

An interactive design tool for urban planning using the size of the living space as unit of measurement

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MSc Geomatics Thesis

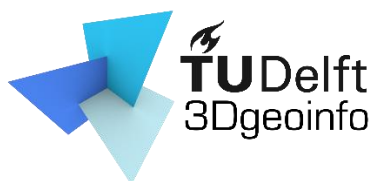
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Abstract

In urban planning, one of the common units of measurement for population density is the amount of households per hectare. However, the actual size of the households is seldom considered, neither in 2D nor in 3D. This thesis proposes a method to calculate the average size of the households from existing urban areas based on available open data and to use it as a design parameter for new urban developments. The proposed unit of measurement is comprehensive of outdoor and indoor spaces, the latter comprising both residential and non-residential space. As a test case, the Haven-Stad project in Amsterdam was chosen, specifically its second phase, Sloterdijk One, envisioned by the municipality of Amsterdam to host 11220 households and 7480 working places by 2040. The sizes of typical households, as well as a series of other KPI's (Key Performance Indicators) were computed in different neighbourhoods of Amsterdam based on their similarities with the vision of Sloterdijk One. In the second part of this thesis, the resulting size of the households were used as a design parameter in a custom-made prototype tool to generate semi-automatically several design proposals (called scenarios) for urban developments. Additionally, each scenario can be converted into a Geo format to visualize it in web-based virtual platforms such as Google Earth and Cesium JS. Significant differences among the resulting design proposals based on this new unit of measurement were encountered, meaning that the average size of a household plays indeed a major role.

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Acronyms

AHN ₃	<i>Actueel Hoogtebestand Nederland 3 – Current height file Netherlands 3</i>
CRS	Coordinate Reference System
KPI	Key Performance Indicator
LoD ₁	Level of Detail 1
FSI	Floor Space Index
FME	FME software (Safe Software)
GH	Grasshopper software
GSI	Ground Space Index
NAP	<i>Normaal Amsterdams Peil – Normal Amsterdam Level</i>
NHDI	Neighbourhood Household Density Index
ANPI	Average Neighbourhood Price Index
NR	Non-residential use
ANYI	Average Neighbourhood Year Index
PI	Parking Index
RESID	Residential use
Rhino	Rhinoceros software

1. Introduction

Geomatics and Geodesign are two concepts tightly related by their *spatial dimension*; the first one is the discipline responsible for handling spatially referenced information (*ISO/TR 19122:2004*), and Geodesign is a multidisciplinary approach to face spatial challenges in built and natural environments (*Steinitz, 2012*). This thesis is an example of how these two concepts can find their connection using the size of the living space as a unit of measurement in urban design projects.

In urban planning, one of the common units of measurement for population density is the amount of households per hectare (*Torrens & Alberti, 2000*). However, the actual size of the households is seldom considered, neither in 2D nor in 3D. In this thesis, the overall idea is to add the spatial size of the households, and - more in general - the size of the typical "living space" to the urban design process. The size of the living space will be first estimated from a virtual city model of a real city, and then used as a quantitative design parameter for a new development area.

Please note that the concept of living space is intended here to be comprehensive of indoor, outdoor, residential and non-residential spaces, and considers all the spatial elements inside of a neighbourhood, such as green areas, water, streets, pedestrian areas, bicycle lanes, parking lots, etc.

As test case, the Haven-Stad project in the city of Amsterdam was chosen because of its envisioned development plans: 70000 new households in the following 20 years are expected to be built. In particular, the second stage of the project called "Sloterdijk One" located in a western area of Amsterdam, was chosen due to its size (58 hectares) and the planned number of new households (11,220) to be built over that area.

In the first step, the major goal is to describe and characterise quantitatively the current situation of Amsterdam (and its neighbourhoods) by computing a series of meaningful KPIs (Key Performance Indicators). Such KPIs, combined with professional knowledge in urban planning, can help city makers in 'reading' and understanding the *city of the present*.

Furthermore, different spatial and non-spatial datasets were therefore collected and harmonised. KPIs were computed to take into account aspects tied to land use, housing density, price of the households, quality of life, year of construction of the buildings, etc.

Thanks to these KPIs, and having in mind the overall target goals and regulations given by the Municipality of Amsterdam for "Sloterdijk One" (e.g. density: 192 households/hectare, residential use: 80% of new construction spaces, social housing: 30% of households, quality of life: high - *Sloterdijk I Strategie nota 2016*), similar *existing* neighbourhoods in Amsterdam were identified and selected.

In the second step, different calculation methods were defined and implemented for each selected neighbourhood in order to extract a number of parameters and eventually compute the size of the typical living space in each neighbourhood.

For each neighbourhood, average values for indoor spaces (calculated as volumes in 3D) and for open spaces (calculated as areas in 2D) were extracted. Computation of indoor spaces was further specialised into residential and non-residential. LoD1 (Level of Detail 1) geometries of buildings were used for this purpose. First, non-residential spaces were computed, and then gross residential spaces were obtained as difference between the LoD1 volumes and the non-

residential ones. A conceptually similar approach was followed to compute the outdoor spaces, though they were obtained as values of areas.

Finally, in the third step, the different sizes of the living spaces obtained in the previous step were used as reference to design the *city of the future* helped by a custom-made software. This software (also called tool), is a prototype to create semi-automatically design proposals for urban developments. The purpose of the tool is to speed up the design process and allow the creation of many design proposals in the same study area in a quick and interactive way. The user can set and vary several design parameters and, on the fly, a new design proposal is generated.

Additionally, each proposal could be exported in CityGML format and imported into an existing city model platform in order to facilitate data visualisation and exploration in the urban context, using for example the Cesium JS web-based library or Google Earth.

The following chapters will report in detail about each above-mentioned steps, will outline the methodology and workflow established, will describe the challenges encountered, and illustrate and comment on the partial and final results.

1.1 Research question

The main research question for this thesis is:

What is the size of the living space in Amsterdam in relation with housing density and housing prices, and how this dimension can be used as a unit of measurement for new housing developments like Sloterdijk One in the Haven-Stad project?

1.2 Objectives and scope of the research

Two main objectives are present in this thesis, the first one, is to create a method to calculate the average size of the living spaces in Amsterdam and the second one is, to understand how these dimensions can be used for urban development projects.

The first goal is aimed to understand the current situation of our cities through existing open data. The generated information is intended to facilitate the way of reading the city for urban planners and propose a new unit of measurement in urban development projects.

The second part of the thesis is related with the creation of a prototype software. The scope is to find a method to make research by design, allowing the user to create several design proposals in a quick and graphical way, using the unit of measurement calculated previously.

The tool is also intended to help governmental parties during the decision-making/design process. Sometimes, these processes can last up to 10 years before the first step is made. During these years, the guidelines or parameters of a project can change or lapse, because of this, the tool can be used in the following stages of the design process:

- **Before:** To help establish the minimum parameters of a new project.
- **During:** To review the guidelines and check if the parameters are up to date.
- **After:** To adjust the parameters or add extra information to the analysis over time.

Finally, the tool was also thought to facilitate the participation of many stakeholders from different fields of expertise in the same project, as it allows the visualization and digitization of ideas in a quick way. A process that nowadays is expensive and time consuming.

1.3 Overview of the research

The described goals of this research can be translated into a workflow in which geographical data is the main source of the process (figure 1).

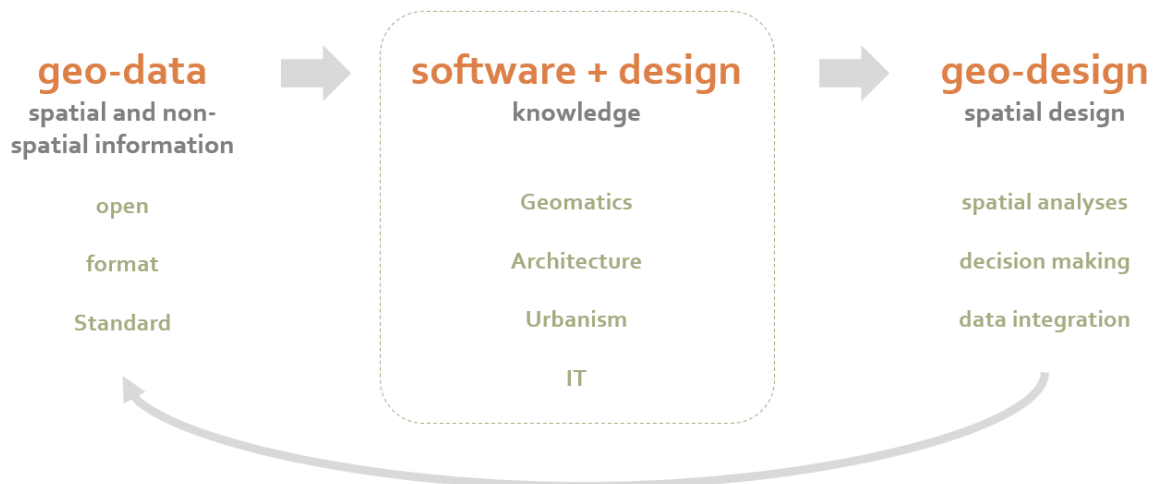


Figure 1. Workflow of the research project.

Spatial information from the existing built environment is the main input. This data, in most cases, needs to be pre-processed and harmonized to be useful, as it comes from many different sources.

Once this information is in the desired format, it is imported in a software, in which users, based on professional knowledge, process and analyse this information to generate multiple design solutions for urban challenges. On this stage, the Geomatics approach described by *Steinitz (2012)* is a reference to face spatial challenges from multiple points of view. As users can have different areas of expertise, the resulting outcomes from the same project can be contrasting among each other.

The output of this research is the combination of knowledge, design, software and spatial data, within this consideration, it can be named as geo-design or spatial design.

Finally, in order to increase the chances of reproducibility of this outcome, it could be helpful to use an international standard format, for example, CityGML (*Kolbe 2009*). By adopting this format, the process will facilitate a global integration of information for possible benefits in a near future.

1.4 Scientific Relevance

According to an article published by the UK government (*CPRE, 2002*), when designing a low-density housing development, the land is wasted. It is true that, those households enjoy bigger open spaces, but it is completely unsustainable. In the Netherlands, one of the smallest and denser countries in Europe (*World Bank WV.1*), this issue has great relevance, especially in urban environments like Amsterdam, where the lack housing is becoming a primal need (*Structuurvisie Amsterdam 2040*). For this reason, it is important to understand the size the living spaces (indoor and outdoor) when designing future urbanizations.

The quality of life, in residential areas, is another parameter recurrently studied but hardly quantifiable. Most of the people make a direct relation between high liveability green spaces but this is only one parameter out of many. For example, regarding open spaces, a scientific study in the Netherlands (*Maas et al. 2016*) revealed that while the greener is the neighbourhood, healthier its inhabitants, or according to *White et al. (2012)* in the UK, the inhabitants can be happier with bigger green spaces.

Regarding indoor spaces, the size of the households is also a sign of good quality of life. According to *Foye* in the UK (*2016*), bigger dwellings can increase the levels of subjective well-being but only for a short period.

Having said this, a good method to calculate the size of the living space can help to improve the quality of the built environment by providing information necessary to use wisely the land that remains available in cities.

2. Theoretical background & related work

2.1 Used concepts overview

Urban planning

According to *Hall et al. (2010)*, urban planning is a technical process aimed to create a spatial representation of activities (land uses) to improve the quality of the built environment. For this thesis, the urban planning discipline is approached from a technical point of view, trying to speed up and facilitate the work of urban planners.

Urban planner

Is the professional figure in charge of creating urban planning projects. This character is the intended user of the parametric tool created in this thesis.

Urban development

According to *Steiner (2006)*, urban development is the way to manage the expansion of cities. For this thesis, urban development is referred to the typology of the projects designed with the help of the interactive tool.

Housing density

"Density refers to the number of housing units per area of land", *Steiner (2006)*. For this project, the density is always calculated as gross density, using the number of households per hectare, including infrastructure, open space and private space.

Private space

Private space is the land included inside of parcels or plots. Even if the municipality is the owner or it is designated to a public space function. The used plots dataset is the *Basisregistratie Kadaster (BRK)*.

Public space

Public space is the land outside of the private plots, better known as the streets, parks or squares. It is the land administrated directly by the municipality.

Indoor space

Is the gross space occupied by the buildings or covered areas by human-made constructions.

Open space

Is the uncovered space, private or public.

Green space

This is the space dedicated to vegetation including planting stripes in sidewalks.

FSI

Floor Space Index is a proportion measurement that compares the total area of construction with the surface of the plots (figure 2).

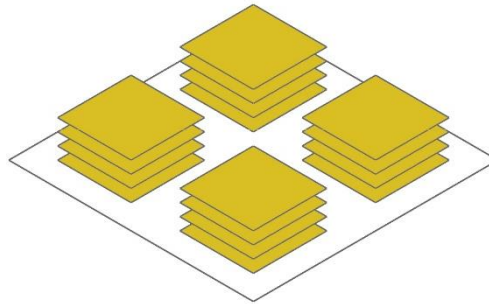


Figure 2. Graphical representation of the FSI.

GSI

The Ground Space Index is a proportion measurement that compares the area of the building footprints with the surface of the plots (figure 3).

