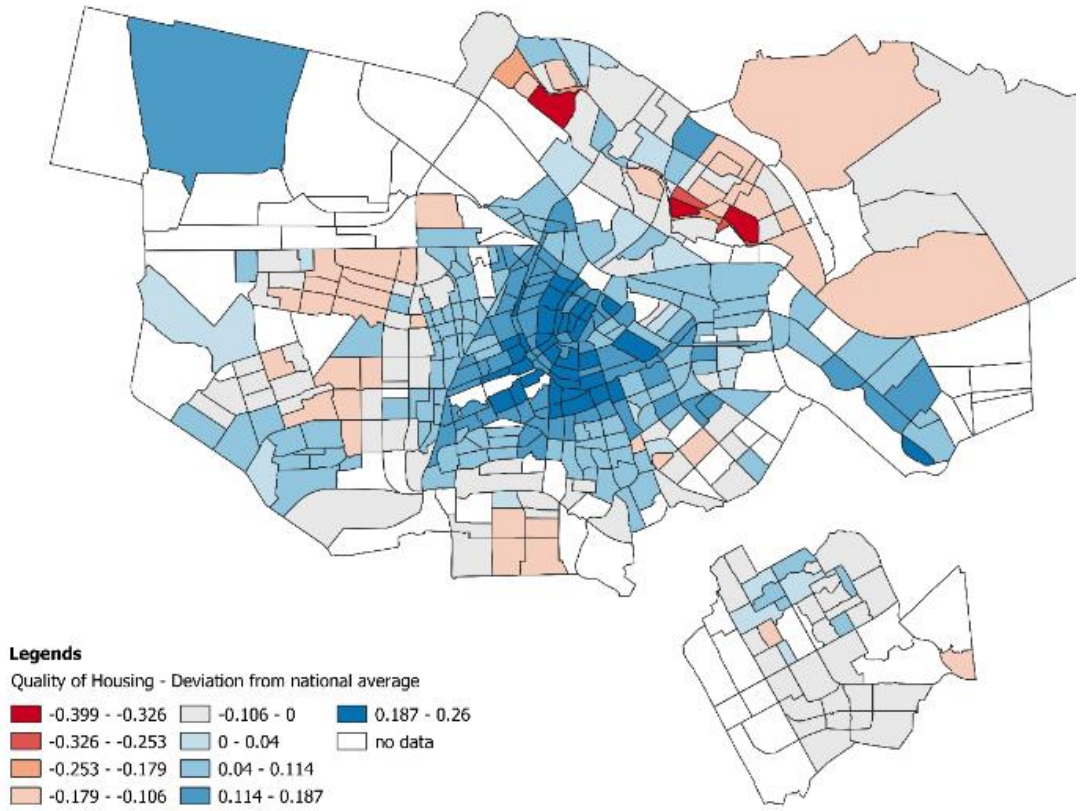
Building ages

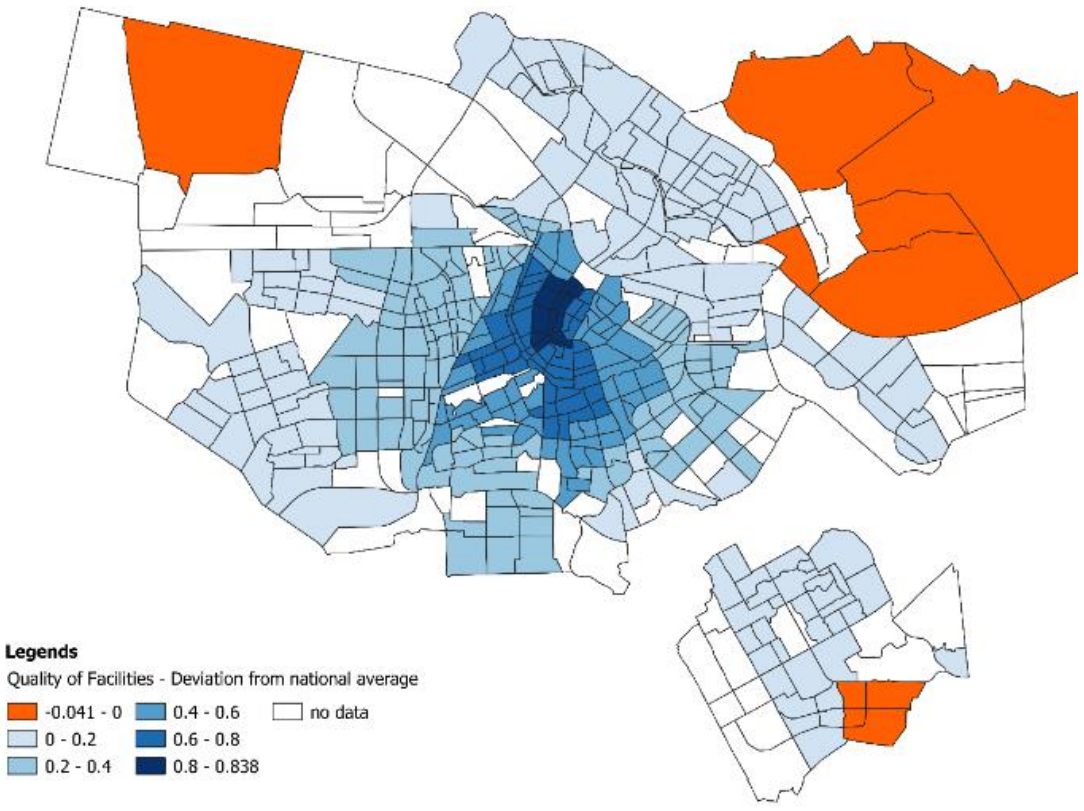


Housing prices

Urban KPIs for the pre-design stage

The city context



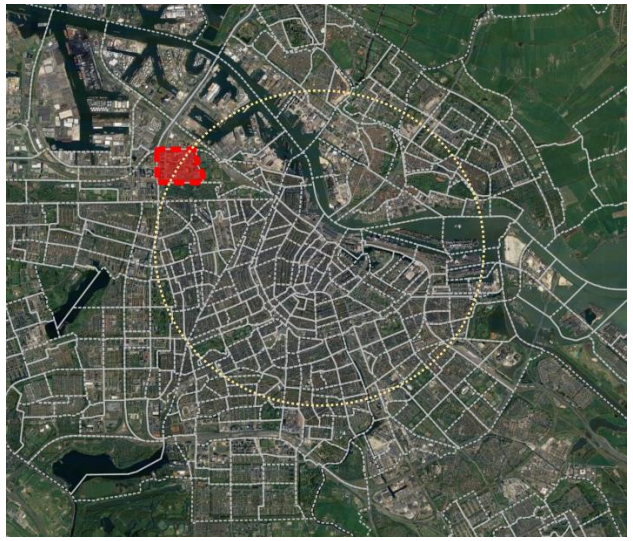


Quality of life

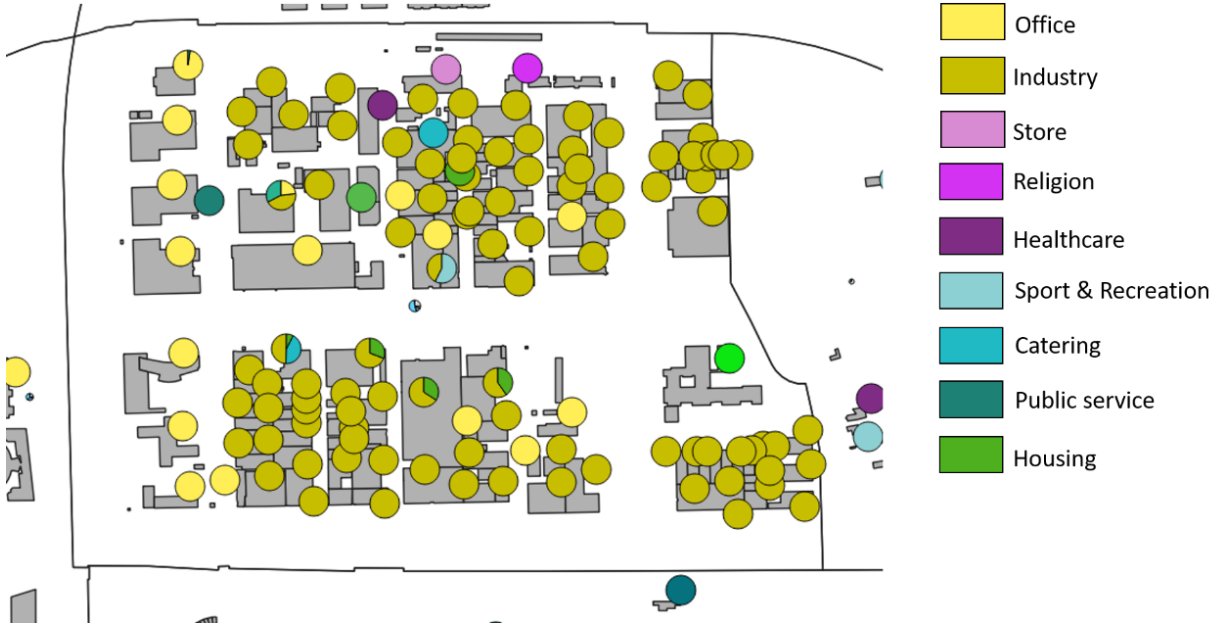
Urban KPIs for the pre-design stage

Design KPIs for the new development project – Context of the development site

With the same approach, from the same database, information at a specific neighborhood can be queried.



Location: The area is within the same region with the second development ring (1900-1945) with regard to the distance to the city center.



Query information at the building level from the "Building_info" table

Urban KPIs for the pre-design stage

Design KPIs for the new development project

Query from the "Buurt_" tables to get an overview on the development site on:

- Demographic
- Liveability
- Buldings
- Housings
- Indoor urban amenities
- Outdoor urban amenities

(Expanded KPIs compare to the current approach)

Outdoor amenities	Values	Values (400m buffer)
Water surface area (m2)	4818.36	150953.5
Green landscape area (m2)	121480	563880.2
Local street area (m2)	49818.72	119691
Outdoor parking area (m2)	21068.22	39567.85
Bike path area (m2)	12359.57	39222.3
Foot path area (m2)	33375.99	136071.5
Regional street area (m2)	19932.99	45598.65

It results in …

Housings	Values