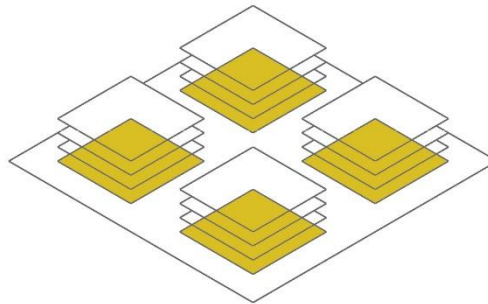


Figure 3. Graphical representation of the GSI.

Proportion of residential and non-residential space

According to *van Nes et al. (2012)*, the Function Mix model is a measurement that indicates the de degree of multi-functionality of a determined urban area based on a three-dimensional model considering the amount of amenities, dwellings and working places.

For this thesis, this reference will be translated into a bi-dimensional ratio, calculating the proportions among residential and non-residential space.

2.2 Related Work

OnTheGo - *The Why Factory 2017-2018*

Aimed to optimize interior spaces in buildings, students and researchers from TU Delft (*The Why Factory 2017-2018*) calculated the minimum space needed to realize routine activities of daily life. The volume calculation was made by placing sensors in the human body while the activities were made. The resulting information was voxelized and distributed inside of a virtual box (the future building). Afterwards, this cluster of 3D spaces was flattened into a 2.5D representation, and interpreted as a building façade. Finally, the extrusion of the negative space became the shape of the final building (figure 4).

This project is focused purely on local measures ignoring the environmental conditions of the daily activities.

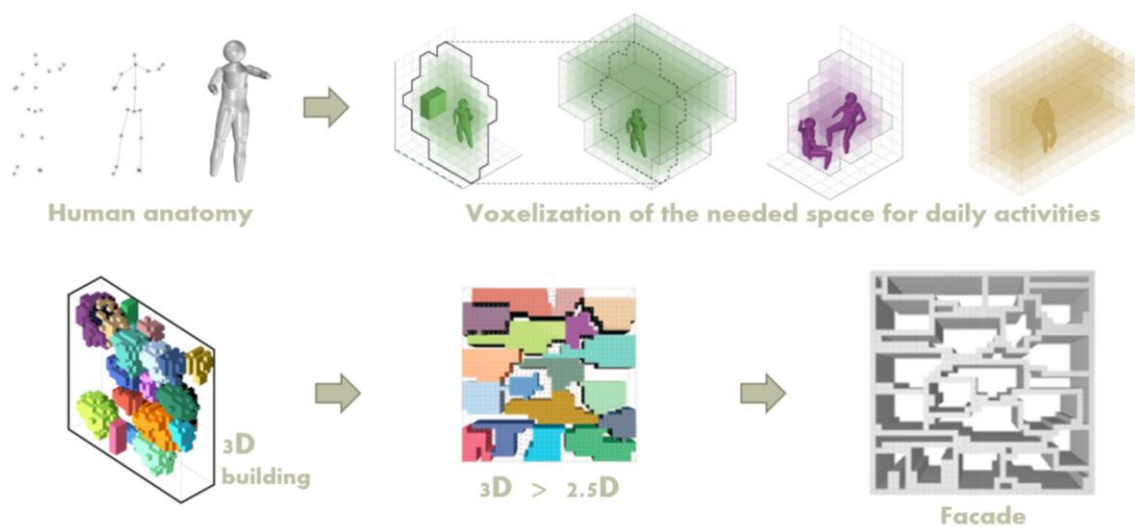


Figure 4. Extract from the procedure ONTHEGO project - *The Why Factory (2017-2018)*.

Inspired by this project, a similar approach was used on this thesis by using the average size of the living space and multiply it to design a new part of a city.

An Experimental Methodology for Urban Morphology Analysis - *Kepczynska-Walczak et al. 2017*

Regarding to data analysis, the authors propose a method to process urban data based on GIS tools and New Urbanism typologies in an automated way. The results are a classification of the urban space based on different 8 parameters: Floor-area ratio, Height of built-up areas, Lot coverage, Residential density, Frontage buildout, Lot proportions and size, Block size (only in irregular urban blocks method) and Land use mix.

Each of these parameters were combined as multi-criteria analysis on different scales: urban blocks (current grid of the city structure) and squared blocks (100 x 100 meters). The resulting maps and data allow the comparison between areas within the city, for example, the difference

in proportions between an historical urban core and the modern urban developments of the city.

This method was carried out in a city scale using as a test case the city of Lodz in Poland (figure 5).

In relation with this thesis, a similar approach is studied on this graduation project but in a smaller scale (neighbourhood size) and adding 3D implementations for volume calculations.

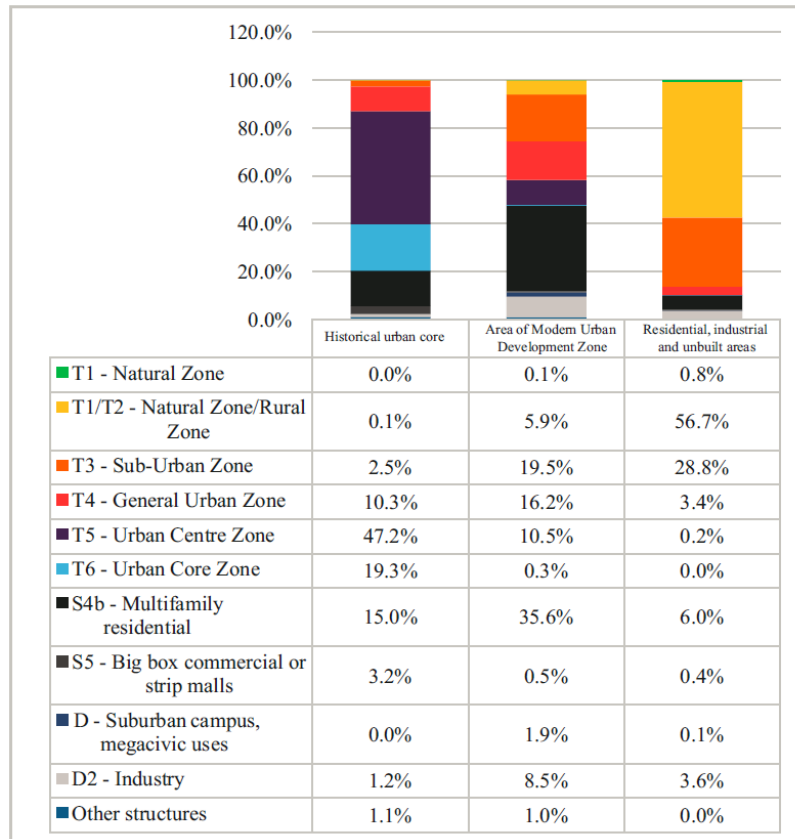


Figure 5. Extract from the results of the research. Comparison of the different spaces by function in Lodz Poland (Kepczynska-Walczak 2017).

The relation between the size of living space and subjective well-being - Foye, 2016

The focus of this research is on the effect of the size of the living space in UK citizens, based on the British Household Panel Survey (BHPS). The concept of well-being in this research was always considered as subjective, nevertheless, patterns of positive impact were defined as well-being indicators found mostly in male citizens when the size of the household increases. In most of the cases, these effects were manifested only temporarily.

A point in Foye's research that clearly fits with the research of this thesis is the study of the home size reduction on recent years in UK. This behaviour seems to be relevant in the all Europe, leading designers to redefine the way of conceiving new developments.

Interactive Visualization Tool (InViTo) – Pensa et al., 2014

This research gives interactive and visual support in the decision making process of large-scale urban planning projects. It allows the user to manage interactively dynamic urban scenarios. According to the author, the main goal of the tool is to calculate and visualize accessibility in participated planning processes.

The tool was implemented in Rhinoceros and Grasshopper because of its capacity of manage and visualize data on real time with the possibility of customization. This software allows the user to create virtual shapes using generative algorithms.

One of the strengths of the tool is the combined use of spatial data and generative models to facilitate the communication of information among different stakeholders by using Google Earth as a post-visualization tool to involve non-experts in the decision-making. The drawback of the tool is that the output is a 2D product, which in a large scale is effective but in a smaller scale is lacking of spatial attributes.

Interactive Urban Synthesis - Koenig et al. 2017

This paper proposes a method to generate urban development projects based strictly on computer-based design. It allows the user to create multiple design scenarios in a quick, but not interactive way as the possibility of manipulating the generated geometries is not allowed (figure 6).

The method was implemented in Rhinoceros and Grasshopper and it starts with the creation of a road network in a determinate area based on, partially, random values. From this generated infrastructure network, are dependent the blocks and subsequently, plots, which are generated as well in an automated way.

The project is fully implemented in 3D considering the topology of the terrain and 3D buildings.

The tool solved the four processes in the urban structures proposed by *Webber et al. (2009)*: road network, land use areas, parcels and buildings, but it lacks of human interaction. Having said this, the user can only evaluate the results but not improve the quality of the design based on professional knowledge.

Finally, the authors state that their project can be complemented with a database containing a collection of pattern analysis from existing urban situations for the generation/evaluation of urban layouts, which is one of the proposals of this graduation project.

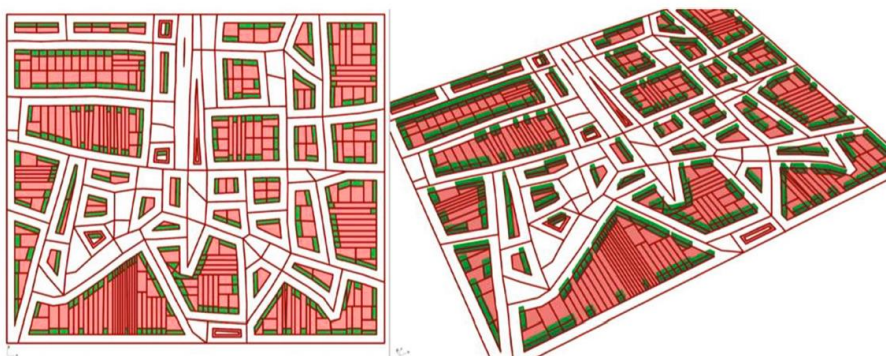


Figure 6. Urban fabric generated with the tool (Koenig et al. 2017).

CIM-St A Parametric Design System for Street Cross Sections - *de Klerk et al. 2017*

This paper contains a method to generate, semi-automatically, street cross sections for road types. This is an extended version of other web-based tools with the same scope, for example, the Abu Dhabi Urban Street Utility Design Tool (<http://usdm.upc.gov.ae/USDM>), Streetplan (<http://streetplan.net>) or Streetmix (<http://streetmix.net>).

The method was thought for Rhinoceros and Grasshopper and complemented with a personalized user interface (Human UI, <http://www.food4rhino.com/app/human-ui>). At the beginning of the process, the user can upload an XML database with the concepts to use as street components, for example, sidewalks, car lanes, bicycle lanes, green stripes, parking lines, etc. (figure 7).

The tool is intended to create final and accurate design proposals. For this graduation project, a similar and simplified method is used to design the basic parameters in road modelling to calculate open spaces in an urban design project.

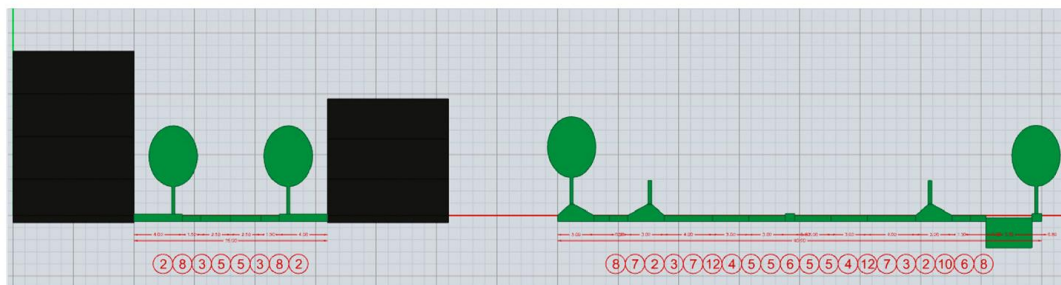


Figure 7. Examples of the generated street profiles (de Klerk et al. 2017).

City-Maker - *Beirão 2012*

This doctoral thesis is focused on generating interactive urban design proposals for medium scale projects by using urban design induction patterns. The implementation of the software is Grasshopper based integrating the GIS logic for modelling the city. The research is well addressed from the urban planning perspective having as main goal the generation of better design proposals focusing in the urban fabrics of the city (figure 8). The road modelling and the block design act as protagonists in the design process while the indoor space or buildings have less importance.

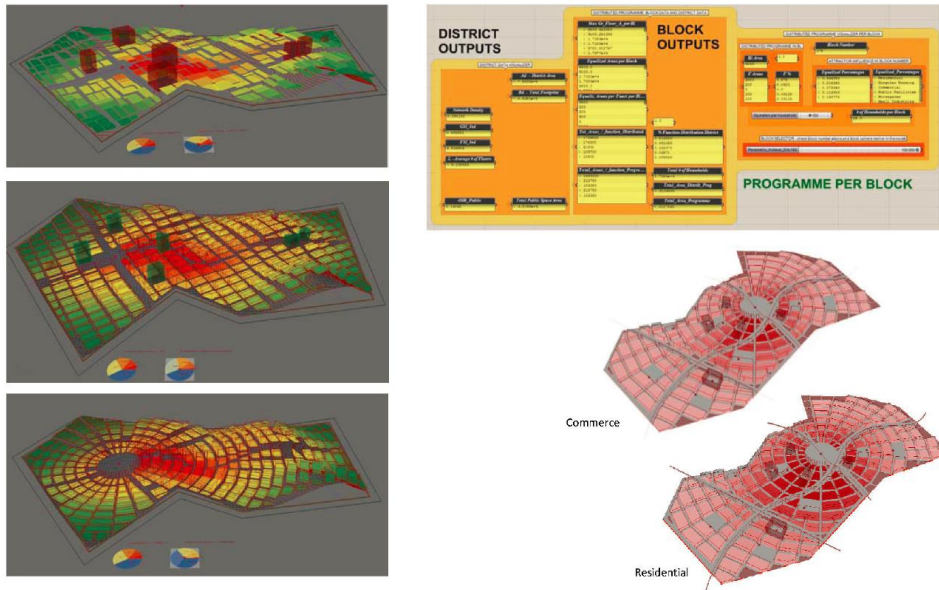


Figure 8. Extract from the City-Maker project. The three images on the left show the three available grids. The upper right corner shows the data output interface in which density indicators are shown at district scale, block scale and per block. The lower right corner shows the distribution of commercial and residential use in the plan.

Kaisersrot 2001 – KCAP Rotterdam

Kaisersrot is a computer based design neighbourhood using the needs of the future residents as inputs and constraints for design tool. Each resident provided basic information about their future building, for example, the size of the plot, proportion, program and location of the building. The plots contain further information regarding the location of shops, public transport, water bodies or nature. Based on this information, roads and plots are generated automatically (figure 9).

The tool used to design the Kaisersrot project is a software that can complement this thesis in a preliminary step by creating the basic information needed to run the design tool (plots and roads).

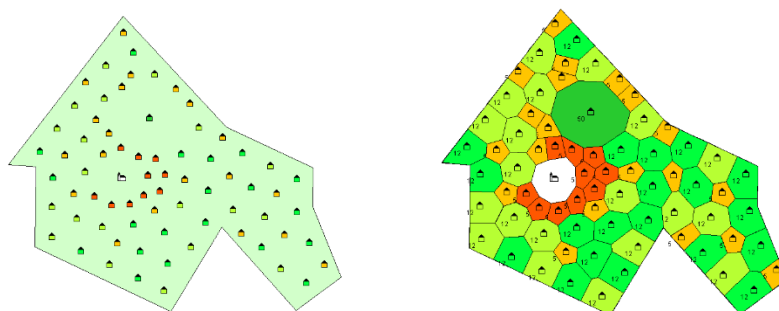


Figure 9. Screenshots from the software used in the Kaisersrot project. <http://adaptivearchitektur.com/ablog/?p=224>. Left, position of the buildings. Right, plot shape generation.

Möbius Moeller – *Design Automation Lab (2019)*

The Möbius Modeller is an open source software aimed to create parametric 3D models. It can be comparable with Grasshopper but the advantage of Möbius is the capacity to combine geometric data with semantic information.

Möbius is browser-based (for now, only for Google Chrome) running geocomputational procedures locally. It contains specific libraries to create personalized scripts and it has implemented the capability of dealing with attributes for objects as common GIS software.

The drawback of the tool is the limited interaction with the user when creating generative models.

For this thesis, this software was an alternative to Rhinoceros and Grasshopper for the implementation of the 3D modelling tool but the short time for development and the limitations in interaction led to use Rhino and GH.

In the figure 10, an example of the Möbius Geospatial Modeller, exploring population density in Singapore.



Figure 10. The Möbius Geospatial Modeller, exploring population density in Singapore (source: design-automation.net)

3Dfier – *3D geoinformation group TU Delft (2016)*

The 3Dfier is a tool aimed to transform 2D GIS datasets into 3D models by extruding the building polygons (LoD1) based on the heights of the Dutch pointcloud AHN3, and the rest of the functions use the semantics of the polygons to perform the lifting (figure 11).

The elements of the generated 3D model are classified in buildings, terrain, roads, water, forest and bridges. The output formats can be a CityGML, OBJ, CityJSON, CSV and PostGIS.

This tool was thought as an alternative to create LoD1 buildings in this thesis, nevertheless, a simplified method was used in order to make tests and have the possibility to change the

method about the height calculation of the buildings, for example, using the median, mean, max and min Z values of the AHN₃ points.



*Figure 11. Screenshot from an explanatory video "Delft in 3D by TU Delft"
(source: Filip Biljecki vimeo - <https://vimeo.com/181421237>)*

3. Methodology

As explained briefly in the introduction, the methodology of this research is divided in three successive steps; the first one describe and characterise quantitatively the current situation of Amsterdam (and its neighbourhoods) by computing a series of meaningful KPIs. In the second one, different calculation methods were defined and implemented for each selected neighbourhood in order to extract a number of parameters and eventually compute the size of the typical living space in each neighbourhood. Finally, in the third step the different sizes of the living spaces obtained in the step two are used as reference for the successive implementation of a design tool for urban planning (figure 12).

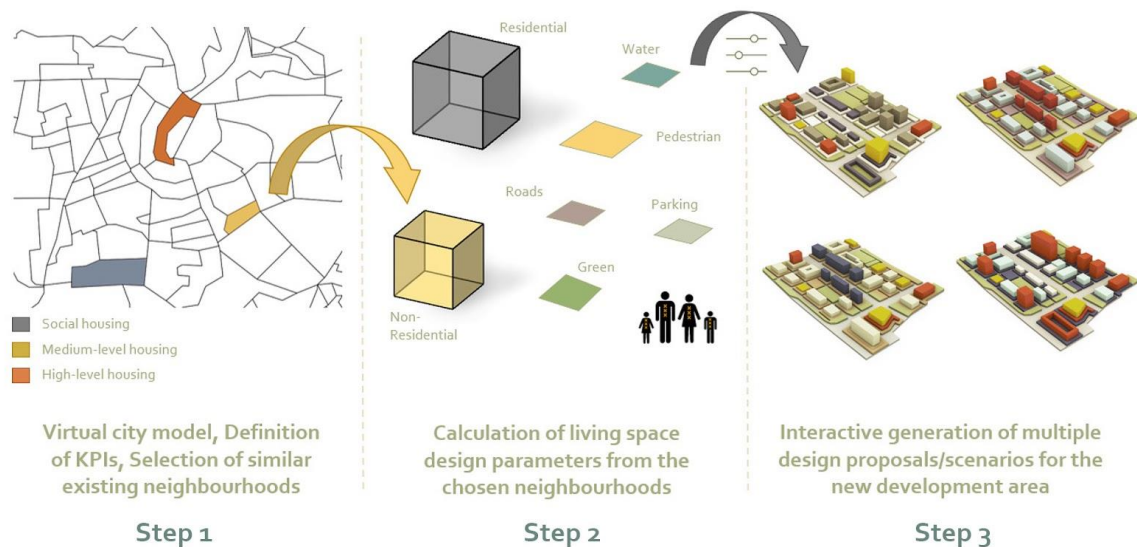


Figure 12. Step-wise graphical overview of the proposed methodology.

3.1 Selection of similar existing neighbourhoods

Sloterdijk One is the second stage of the Haven-Stad project. Currently, it is a low-density industrial area, envisioned for the future as a high density/mixed-use urbanization aimed to vent the housing needs pressure in the city. Its strategic location, one kilometre away from the Sloterdijk train station and 3.7 km from the Amsterdam Central Station, makes the project a desirable living area for many residents (figure 13). The guidelines of this project will be the minimum criteria for searching study areas in the city. The most relevant parameters are:

Use: 80% Residential, 20% Business.

Density: 192 Households per hectare.

Housing types: Social housing, medium-level and high-level housing.

Quality of life: Super high *.

Source: *Sloterdijk I Strategie nota 2016*.

*In the document is not specified how the quality of life is measured.



Figure 13. Sloterdijk One location in Amsterdam.

As Sloterdijk One is only comprehensive of one neighbourhood (*buurt* in Dutch), for this research, the *buurt* (the smaller element in the administrative units of the Dutch datasets) will be used as scale unit for spatial analyses. In order to find similar characteristics to Sloterdijk One, it is necessary to look to the following data sources:

- Land use
- Housing density
- Price of the household per square meter
- Quality of life
- Year of construction of the buildings

These elements were selected among others because of their relevance in relation with the Sloterdijk One requirements. The land use is a fundamental element to find neighbourhoods predominantly residential, as one of the scopes of this research is to calculate the size of households in residential areas.

As Sloterdijk One is envisioned as a high-density urbanization for the Netherlands (192 households per hectare), the density is one of the most important elements to search candidate neighbourhoods in Amsterdam.

The price of the household per square meter is used as a reference to catalogue the socio-economic status of the neighbourhoods in social, medium-level or high-level housing. In the Sloterdijk One guidelines, it is requested to make a division of the new dwellings as follows:

- Social housing (30%)
- Medium-level housing (40%)
- High level housing (30%)

The criteria to apply a socio-economic status to the neighbourhoods was:

- Social housing – Below 5000 €/sq. meter
- Medium-level housing - between 5000 and 6000 €/sq. meter
- High level housing - Above 6000 €/sq. meter

One of the most emphasized points in the guidelines of the Haven-Stad and Sloterdijk One is the pursuit of high quality of life (*Sloterdijk I Strategie nota 2016*). For this reason, it is necessary to know the level of liveability of the neighbourhoods.

Finally, the year of construction of the buildings is included to have a reference of the age of the neighbourhood. This parameter is used to understand if the area is a recent development or a historic part of the city, as different spatial characteristics are present based on this parameter.

Based on the analysis of these KPIs, candidate neighbourhoods were selected to calculate their size of the living spaces.

3.2 Living space calculation

The space calculation method is divided in two main categories: indoor space (calculated in 3D from building geometries LoD1) and open space (calculated in 2D). All the calculations are carried out using as a reference the household. In the figure 14, an overview of the classes taken into consideration for space calculation.

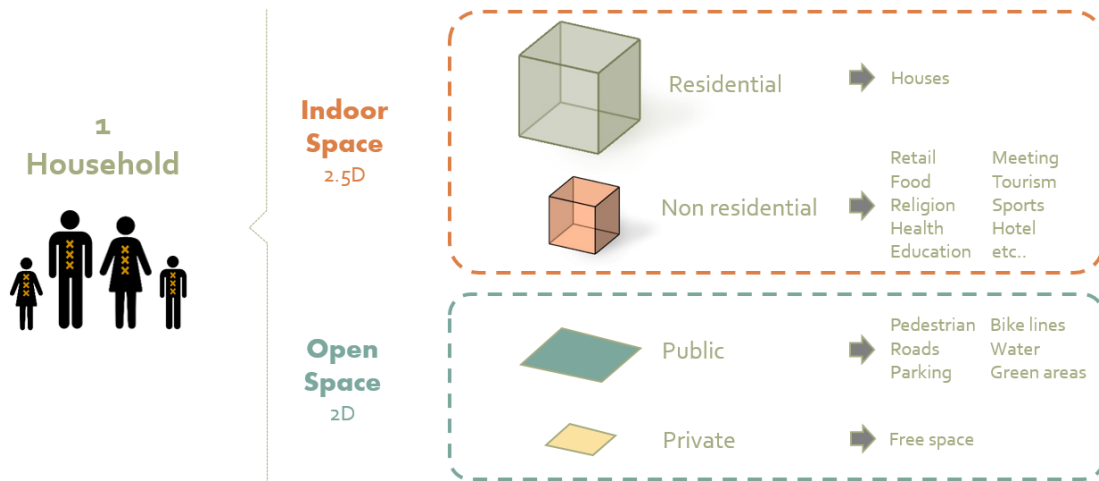


Figure 14. Classes to consider in space calculations.

For this method, all the buildings comprehended in the neighbourhoods are considered as indoor space and further specialised into residential (RESID) and non-residential (NR).

In order to isolate the residential space from the rest, the first step was to create LOD1 building geometries to calculate the volume of indoor space. Subsequently, non-residential spaces were computed and then gross residential spaces were obtained as difference between the LoD1 volumes and the non-residential ones. An example is given in figure 15.