Number of dwellings (SFH)	3
Number of dwellings (MFH)	0
Number of dwellings (mixed-use)	6
Total number of dwellings	9
Average volumetric size of dwelling (m3)	7036
Median volumetric size of dwelling (m3)	5891
Total dwelling volume (m3)	63325
SFH- Average volumetric size of dwelling (m3)	7140
SFH- Median volumetric size of dwelling (m3)	5891
SFH- Total dwelling volume (m3)	21421
MFH- Average volumetric size of dwelling (m3)	0
MFH- Median volumetric size of dwelling (m3)	0
MFH- Total dwelling volume (m3)	0
Mixed-use- Average volumetric size of dwelling (m3)	6984
Mixed-use-Median volumetric size of dwelling (m3)	2149
MFH- Total dwelling volume (m3)	41904
Percentage of housing volume / total volume	3.8%

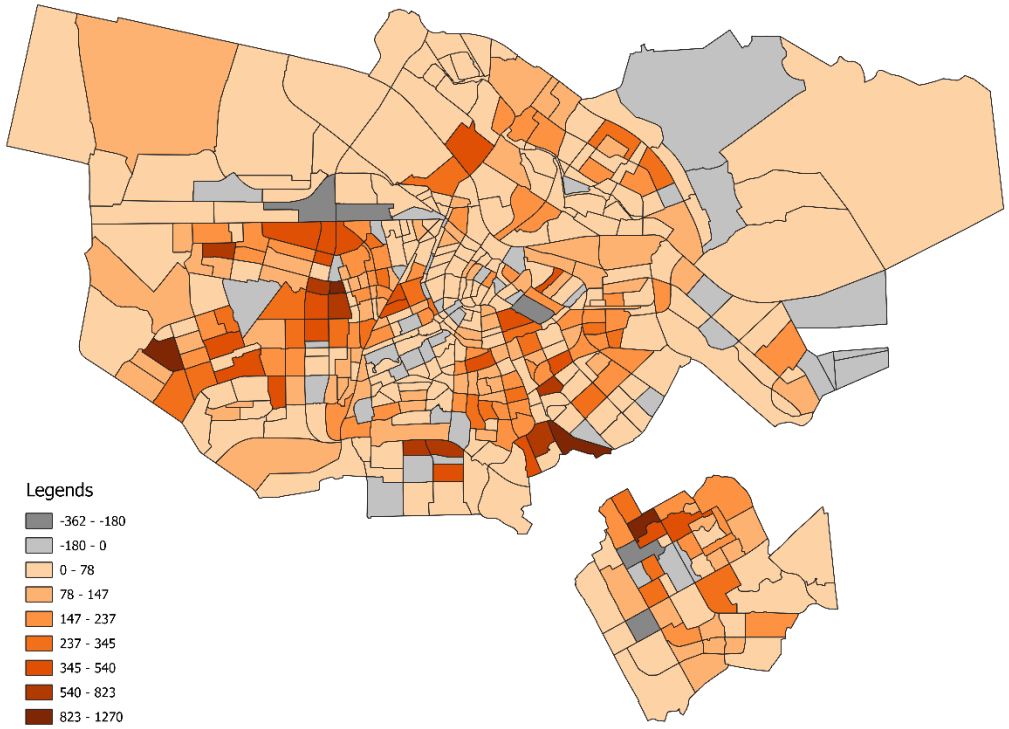
Urban KPIs for the pre-design stage

Design KPIs for the new development project

Number of households to number of dwellings

Current approach: use number of households instead of number of dwellings

Proposed approach: Query number of dwellings from the database



The difference between the number of households and the number of dwellings (household minus dwelling)

Solution:

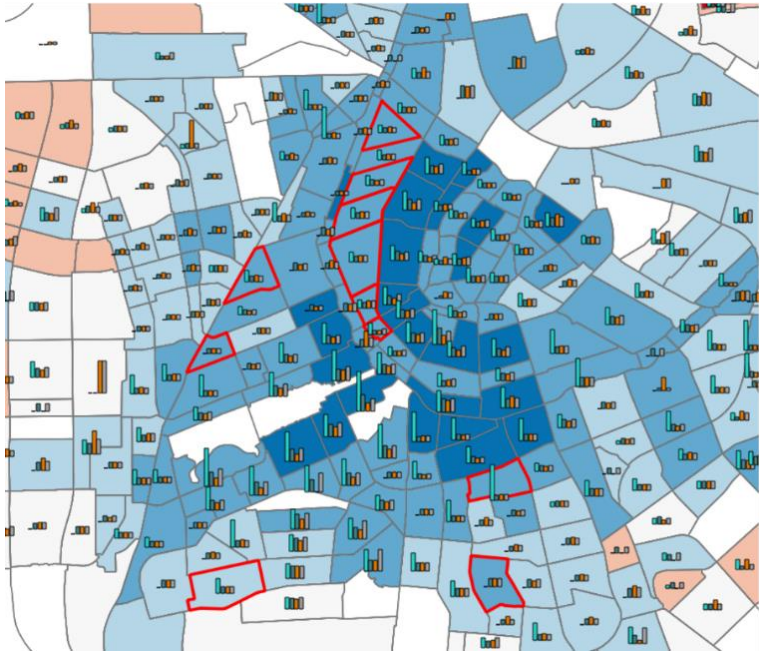
- Query for the average ratio between number of households and number of dwellings in the area surrounding the urban core.
- Resulted ratio: 1.16
- From 12864 households maximum to **11074 dwelling units**