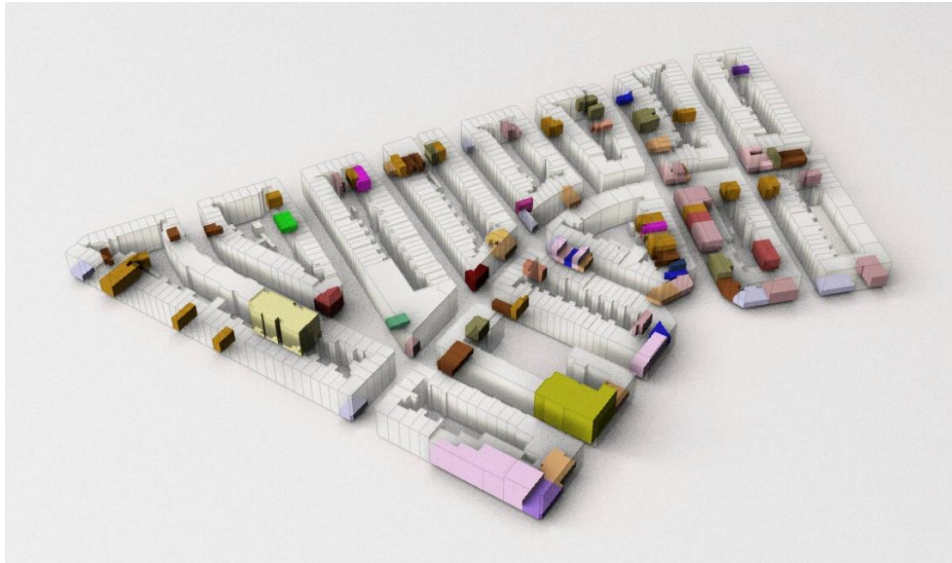


Figure 15. Example of indoor space calculation in Fannius Scholtenbuurt (Amsterdam). White/transparent volumes: LoD1 buildings, coloured volumes: non-residential spaces (colour coding corresponds to the type of space).

This resulting residential space was then divided by the number of households in the neighbourhood to calculate the average size of the households. The same procedure was used for non-residential spaces to calculate the amount of NR space per household. Additionally, the NR space was divided by the number of people working in the neighbourhood to calculate the average size of a single working place.

Regarding to open space, the areas were divided in private and public and this latter in turn subdivided into six more functions:

- Roads
- Green
- Parking
- Bike lines
- Water
- Pedestrian

The same as the indoor space, all open spaces were calculated using one household as reference.

3.3 Creation of the tool to generate multiple design scenarios

In this part of the methodology, the spaces calculated in the previous step will be used as a reference for a prototype software aimed to create fast, graphical and interactive design proposals for urban development projects. In the figure 16, the overview of the method used to create an interactive 3D modelling tool.



Figure 16. Overview of the third step of the methodology to generate multiple design scenarios.

The first part of this methodology step is the selection of the parameters to consider in the tool. These inputs were based on the *Haven-Stad* project guidelines, in which a general overview is shown in the table 1.







		Now	Future
	m2	360.311	1.122.000
	jobs	4.731	7.480
	households	0	11.220
	schools	0	8
	hospitals	0	8
	m2 sport	0	56.100

Table 1. Overview of needs for Sloterdijk One.

Source: *Ontwikkelstrategie Haven-Stad 2017*.

The type of interactively settable parameters, as well as their acceptable range of variability is complemented with the guidelines from the *Sloterdijk I Strategie nota 2016*:

- 80% residential
- 20% non-residential
- Respect existing mobility infrastructure
- 23mt. Max height commercial
- 30mt. Max height residence
- 40mt. Max height offices
- FSI = 2.2 / 3.5
- Car index = 0.9
- Super high quality of life

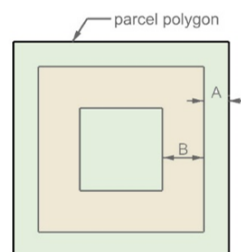
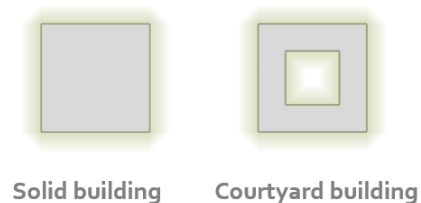
All these parameters are comprehended in the input and output of the tool. Some of them are parametrically editable and others calculated in on the fly.

Other parameters, commonly used in urban planning, were added to the tool in order to facilitate the decision making process. Following, the list of the parameters added to complement the results:

- GSI
- Square meters of construction (RESID and NR)
- Number of households in new and existing buildings based on an average size of the household (calculated in step 1.2)
- Number of working places in new and existing buildings based on an average size of the working space (calculated in step 1.2)
- Amount of non-residential space per household
- Mixed-use buildings with NR in lower storeys
- Number of storeys by building function
- Storey height by function
- Open space statistics per household (water, pedestrian, parking, green, roads and biking)

Once the parameters are defined, it is necessary to establish geometrical constraints for buildings. In the 3D modelling tool, it is possible to consider relevant existing buildings and create new ones. The existing buildings can be imported geometries and the new are created directly in the tool. Having said that, a parcellation dataset including road infrastructure and the volumes of the existing buildings is needed to create the respective calculations.

The new building footprints are created based on the shape of the plots. The possibilities are solid or courtyard buildings. In the case of courtyard building, the thickness of the building can be modified by the user (figure 17).



A = distance from the plot border to the building
B = thickness of the building

Figure 17. Top view of the parameters for new buildings.

The function of the new buildings can be residential, non-residential and mixed-used. For residential volumes, it is possible to determine the percentage of households in mixed-use buildings and the rest is distributed in residential buildings. For non-residential buildings, the tool is more flexible, there is no maximum limit of NR space, but the real-time calculations show statistics about the amount of NR space in the scenario.

In NR buildings, the user can establish the number of storeys and storey height. If the output parameters exceed the desired amount of non-residential space, with these two parameters, the user can modify the scenario.

Regarding to open spaces, the road infrastructure is the base for design and calculations. In the tool, it is possible to have different roads types and for each of them calculate the amount of water, green, roads, parking, bike and pedestrian. Many roads can compose each type and every type can have a specific width.

Intersections are considered as roads and the effective space of calculation for the other functions are the remaining line segments (figure 18).

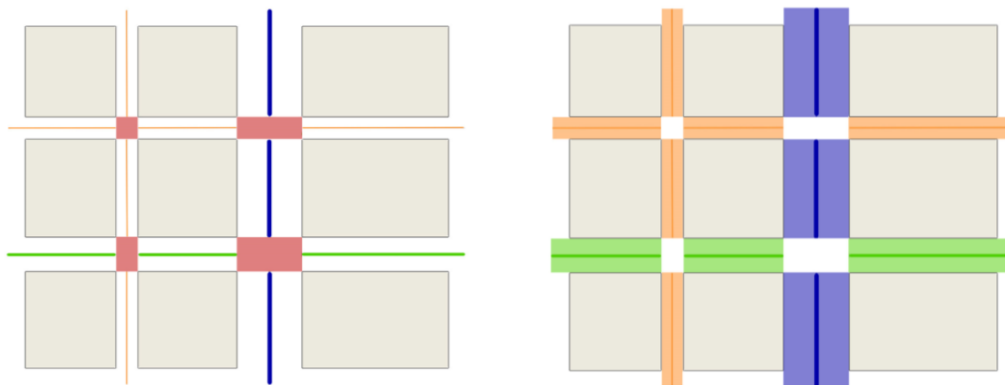


Figure 18. LEFT - In red: intersections considered as car traffic space. RIGHT - In orange, green and blue the effective space for calculations. The colour indicates the type of the roads.

The six outdoor space functions are calculated as follows (figure 19):

- Sidewalk – width of the sidewalk on each side of the road
- Biking space – number of bike lanes and width
- Parking – number of parking lines and width
- Roads – number of traffic lanes and width
- Water – width of the water body along the road
- Green – The remaining space (the difference between the width and the other functions)

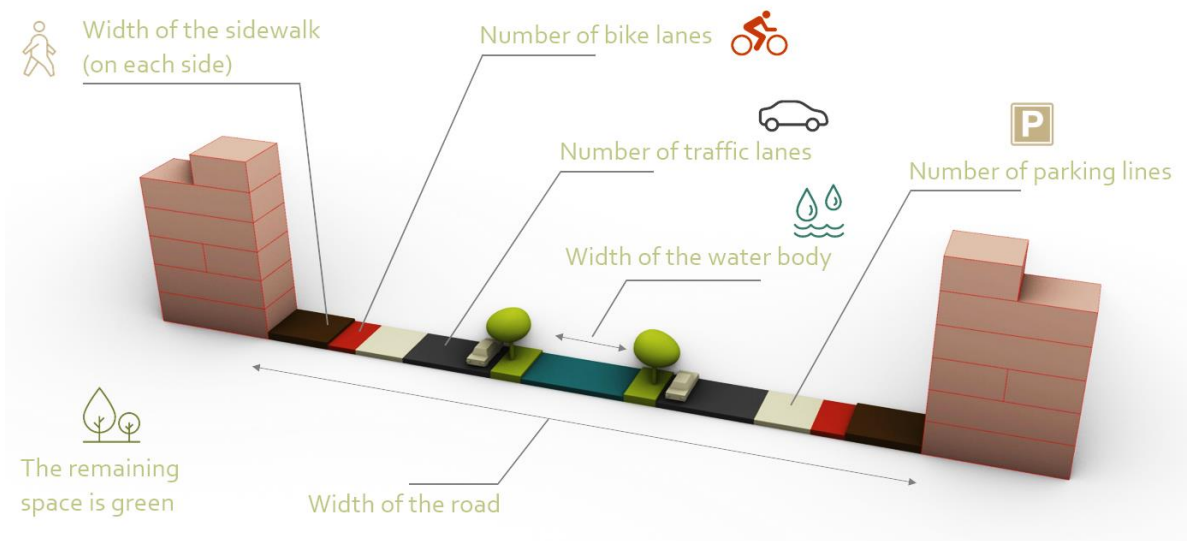


Figure 19. Outdoor spaces (The trees were not modelled in the overall model, only schematically for the 3D section model).

4. Implementation of the methodology

4.1 Implementation - Selection of similar existing neighbourhoods

Most of the GIS analysis and calculations of this thesis were carried out using the software QGIS and FME.

The selection of the neighbourhoods to analyse was based on the following datasets and procedures:

Land use 2017

Dataset description:

2017, Land use Amsterdam

Dataset	GRONDGEBRUIK_2017
Page link	https://maps.amsterdam.nl/open_geodata/?k=152
Number of objects	8764 (Amsterdam – CSV file with geometry)
Recency	May 2017

Grondgebruik_2017 (Use of the land 2017) is an open dataset provided by the Municipality of Amsterdam. It was overlaid to the city map to find areas predominantly residential. The used attribute was "Living areas (inc. facilities)". In the figure 20, a visualization of the areas predominantly residential in Amsterdam.

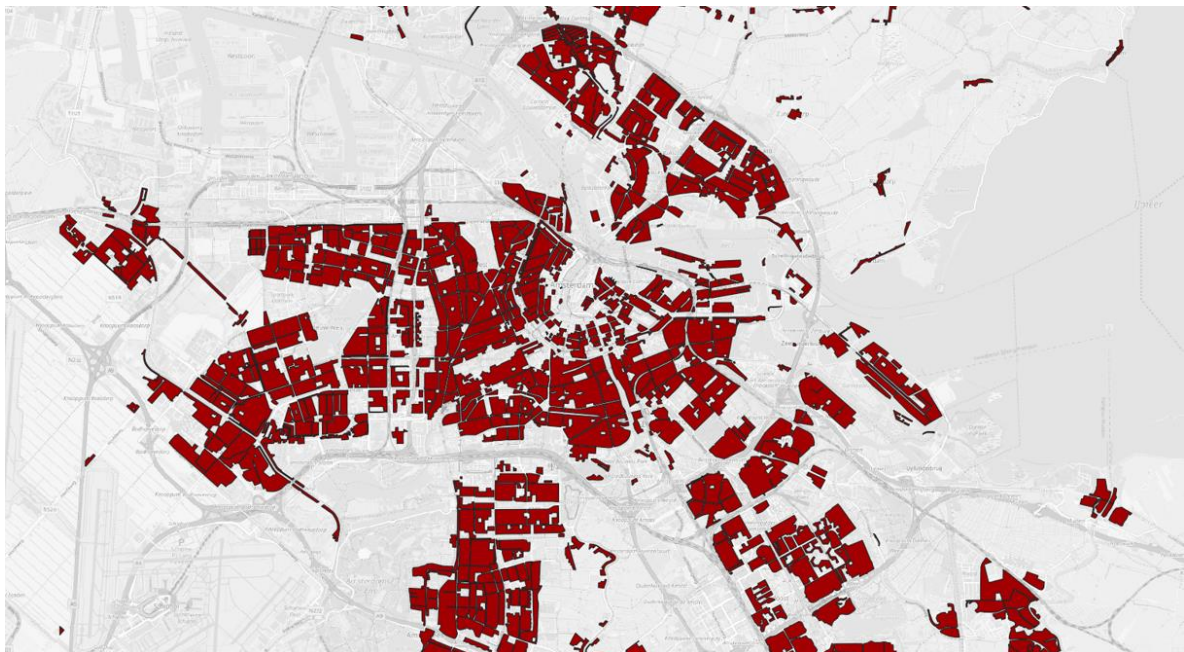


Figure 20. In red: areas with a predominantly residential use in Amsterdam (861 polygons - Land use 2017).

Quality of life

Dataset description:

2016, Liveable meter Netherlands – www.leefbaarometer.nl

Dataset	Leefbaarometer 2.0 = meting 2016
Page link	https://data.overheid.nl/data/dataset/leefbaarometer-2-0---meting-2016
Number of objects	12822 (Netherlands - XLS file no geometry)
Recency	2016

To have an idea about the liveability of the neighbourhoods, the *leefbaarometer* (*livable meter* – www.leefbaarometer.nl, an official Dutch dataset about the quality of life) was used as a Quality of life index.