Urban KPIs for the pre-design stage

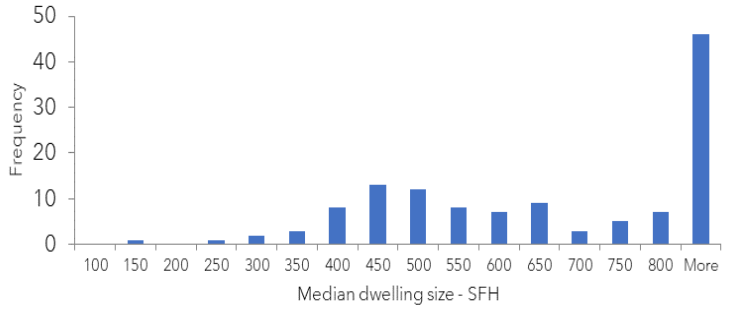
Design KPIs for the new development project

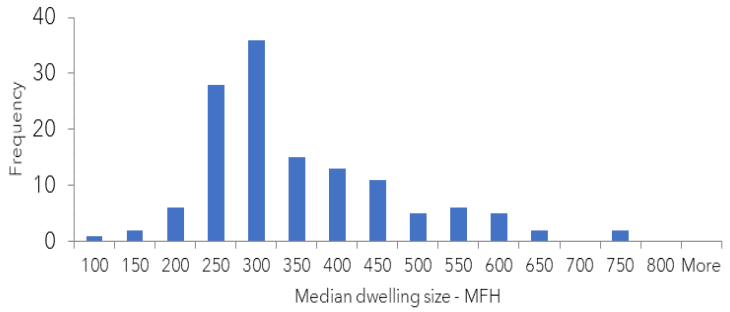
Average volumetric size of dwellings

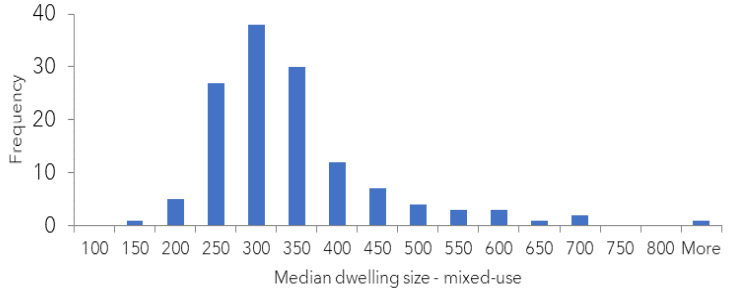
Current approach – template neighborhoods

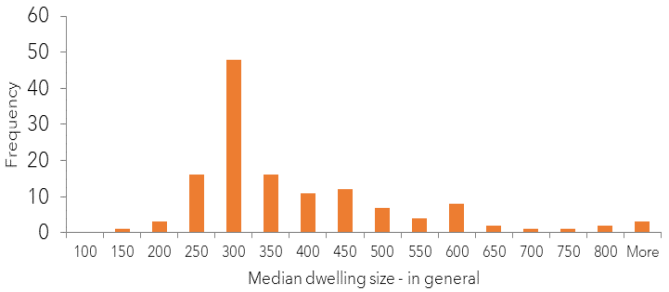


Proposed approach – query figures from different neighborhoods









Minimum 300 m3/dwelling unit

From city's regulation:
Minimum 25 m2/dwelling unit (net area) → 90 m3/dwelling unit (gross volume)

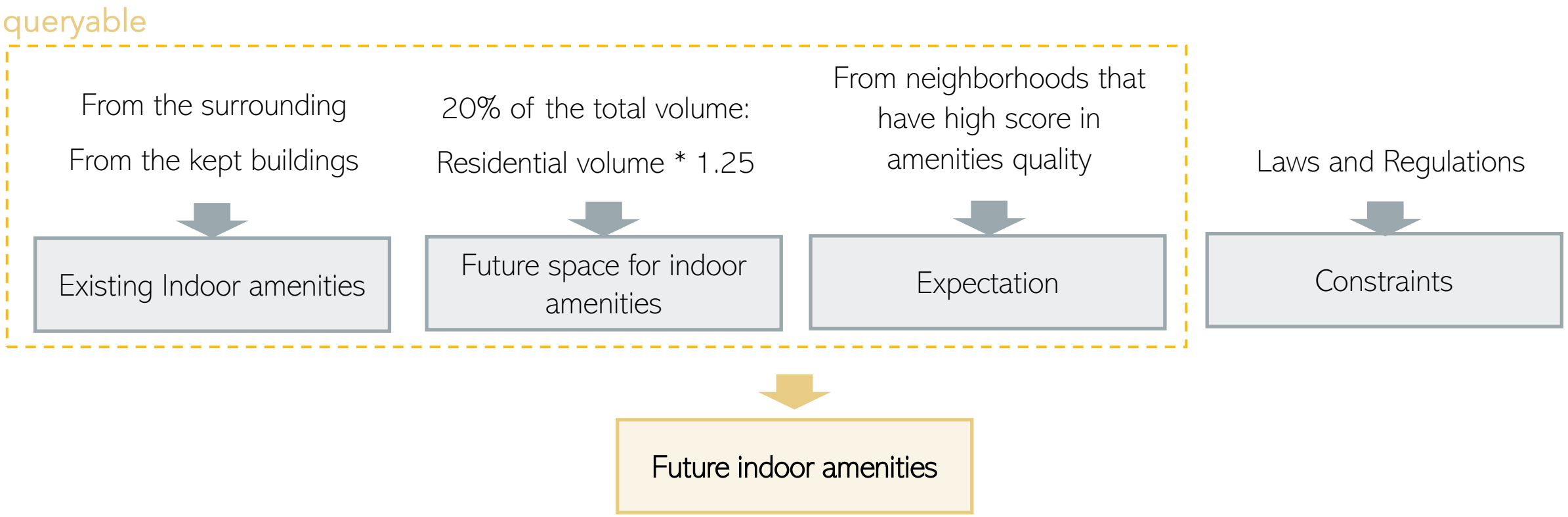
Urban KPIs for the pre-design stage

Design KPIs for the new development project

Indoor amenities

Current approach: Not available

Proposed approach: Query from the database

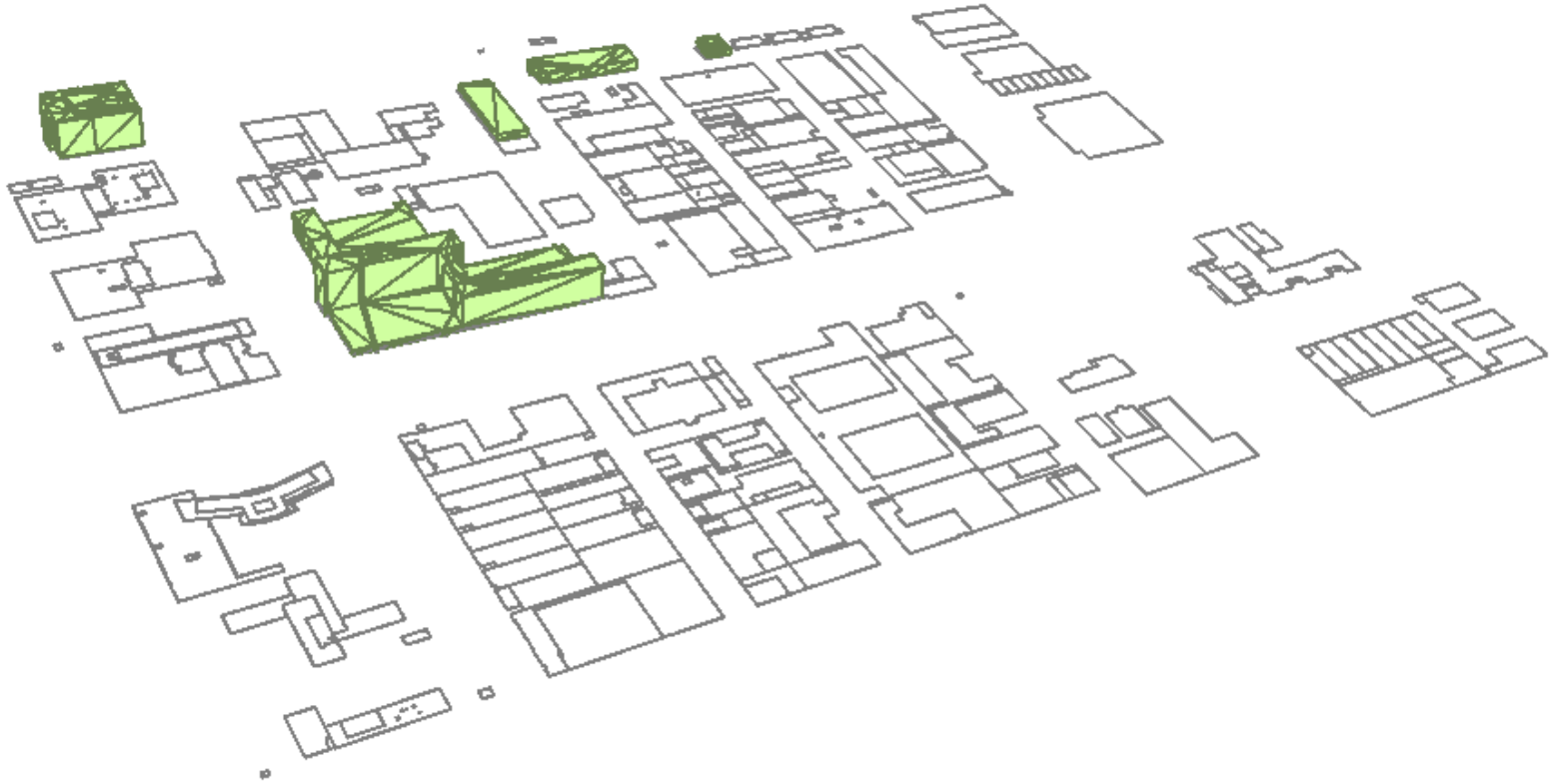


Urban KPIs for the pre-design stage

Design KPIs for the new development project

Current approach: Import the whole area and manually select building to be kept in Grasshopper

Proposed approach: Query geometries of buildings to be kept from the database



Urban KPIs for the pre-design stage

Conclusion

The “Buurt Generator” does not substitute the “urban planners” !!!

Deliver more KPIs and specific information to explore and describe the city context more comprehensively.

KPIs must comply with stakeholders’ needs and the existing regulations and constraints of the city.

Temporal (spatial) datasets, detailed quantitative or descriptive data could also be added to further clarify the city context.

Some constraints were added to remove some probably wrong data.

Some assumptions were made on the data, too.

Further in-depth investigation must be conducted to overcome data inconsistencies.

Official reports on the detected problems could be generated to be submitted to the authorities.

Urban KPIs for the pre-design stage

National datasets

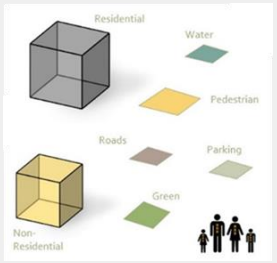
BGT BRK AHN3 CBS (3D)BAG ...PDOK

Local datasets

Amsterdam Maps data

Semantic 3D city model

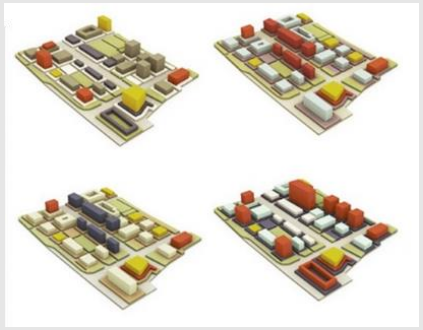
Spatial analysis
(KPIs & design parameters)



is not treated in this thesis

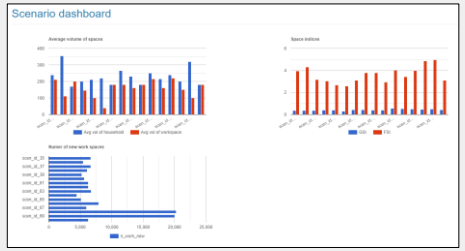
Urban planning constraints

Design process and scenario generation



Scenario evaluation
Integrate scenarios with the 3D city model

Share, compare, evaluate scenarios online

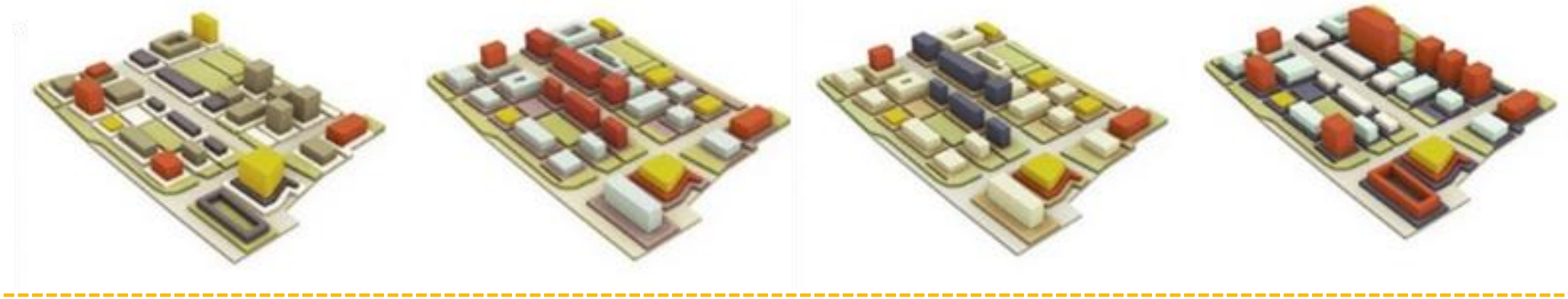


Provide feedback

Choose scenario

Post-design evaluation

Design stage



How to compare the scenarios and select the best (or better) one?