For this dataset, initially, only the highest scores (7, 8 and 9) were selected aimed to find the best-ranked neighbourhoods (figure 21). After several trials, also lower rankings were added to the selection to include neighbourhoods in the modern areas, i.e. the Nieuwe West area.



Figure 21. Map of the liveability scores of 7, 8 and 9 within areas predominantly residential (Leefbaarometer).

Housing density in households per hectare

Dataset description:

2017, CBS Districts and Neighbourhoods Netherlands

Dataset	CBS Wijken en Buurten 2017 (ATOM)
Page link	https://geodata.nationaalgeoregister.nl/wijkenbuurten2017/atom/wijkenbuurten2017.xml
Number of objects	13308 (Netherlands – ESRI SHP file)
Recency	2017

The *CBS Wijken en Buurten 2017* (*CBS Districts and Neighbourhoods 2017*), is an Official Dutch dataset containing the information related to the census of the Netherlands. From this dataset,

two parameters were used to calculate the density of each neighbourhood: *AANTAL_HH* - *Aantal huishoudens* (number of households) and the *OPP_LAND* - *Oppervlakte land in ha* (Land surface in Ha). This KPI was created using the following formula:

For each neighbourhood:

$$\text{Neighbourhood Household Density Index (NHDI)} = \frac{H}{A}$$

H = number of households in the neighbourhood (*AANTAL_HH*).

A = area of the neighbourhood (only land is considered, no water areas) in hectares (*OPP_LAND*).

For the density, neighbourhoods with an NHDI higher than 95 households per hectare were intersected with the map made in the previous step to find high-density residential areas.

In the figure 22, the map of the housing densities within areas predominantly residential.

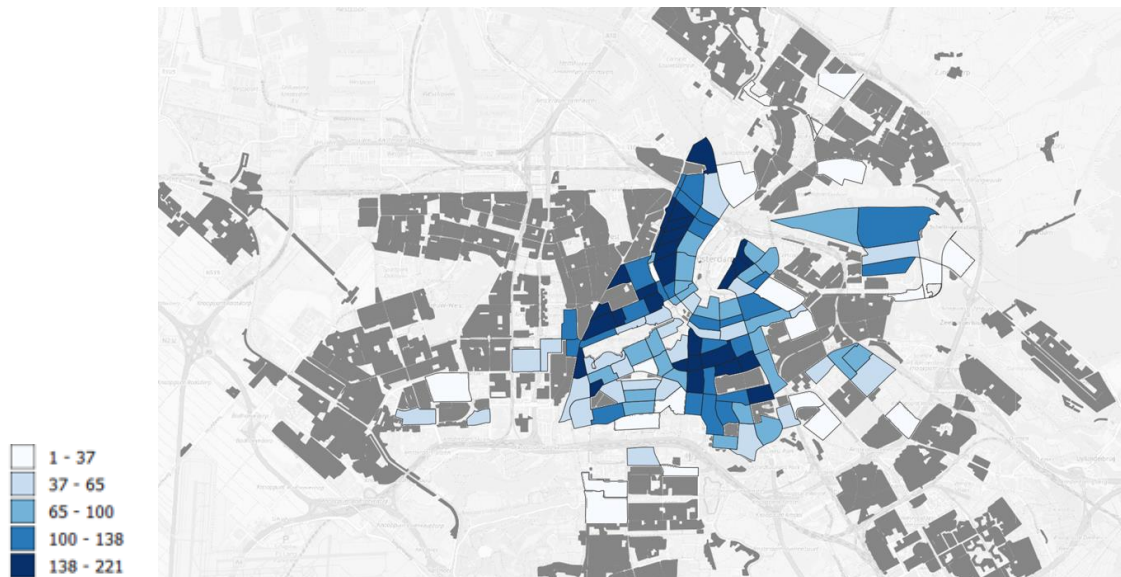


Figure 22. Map of the housing densities within areas predominantly residential and scored with 7, 8 or 9 in the Leefbaarometer (Legend in households/hectare).

Average price per square meter of households

Dataset description:

2015, House value Amsterdam

Dataset	Woningwaarde_2015
Page link	https://maps.amsterdam.nl/open_geodata/?k=52
Number of objects	N/A
Recency	2002 – 2015

The price of the households per square meter was used to categorize housing types (social, medium or high level). The dataset *Woningwaarde_2015* (*house value 2015*) is provided by the municipality of Amsterdam using contour line-shaped polygons with ranges of prices. To be able to create this KPI, the geometries were divided using the neighbourhood polygons. The following formula was used:

For each neighbourhood:

$$\text{Average Neighbourhood Price Index (ANPI)} = \frac{\sum (\text{Price} * \text{poly_area})}{\sum (\text{poly_area})}$$

Price = Price per sq. meter of a divided polygon

poly_area = Area of the divided polygon

A schematic example of the ANPI calculation in figure 23.

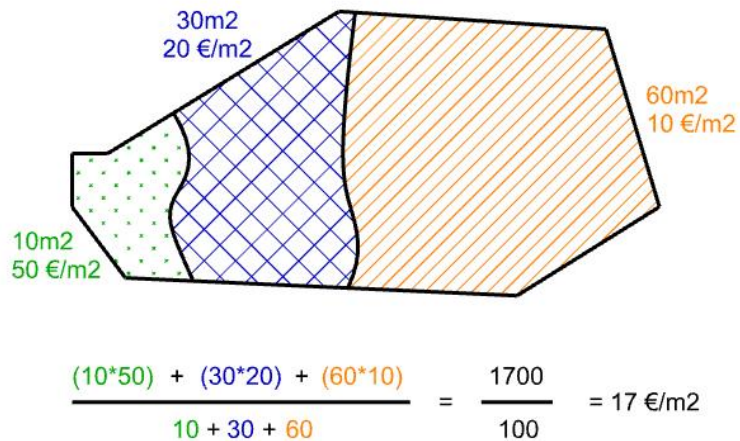


Figure 23. Example of ANPI calculation.

In the figure 24, the map with the ANPI values for the areas predominantly residential and scored with 7, 8 or 9 in the Leefbaarometer.

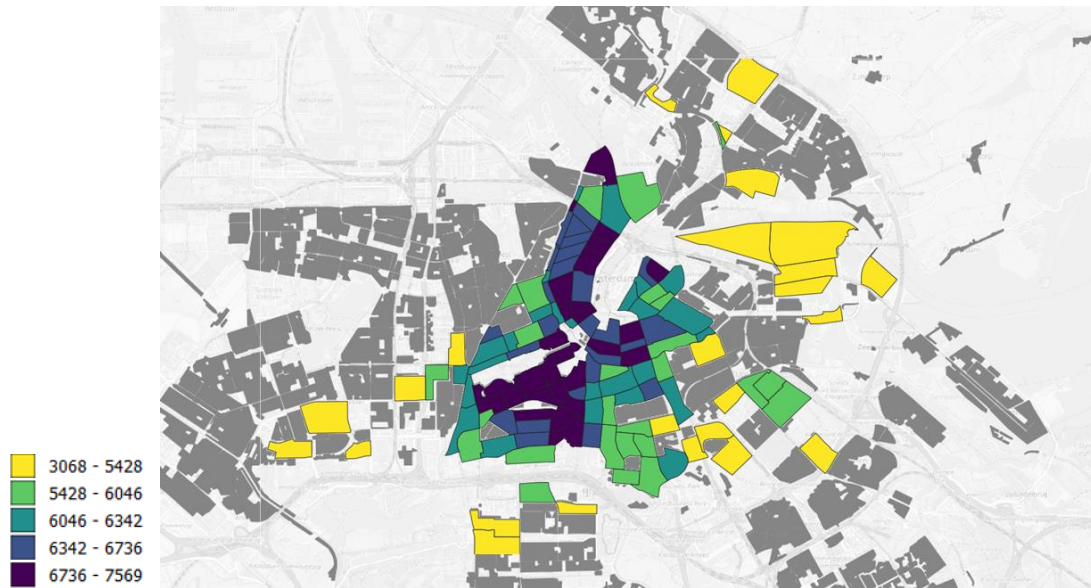


Figure 24. Map of the average price of the households in areas predominantly residential and scored with 7, 8 or 9 in the Leefbaarometer (Legend in euro/sq. meter).

Year of construction

Dataset description:

2015, Year of construction Amsterdam

Dataset	Bouwjaar
Page link	https://maps.amsterdam.nl/open_geodata/?k=110
Number of objects	16869 (Amsterdam – ESRI SHP files)
Recency	September 2015

This parameter was used to understand if the neighbourhood belongs to a recent expansion of the city based on the average year of constructions of the buildings in it. The average year of construction of the neighbourhoods was calculated using the *Bouwjaar* (year of construction) dataset using the following formula:

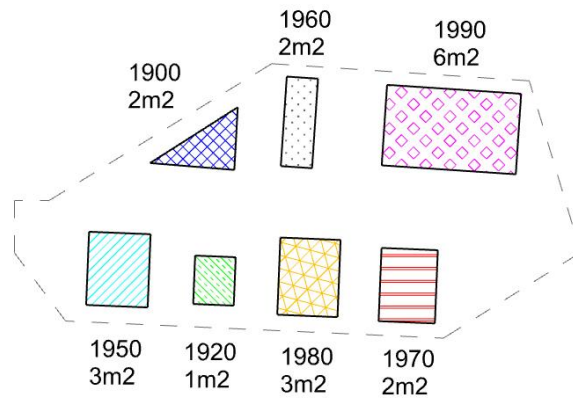
For each neighbourhood:

$$\text{Average Neighbourhood Year Index (ANYI)} = \frac{\sum (\text{Year} * \text{buurt_area})}{\sum (\text{buurt_area})}$$

Year = Year of construction of a single building within the neighbourhood

buurt_area = Area of a single building within the neighbourhood

A schematic example of the ANYI calculation in figure 25.



$$\frac{(1950*3) + (1920*1) + (...) + (1990*6)}{3 + 1 + ... + 6} = \frac{37310}{19} = 1964$$

Figure 25. Example of ANYI calculation.

In the figure 26, the ANYI values for the areas predominantly residential and scored with 7, 8 or 9 in the Leefbaarometer.

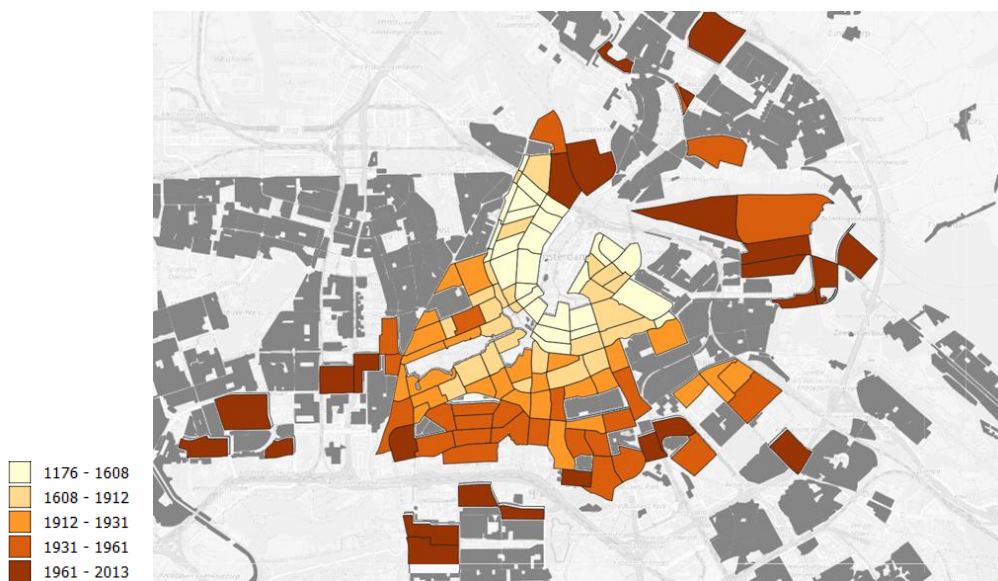


Figure 26. Map of the average years of the neighbourhoods in areas predominantly residential and scored with 7, 8 or 9 in the Leefbaarometer (Legend in years).

Finally, queries and data filters were used in the outputs from the previous steps to find the candidate neighbourhoods to analyse. In the figure 27, an example of the criteria and ordering used to find the most similar characteristics to Sloterdijk One.



Figure 27. Example of the criteria and ordering used to find the most similar characteristics to Sloterdijk One.

4.2 Implementation - Living space calculation

For indoor spaces calculation, the footprints of the buildings were extracted from the *Bouwjaar* dataset (see previous chapter for details), and the heights of the buildings from the AHN3 pointcloud (*Actueel Hoogtebestand Nederland 3 – Current height file Netherlands 3*).

Dataset description:

2018, Current height file Netherlands 3

Dataset	Actueel Hoogtebestand Nederland 3
Page link	https://www.pdok.nl/nl/ahn3-downloads
Number of objects	N/A
Recency	2018

A pre-processing of the pointcloud was necessary to manage it in a fast and efficient way; smaller pointclouds were created by dividing the original one using the neighbourhood polygons (*Wijken en Buurten* dataset, figure 28). This process was made using the FME software (www.safe.com).

To extrude the building footprints, first, it is necessary to extract the height of the buildings and ground floor from the AHN3. The smaller pointclouds made previously were further divided using the building polygons and the median height was calculated using the Z values of the points (figure 29).

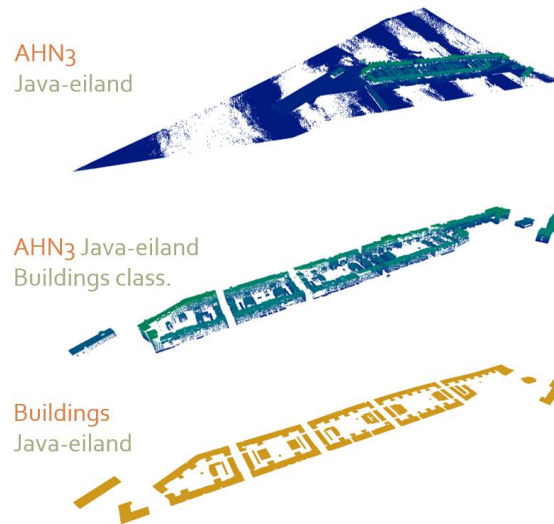


Figure 28. Example of pointcloud division.

As the AHN3 use the NAP level (*Normaal Amsterdams Peil – Normal Amsterdam Level*) as reference, it was necessary to calculate the height of the ground to know the starting point of extrusion. The classification of the AHN3 was used to isolate the points of the ground and calculate its average height.

Based on several visits on site, for all the LoD1 buildings, it was considered an underground storey of 4 meters for storage.

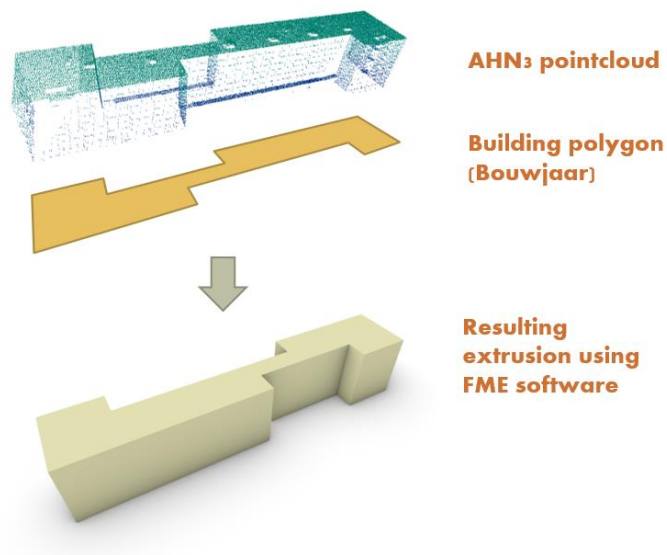


Figure 29. Example of extrusion of LoD1 Buildings.

For this thesis, the explained method was implemented to create LoD1 building geometries. Due to the willingness of using the median height of the pointcloud points as building height.

Nevertheless, other existing tools as the '3Dfier' (TU Delft 3D Geointofmation - 2016) can be used to create 3D models from existing cities in the Netherlands.

Non-residential spaces were calculated using the *functiekaart* (function map). This dataset contain all the non-residential activities in the city. From 80 categories, 39 were found in the neighbourhoods to study.

In the *functiekaart*, the attribute *Oppervlakt* indicates as gross area for each activity, nevertheless, based on several tests, in many cases this information do not correspond with the reality. For example, a test was carried out in a regular-shape 12 storey building in the west part of the city, the *Stadsdeelkantoor nieuw-west* (Figure 30). In the dataset, the area of the polygon referred to this building, calculated with QGIS, is 1366.2 square meters, and the *oppervlakt* attribute is 8937 square meters. By dividing the *oppervlakt* value by the calculated area of the polygon, the result is a 6.5 storey building, almost the half of the real height.

In addition, in the description of the dataset, the *oppervlakt* attribute it is described as an estimation of the area of the non-residential function calculated based on an estimation of the average number of storeys (<https://data.amsterdam.nl/datasets/CWujX-uXU9R8Sg/> Last visit 06-July-2019).

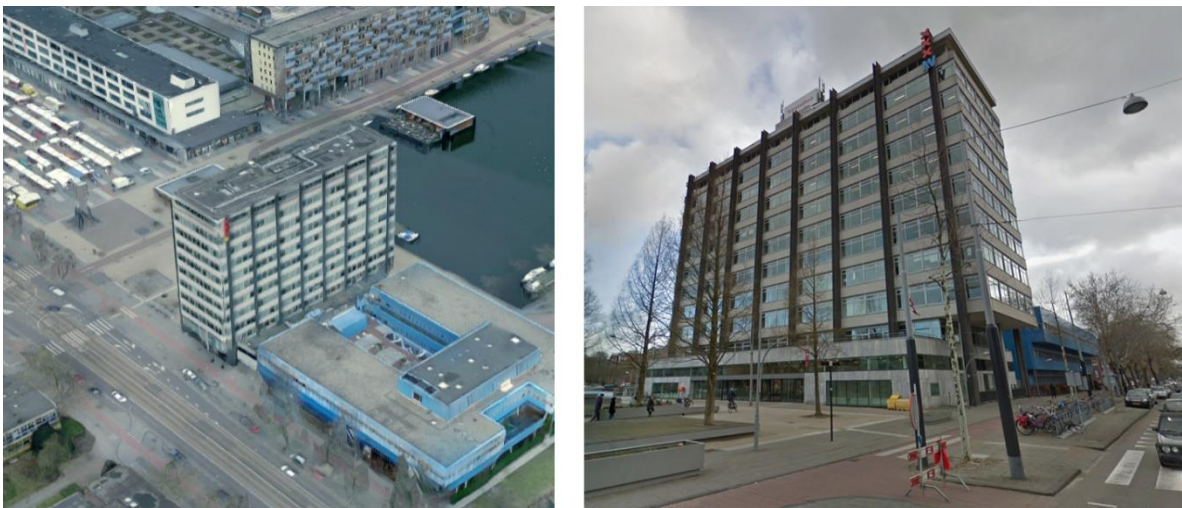


Figure 30. [Left] Aerial view of the *Stadsdeelkantoor nieuw-west*. [Right] Street view. Source: Google maps.

These preliminary tests showed that the quantitative information in the dataset could not be used effectively. Having said this, for the estimation of the non-residential surfaces (and volumes) a set of assumptions was made, based on empirical considerations, personal experience, and some on-site visits. These consist in assigning an average height of 4 m for each non-residential storey, and a specific (maximum) number of storeys for each activity, in case in a building that activity is found. In Table 2, the full list of the assigned building storeys per activity are given.

Dataset description:

2018, Non-residential functions Amsterdam

Dataset	Functiekaart
Page link	https://maps.amsterdam.nl/open_geodata/?k=49
Number of objects	28189 (CSV file)
Recency	2018

Function	Storeys
Art workplace - Craft workplace	1.00
Belcenter - Internet area	1.00
Bicycle rentals	1.00
Bowling - Laser Game - Going Out other	ALL
Brothel - Prostitution - Sexclub	ALL
Café - Diner pub	1.00
Child care (independently)	2.00
Coffeeshop	1.00
Collective workspace	2.00
Consumer services other	1.00
Dance club - Night club - Partycentrum	ALL
Day and night shelter	ALL
Elementary school	ALL
Enterprise - Collective enterprises	2.00
Fitness - Gym - Yoga space	2.00
Gallery - Art library	2.00
Health practice	2.00
Hotel – Lodging	ALL
Leisure reading - Hobby association - Music practice rooms	2.00
Lunchroom - Coffee-wifi (non-alcohol)	1.00
Massagesalon	2.00
Meeting- and activity centre	2.00
Office - Collective offices	ALL
Office with public function - City desk - Visitor centre	ALL
Other religious gathering space	ALL
Public bicycle parking	2.00
Public car parking garage	4.00
Residential care complex	ALL
Restaurant	1.00
Secondary education	ALL
Shop other	1.00
Shop you see a lot	1.00
Smartshop - Sexshop - Tattooshop - Piercings	1.00
Snack bar - Ice cream - Fish stall - Food-to-go	1.00
Souvenirs - Cheese - Tickets - Minisuper - Moneychange	1.00
Store daily food - Neighbourhood groceries	2.00
Supermarket large	ALL
Theatre - Music stage - Events hall	ALL

Unclear function	1.00
------------------	------

Table 2. Number of (maximum) storeys in a building for each non-residential category. "ALL" means the total height of the building containing such activity.

In the figure 31, heights and considerations for volume calculations.

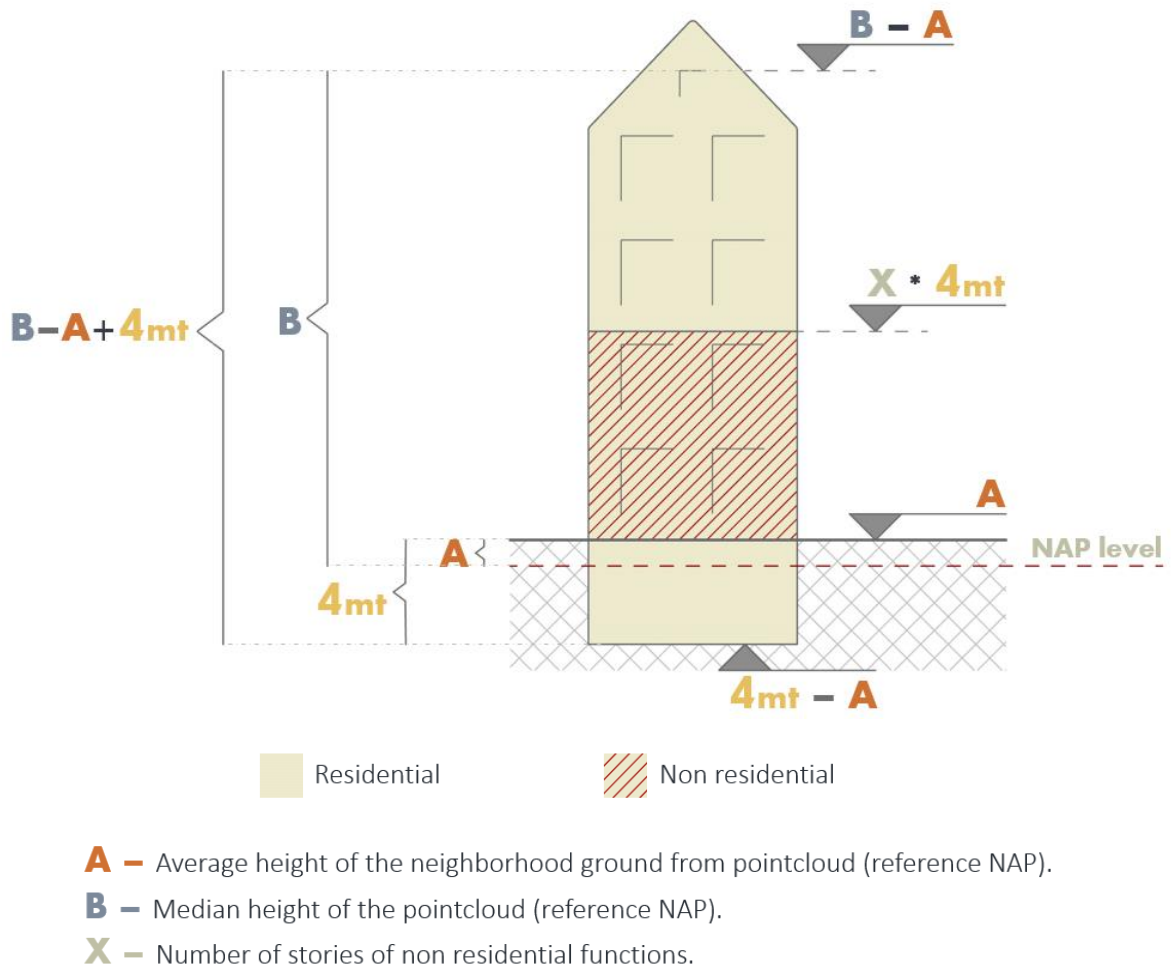


Figure 31. Extrusion criteria for indoor spaces.

Regarding open spaces, the *Basisregistratie Grootchalige Topografie* dataset (BGT - Basic registration Large-scale Topography), layers: *bgt_begroeidterreindeel*, *bgt_wegdeel*, *bgt_waterdeel* and *bgt_ondersteunendwegdeel*, were analysed and processed to identify the six categories of the open space.

Dataset description:

2018, BGT – Basic registration Large-scale Topography Netherlands

Dataset	Basisregistratie Grootchalige Topografie (BGT)
Page link	https://www.pdok.nl/downloads?articleid=1948972
Number of objects	N/A

Recency	2018			
Layers used	<i>bgt_begroeidterreindeel,</i>	<i>bgt_wegdeel,</i>	<i>bgt_waterdeel</i>	and <i>bgt_ondersteunendwegdeel</i>

The final calculation was made using the *Basisregistratie Kadaster (BRK – Basic registration Cadastre)*, in which the all the parcels and public spaces are registered. This dataset was used to separate private and public space. E.g. if a parcel contains at least one building, it was considered as a private plot, otherwise, it was considered public space.