Post-evaluation framework

Post-design evaluation

National datasets

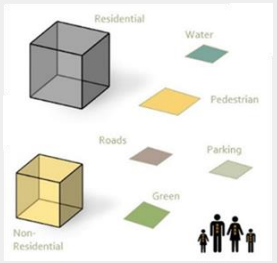
BGT BRK AHN3 CBS (3D)BAG ...PDOK

Local datasets

Amsterdam Maps data

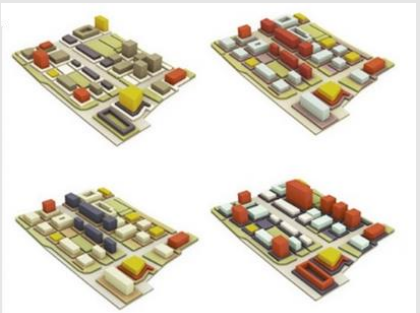
Semantic 3D city model

Spatial analysis
(KPIs & design parameters)



Urban planning constraints

Design process and scenario generation

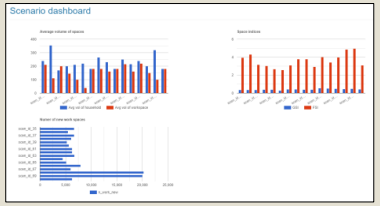


Provide feedback

Post-design framework and implementation

Scenario evaluation
Integrate scenarios with the 3D city model

Share, compare, evaluate scenarios online



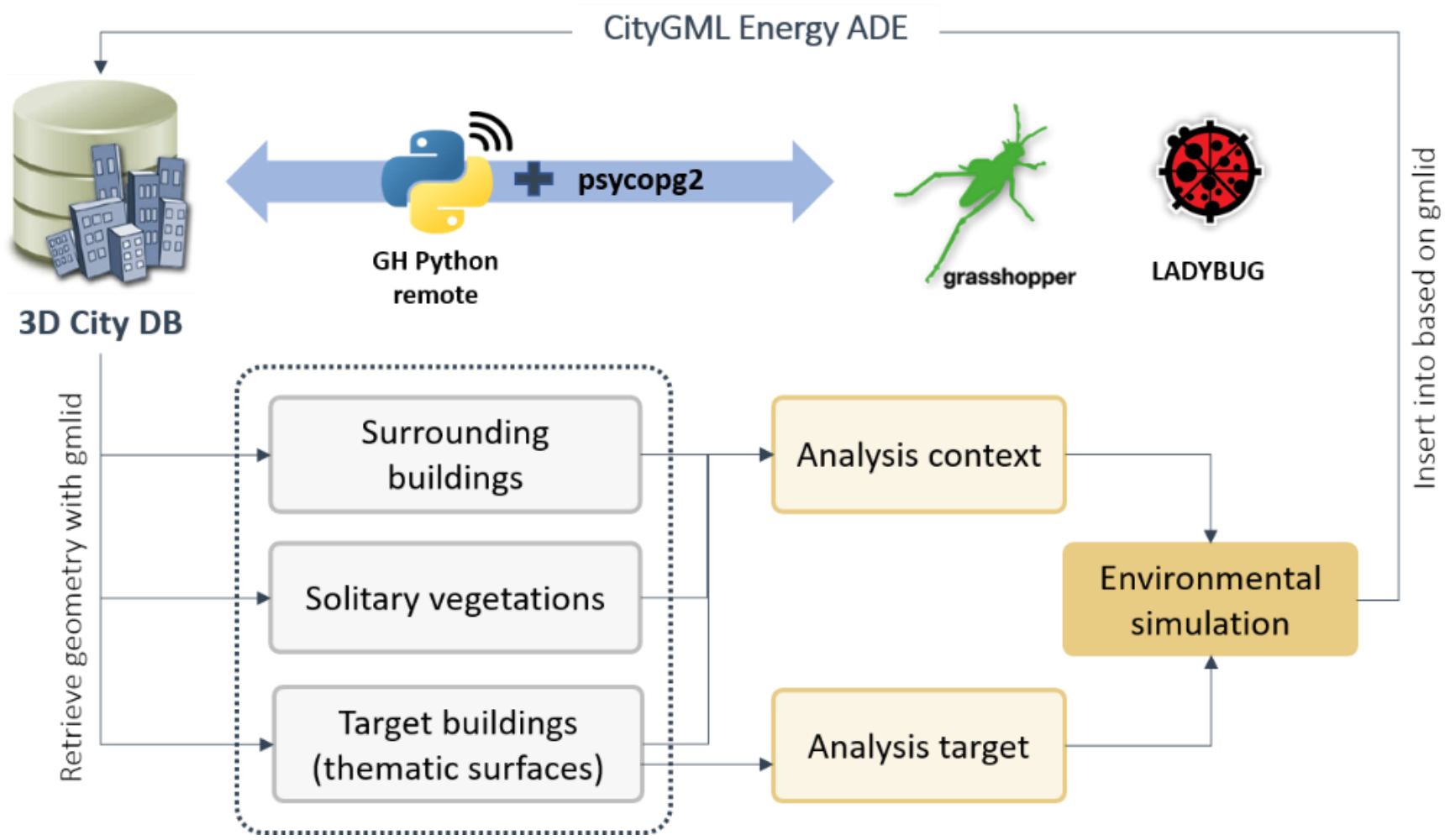
Choose scenario

Post-design evaluation

Themes		Criteria	Indicators	Method/Tool
Environment	Weather	Energy efficiency	Global solar radiation for the scenarios and the surrounding	Grasshopper/Ladybug radiation study
		Outdoor thermal comfort	Outdoor thermal comfort within the scenarios and the surroundings	Grasshopper/Honeybee thermal comfort study
	Green infrastructure	Greenspace	Distribution of private and public green space	2D Spatial statistical analysis (multiple tools available)
		Roadside greenery	Distribution of roadside greenery	2D Spatial statistical analysis (multiple tools available)
	Built landscape	Views	Viewsheds from new buildings and old buildings Height differences compared to the surrounding and compared to the city	3D visibility analysis (multiple tools available)
		Level of compactness	Building volume density	Calculation (multiple tools available)
Social	Accessibility	To green space	Catchment volume of new green spaces	Network analysis (multiple tools available)
		To kindergarten and primary school	Catchment volume of kindergartens and primary schools	
		To public transportation	Catchment volume of public transport stations	
		To leisure destinations	Catchment volume of leisure destinations	
		To health care amenities	Catchment volume of health care amenities	
	Integrity	Level of mixed-uses	Distribution of housing types Distribution of amenities	Network analysis (multiple tools available)
		Evenly distribution	Distribution patterns and the average distance from inhabitants to amenities	Spatial analysis (multiple tools available)
Economic	Local economic, real estates, and jobs	Office, commercial, housing	The net floor area of each function	Calculation (multiple tools available)