Dataset description:

2018, BRK – Basic registration Cadastre Netherlands

Dataset	Basisregistratie Kadaster (BRK)
Page link	https://www.pdok.nl/download/embed2.html?dataset=kadastralekaartv3
Number of objects	N/A
Recency	2018

4.3 Implementation - Creation of the tool to generate multiple design scenarios

The software Rhinoceros (Rhino) was used as the main platform to build the 3D modelling tool. Grasshopper (GH) was used for parametric design and Python programming as coding language.

The created tool combines geometries, data and the knowledge of the user to design urban planning proposals. In the figure 32, an overview of the software operation.

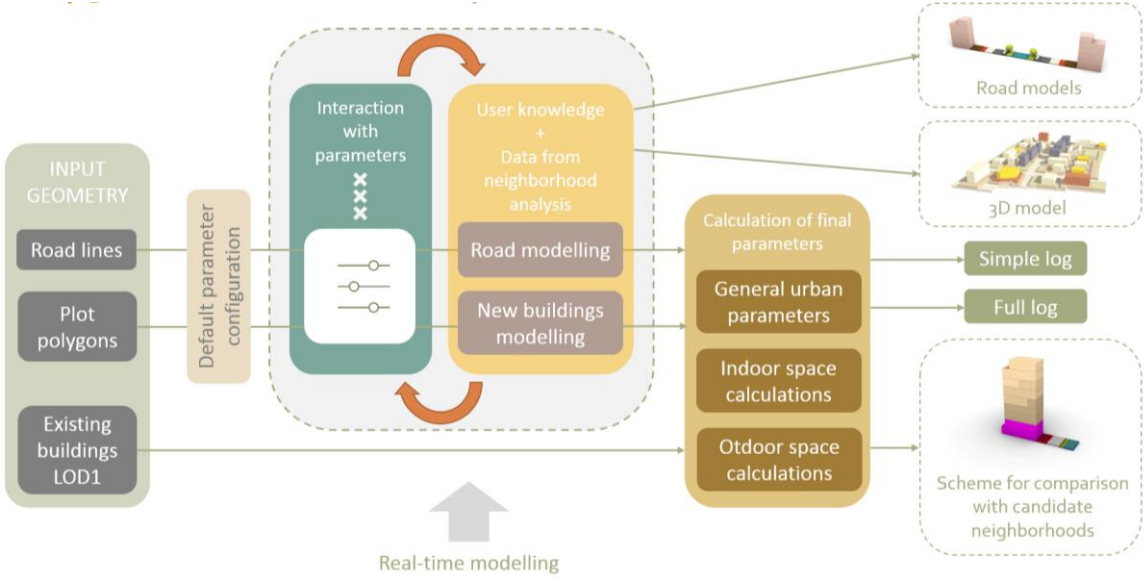


Figure 32. Overview of the software operation.

Input geometry

Three main elements are needed as input of in the tool: the road network (centrelines), the polygons of the plots and the existing buildings to keep in consideration for the design.

The road dataset is imported into Rhino as simple lines or polylines, these should be drawn in the centre of the streets. It may be helpful to identify the different road types with a code for easiness of identification but this is not mandatory. The polygons of the plots should be closed polylines (figure 33). As all these polygons should be oriented counter clockwise (CCW) to perform positive extrusions regarding the Z axis and internal offsets, in the tool is included an orientation checker that identifies the orientation of the plots. If the polygon is oriented clockwise (CW), the tool automatically invert the normal vector of the vertices. The process is made on three steps: 1, Evaluation of the polygon, this process calculate the coordinates of the normal vector. 2, A simple python code separate polygons with CCW and CW orientation based on the Z value of the vector (+1 = CCW, -1 = CW). 3. The polygons with CW orientation are sent to an inverter node in Grasshopper (figure 34).

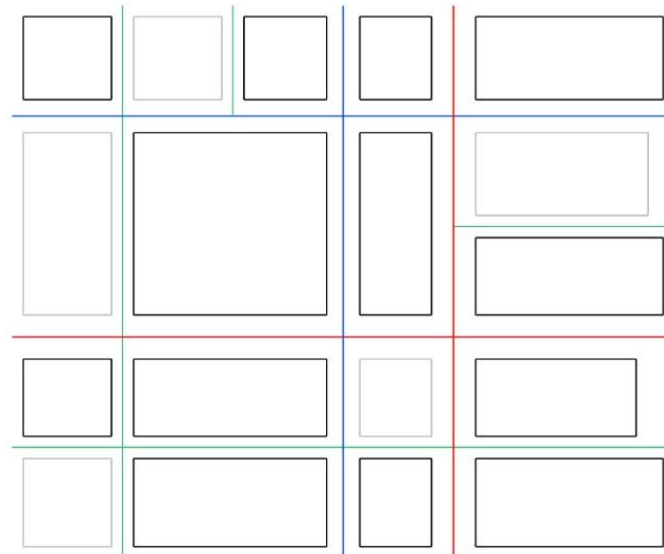


Figure 33. Example of road lines and plot polygons. Red – primary roads. Blue – secondary roads. Green – tertiary roads. Black – public plots. Grey – Private plots.

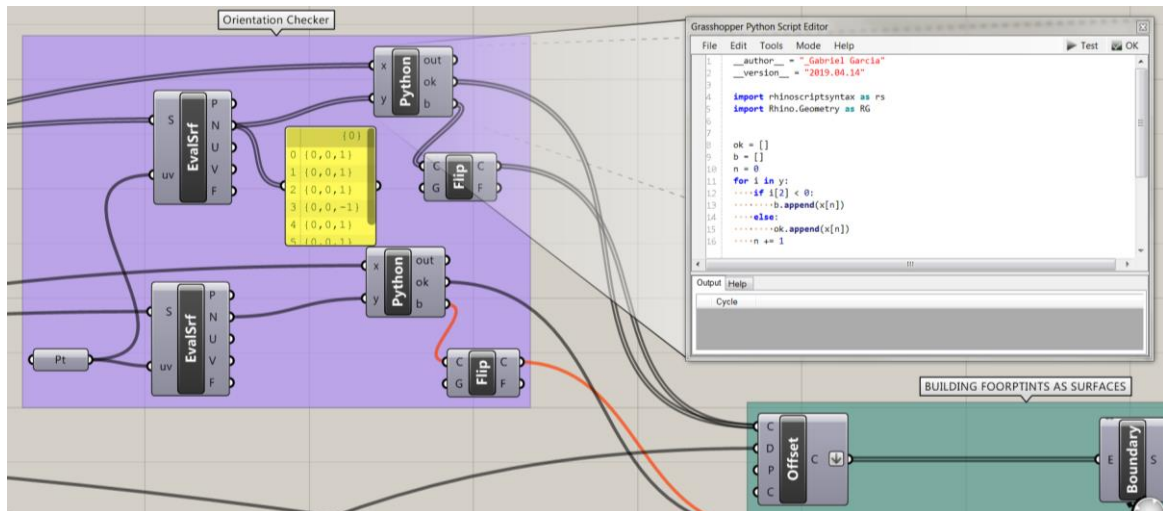


Figure 34. Orientation checker of polygons in Grasshopper. EvalSrf: Evaluation of the polygon, output normal vector. Python code: separate polygons with CCW and CW orientation based on the Z value of the vector. Flip: invert the orientation of the CW oriented polygons.

The volumes of the existing buildings should be solid LOD₁ geometries. The base should be situated at the same height of the road and plot lines. In case of importing meshes into Rhino, the command 'Convert to Nurbs' can convert in one click the meshes into solids.

The same as the previous datasets, it might be useful to distinguish the existing buildings between residential and non-residential to load them in the correspondent GH node.

The user

At this point, it is important to understand who is the user of the tool or for whom is intended. The user, preferably, should have previous knowledge in urban planning and ideally, knowledge of the urban characteristics of the area to develop.

Previous knowledge of the Rhino/Grasshopper interface is needed, especially, to navigate around the 3D model, enable and disable layers and save screenshots in Rhino. The interactive process is carried out in the Grasshopper interface.

The interface of the tool is mainly based on two elements: from the Rhino side, the viewport containing the 3D visualizations and in the GH side, parametric tools to interact with the 3D model. The latter composed by yellow panels providing real-time information to the user and grey nodes to edit the design parameters with sliders (figure 35).



Figure 35. Interface of the tool. Left - 3D visualization in the Rhino viewport. Right - GH window with info panels and data nodes.

It is important to remark that the software is not intended for the public in general but for professionals, as technical language is used.

No python knowledge is needed at this point.

Parametric modelling

Once the geometry datasets are loaded into Rhino, the software contains one default configuration to help the user with an initial set up.

The initial steps to run the program are:

1. Load all the polygons of the plots in the "ALL PLOTS" GH node (figure 36).
 - This will allow FSI and GSI calculations.

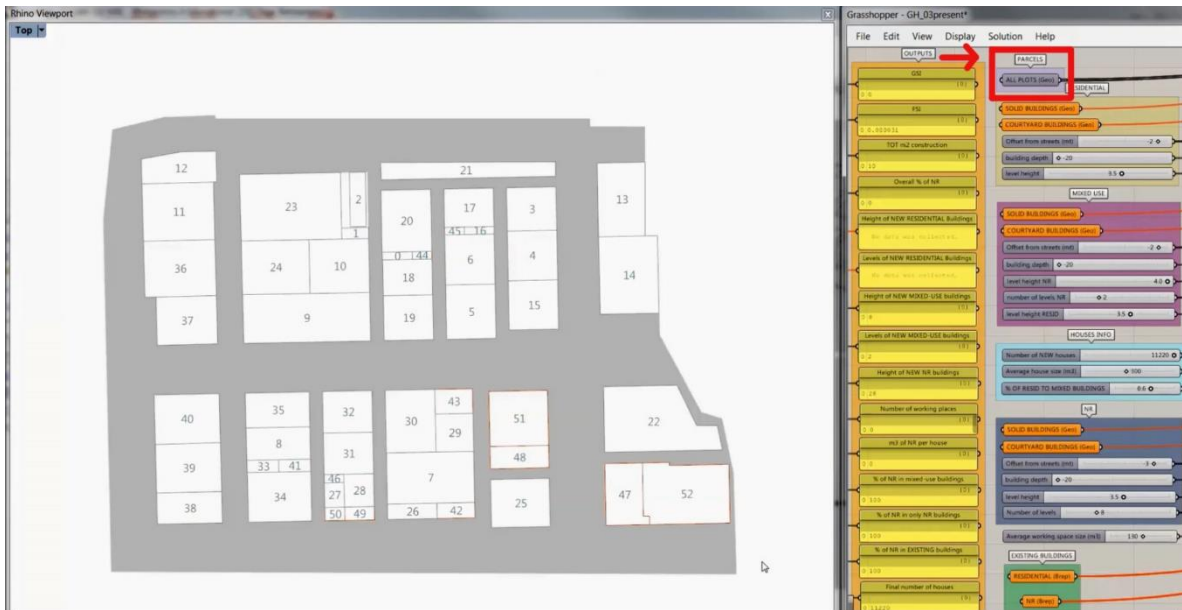


Figure 36. Highlighted in red, the "ALL PLOTS" node to select the polygons to consider in the calculations.

2. Select the existing buildings to keep (figure 37).
 - EXIST RESID
 - EXIST NR



Figure 37. Highlighted in red, the existing building nodes to select the buildings to keep.

3. Select plot polylines for new solid and courtyard buildings on each category, (figure 38).
 - NR SOLID BUILDINGS
 - NR COURTYARD BUILDINGS

- MIX SOLID BUILDINGS
- MIX COURTYARD BUILDINGS
- RESID SOLID BUILDINGS
- RESID COURTYARD BUILDINGS



Figure 38. Highlighted in red, the nodes of courtyard and solid buildings to select the plots to create buildings.

4. Select the road lines for each category (figure 39).

- ROADS TYPE 1
- ROADS TYPE 2
- ROADS TYPE 3

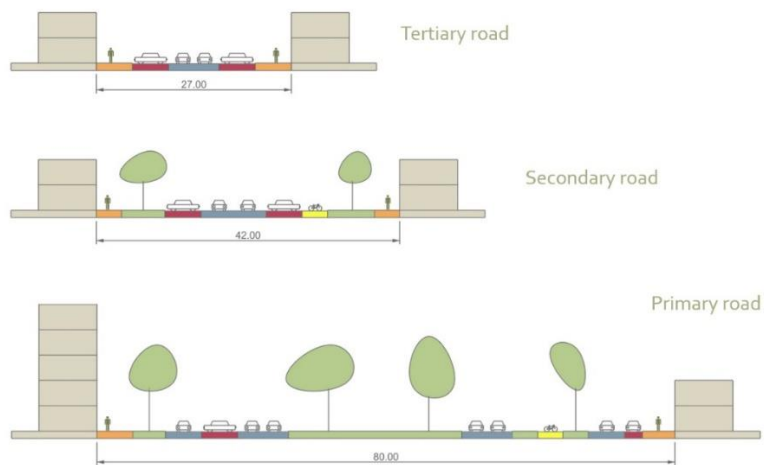


Figure 39. Example of the road types that can be created in the tool. Each type is loaded into GH as single lines in the respective nodes.

*For now, it is only possible to create three road types in the tool.

Once the selection of the geometries is made, the default configuration is visible in 3D on the Rhino viewport.

From this point, the input parameters and automatic calculations are enabled.