Post-design evaluation

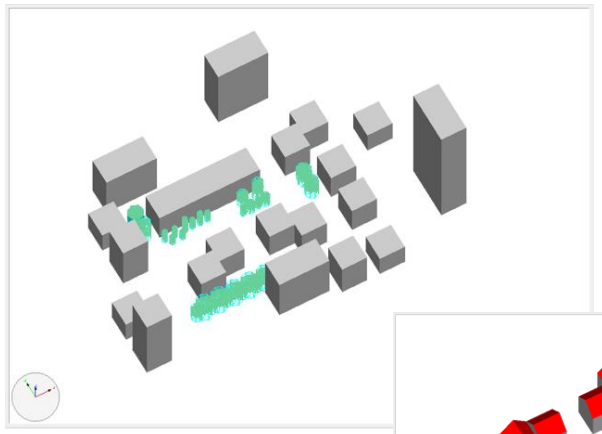
Solar radiation analysis



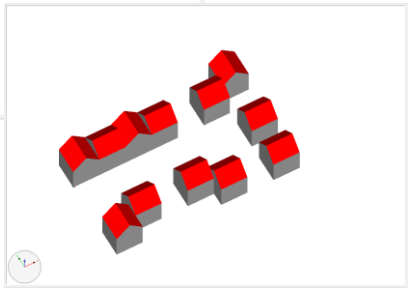
Post-design evaluation

Solar radiation analysis

Dataset for testing: The Alderaan City

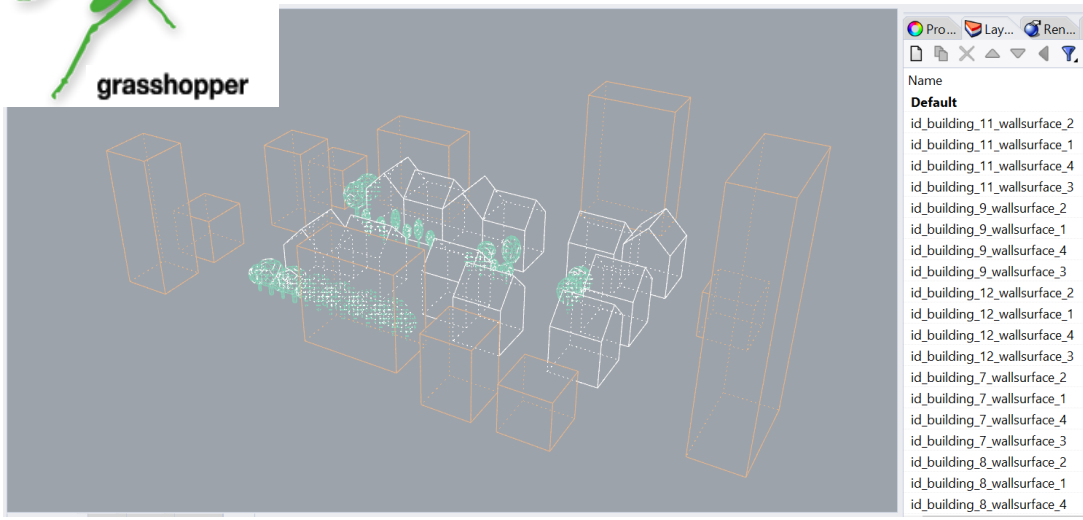


CityGML data



3D City DB

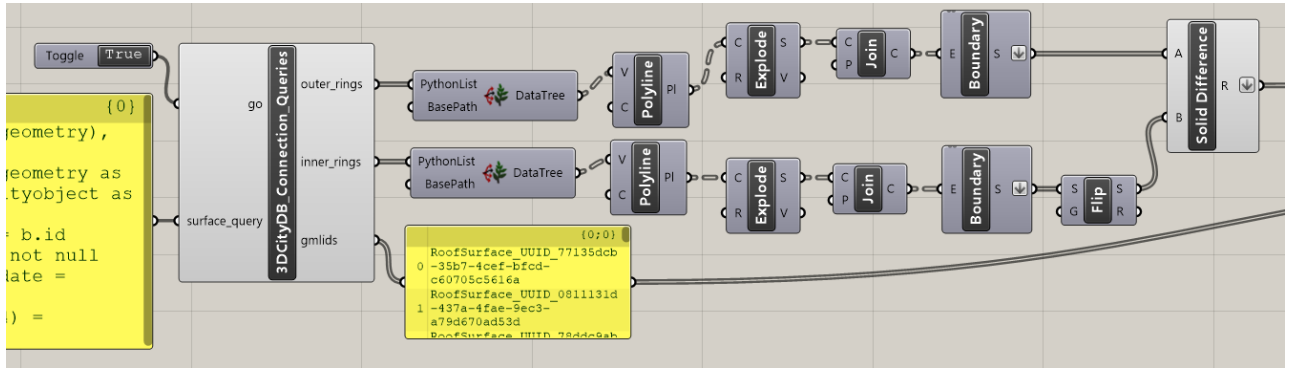
GH Python
remote



Post-design evaluation

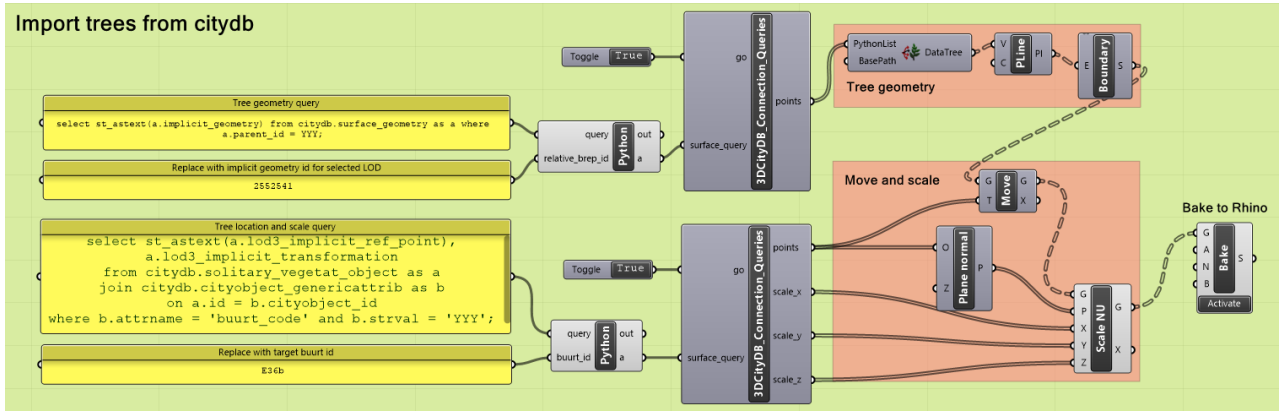
Solar radiation analysis

Query buildings' geometries

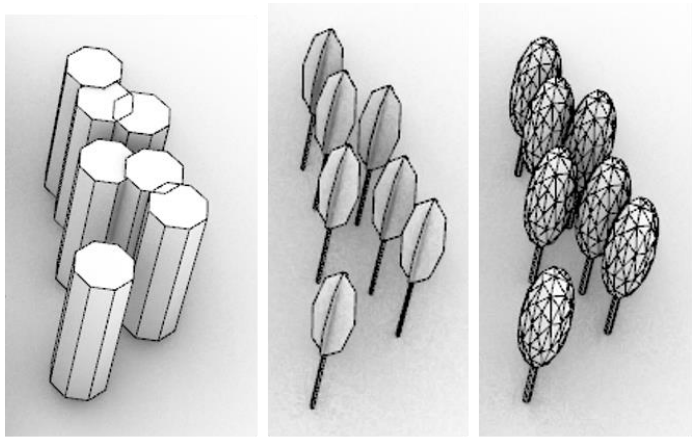


Grasshopper workflow to query and reconstruct surface geometry (Roof surfaces)

Query vegetations' geometries



Grasshopper workflow to query and reconstruct tree geometry



LOD1 LOD2 LOD3

Prototypic geometry

Implicit reference point
(to move geometry to point location)

+

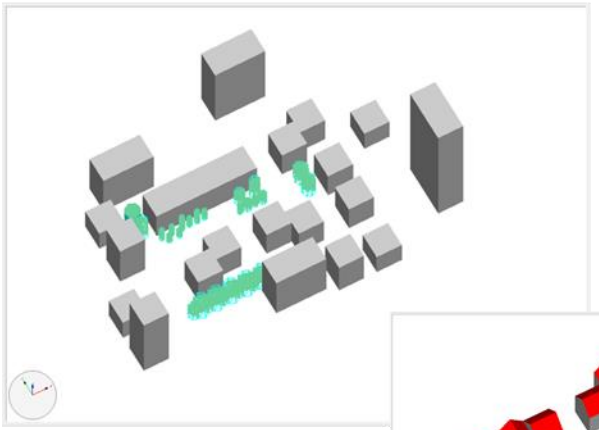
Implicit transformation
(scale geometry)

$$\begin{bmatrix} Sx & 0 & 0 & 0 \\ 0 & Sy & 0 & 0 \\ 0 & 0 & Sz & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

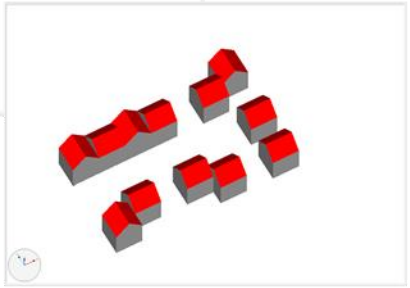
Implicit Representation

Post-design evaluation

Solar radiation analysis



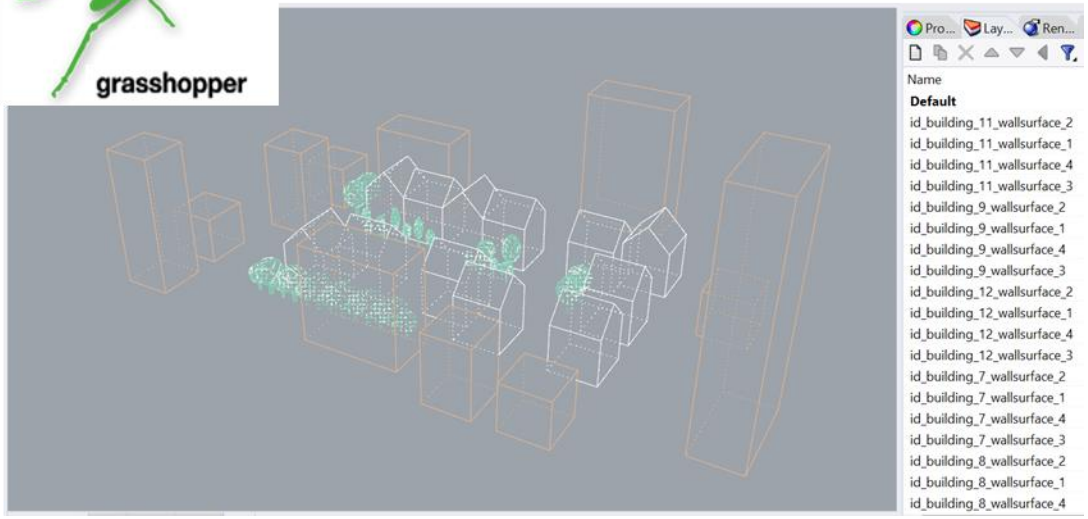
CityGML data

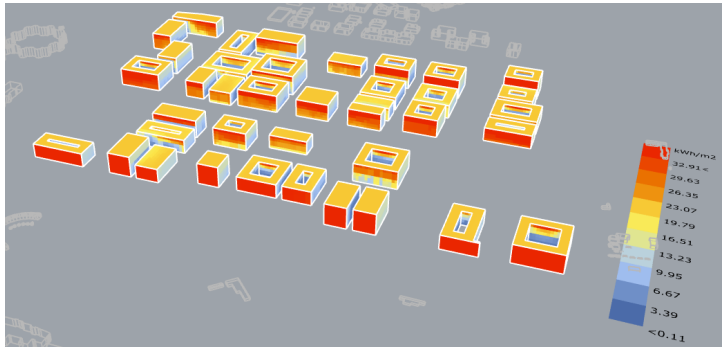


3D City DB

GH Python remote

grasshopper

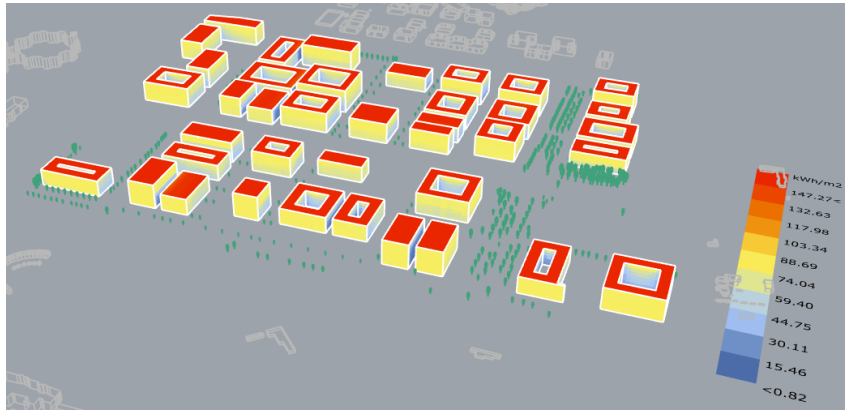




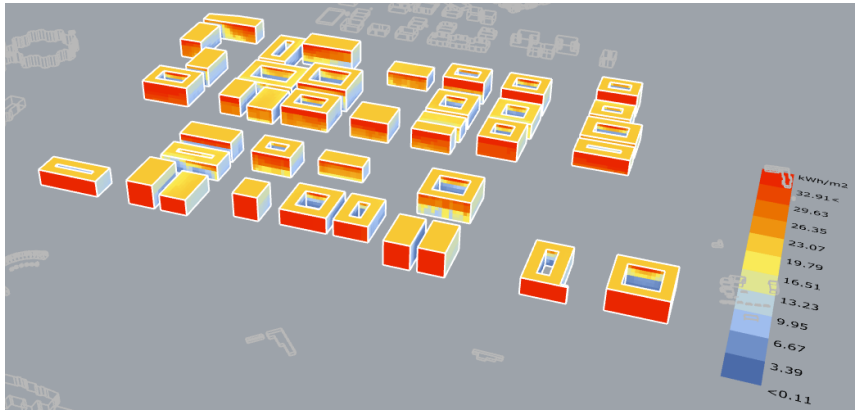
LADYBUG

Post-design evaluation

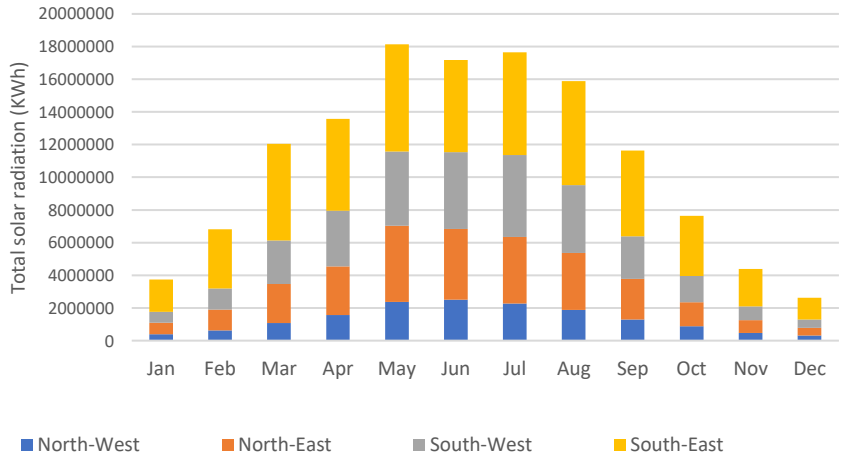
Solar radiation analysis for the scenarios



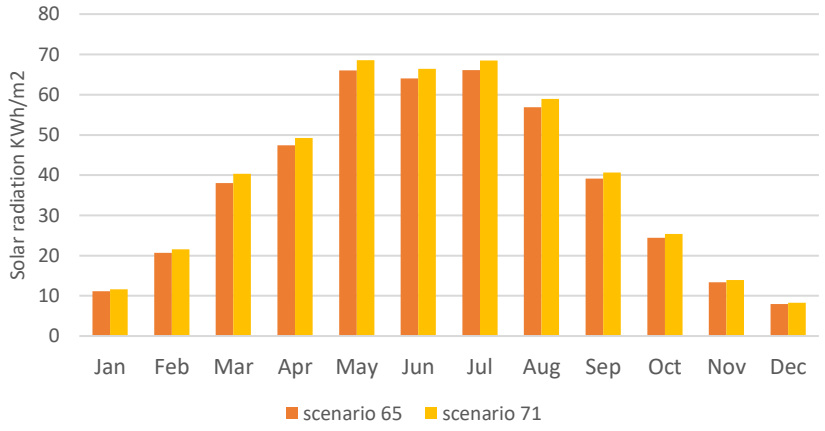
Radiation analysis of scenario 71 in June



Radiation analysis of scenario 71 in January



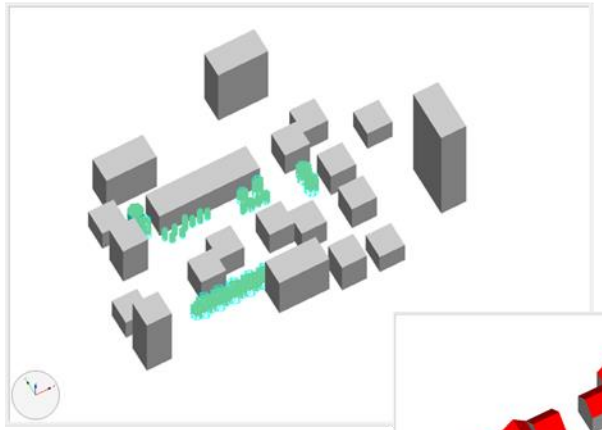
Total solar radiation on wall surfaces according to the wall's azimuth - scenario 71



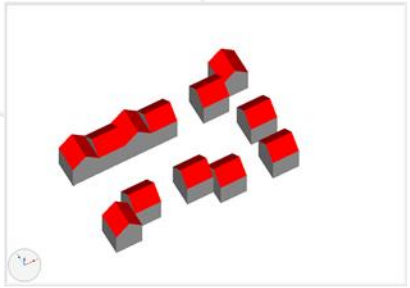
Solar radiation per m2 on wall surfaces – scenario 71

Post-design evaluation

Solar radiation analysis



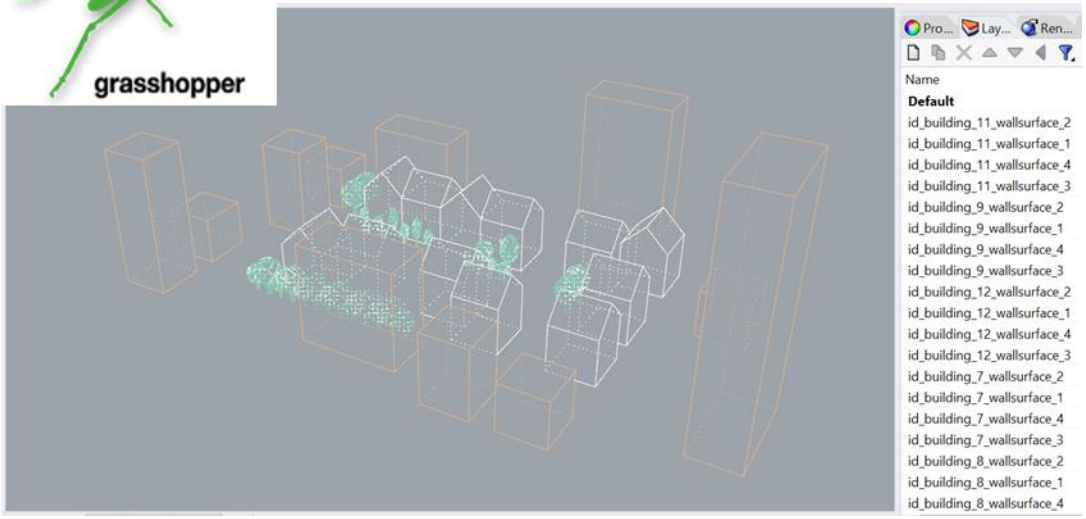
CityGML data



3D City DB

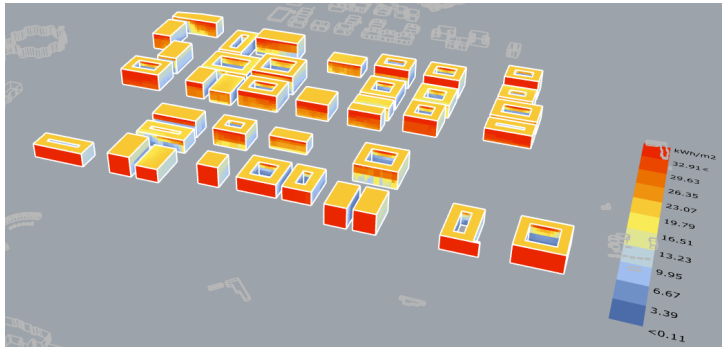
GH Python remote

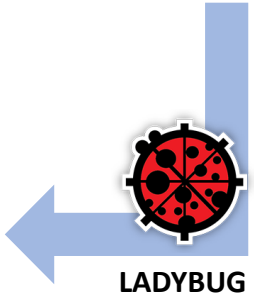
grasshopper



Energy ADE

GH Python remote





LADYBUG

Solar radiation analysis

Write the solar radiation values back to the database employing Energy ADE

Post-design evaluation

Conclusion

Bridging the gap between 3DCityDB and Grasshopper

Urban simulation is a fast-growing field with many applications and plugins being developed that could be employed for the post-evaluation of development scenarios.

The same approach could be reapplied for most of the remaining post-evaluation criteria in the proposed framework.

Promote data circulation and data reuse for other urban applications.

Contributing to testing the implementation of the Energy ADE, finding bugs, reporting them, and having them solved

Conclusion

National datasets

BGT

BRK

AHN3

CBS

(3D)BAG

...PDOK

Local datasets

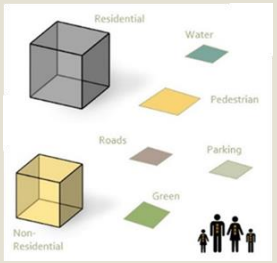
Amsterdam Maps data

Semantic 3D city model

Check accuracy of building stock volume

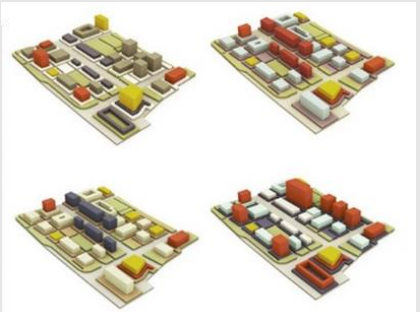
Expand urban KPIs

Spatial analysis
(KPIs & design parameters)



Urban planning constraints

Design process and scenario generation

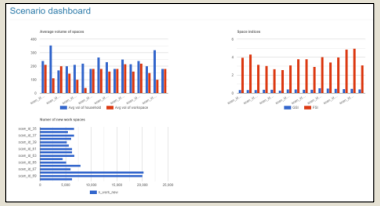


Provide feedback

Post-design framework and implementation

Scenario evaluation
Integrate scenarios with the 3D city model

Share, compare, evaluate scenarios online



Choose scenario

THANK YOU