The editable parameters are:

INDOOR SPACES (figure 40)

- For new RESID, NR and MIXED-USE buildings:
 - Building thickness (in meters, *only courtyard buildings)
 - RESID storey height (in meters)
- Only new NR and MIXED-USE buildings:
 - Number of NR storeys (integer)
 - NR storey height (in meters)
- General info:
 - Number of new households (integer)
 - Average household size (in cubic meters)
 - Percentage of residential space in mixed-use buildings (0.0 - 1.0 value)
 - Average working space size (in cubic meters)

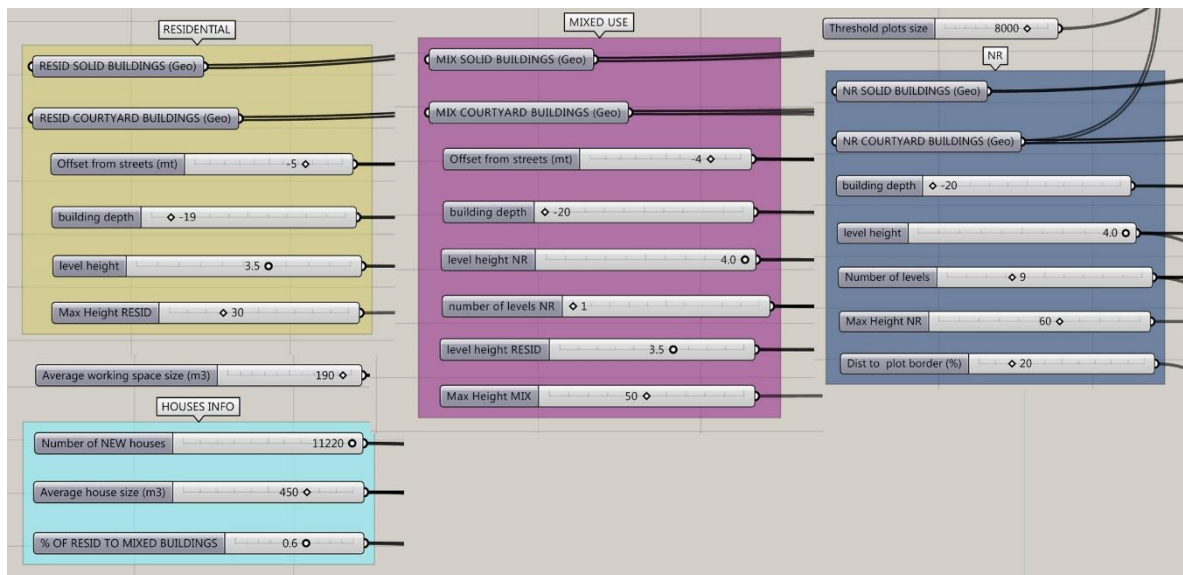


Figure 40. Grasshopper nodes with input parameters for indoor spaces.

OUTDOOR SPACES (figure 41)

- For each road type:
 - Width of the road (in meters)
 - Number of drive lanes (integer)
 - Width of a drive lane (in meters)
 - Number of parking lines (integer)
 - Width of a parking line (in meters)
 - Number of bike lines (integer)
 - Width of a bike line (in meters)
 - Width of each sidewalk of the road (2) (in meters)
 - Width of water body along the road (in meters)
 - Radius of road intersection (in meters)



Figure 41. Example of Grasshopper nodes with input parameters for each road type.

Parameter calculation

Based on the information provided by the user, 3D geometries are created in the model, and from them, information is calculated to create the output data.

Following, the description of the most important parameters calculated in the tool:

- Amount of square meters of indoor space for the whole project. For each building category, the area of the footprints is multiplied by the number of storeys based on the user inputs (including existing buildings to keep based on a 3.5-meter storey height). The sum of these values is the total amount of square meters of the scenario.

- The FSI is calculated by dividing the total amount of square meters of indoor space (previous point) by the total area of the selected plots considered for the project.
- The GSI is calculated by dividing the sum of the areas of the building footprints by the total area of the selected plots considered for the project.
- The density (gross density) is calculated in households per hectare. The total amount of households is computed with the number of new households provided by the user and calculating the number of households in the existing buildings to keep. As the average size of the household is also provided by the user in cubic meters, the volume of the existing buildings is divided by this unit of measurement. Finally, the total amount of households is divided by the total area of the plots plus the total area of the created roads to determine the density of the scenario.
- The final number of working places is calculated by dividing amount of cubic meters of non-residential spaces (new and existing buildings) by the average size of working space provided by the user.
- The correspondent amount of NR space for each household is calculated by dividing the NR volume into the final number of households.
- Heights and number of storeys for new buildings are calculated by dividing the volumes of the new buildings by the correspondent storey height (user input) depending on the function.
- Regarding open spaces, the road lines are cut based on the intersection radius provided by the user. These intersections are considered as road space. The remaining segments are used to calculate the six open functions of open space. For each road type, the sum of the length of all the remaining line segments is calculated as linear meters. Once the width of the road and the five of the six functions are defined (green excluded), the difference between the road width and the sum of the other functions is considered as green space. With this information and the linear meters of each road type, it is possible to calculate square meters of open space for the whole project.
- Additionally, the amount open space is divided by the number of households, to have open space indexes for each household.

Urban design constraints

The parametric modelling process is guided by design rules, warnings or suggestions that guarantee the minimum space quality standards in the project. Some of these constraints were implemented in the grasshopper tool of this thesis and others are in the wish list for future implementations because of its complexity.

The first one is a warning for buildings heights (figure 42). Initially, the user must introduce the maximum heights of the buildings for each type based on municipal regulations or personal

preferences. As the parameters determining the height of the buildings are the number of storeys and the storey height, it is not easy to have under control the height of the building, especially in the mixed-use and residential buildings where, the height is determined by the number of dwellings assigned to the type. The warning method is a simple Python code and a text panel in grasshopper in which is displayed the number of meters exceeding the desired height (figure 43).

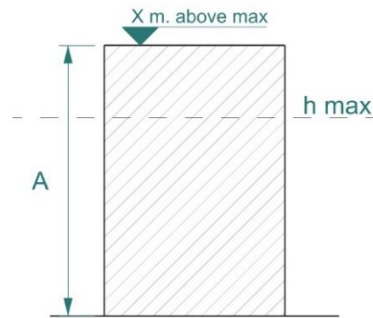


Figure 42. Building height scheme.

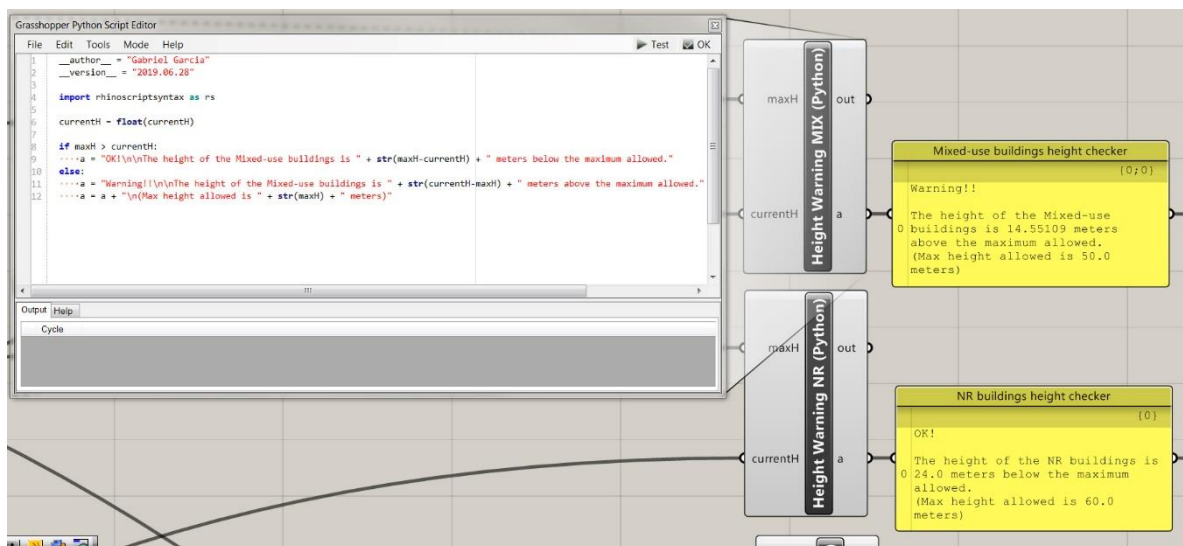


Figure 43. Screenshot of the Grasshopper interface. In the white box, the Python code inside of the GH nodes (grey) for building heights and the yellow boxes are the panels with information for the user.

The distance between buildings is important especially when buildings have considerable heights. To guarantee minimum demands of ventilation and illumination, a rule that controls the distance between the border of the plot and the building was introduced (figure 44). A Python node in GH calculates the distance in meters based on the user input of the percentage desired. This percentage is different for every building type. Automatically the geometry of the building is updated in Rhino (figure 45). For now, this warning message is fully implemented for NR buildings. For residential and mixed-use buildings, this parameter should be introduced manually because this distance is necessary to calculate the height of the buildings.

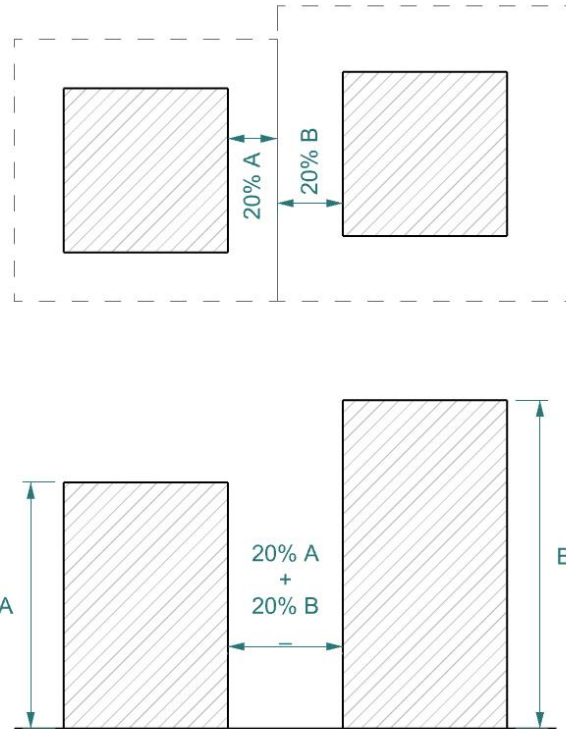


Figure 44. Calculation example of the distance between buildings. Up, top view. Bottom section view.

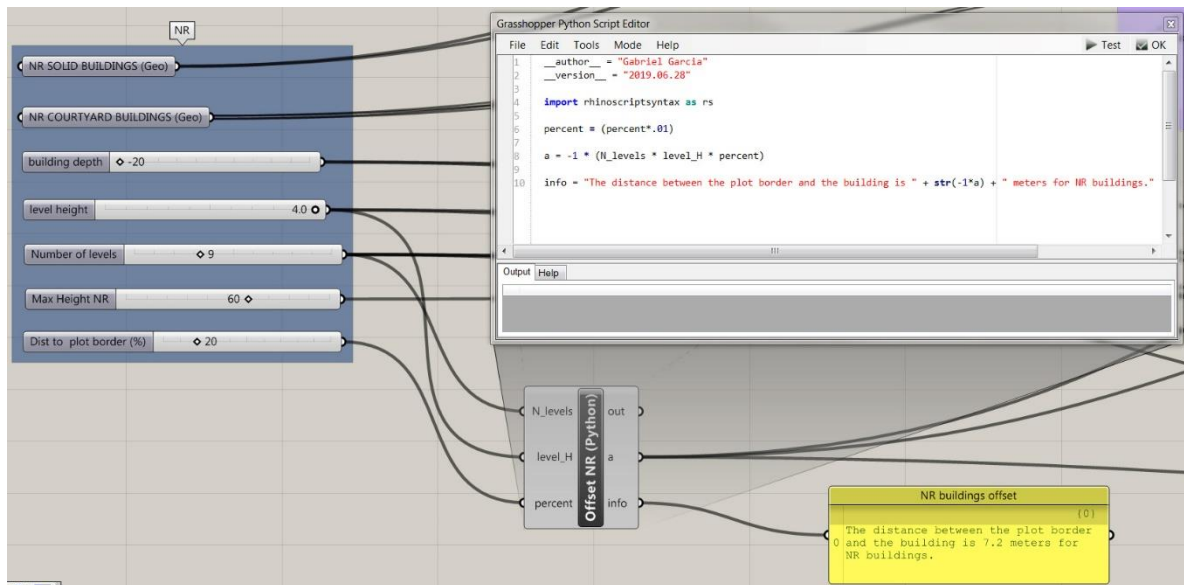


Figure 45. Screenshot of the Grasshopper interface. In the white box, the Python code inside of the GH nodes (grey) calculating the distance between the plot border and the building. The yellow box is the panel with information for the user.

Finally, the selection of the plots to create new buildings is assisted by the calculation of the area. If the area is smaller than a threshold given by the user, the software suggest removing those plots from the selection made. The process controls solid and courtyard buildings. This implementation helps the user to understand which plots may have geometry problems (figure 46 and 47).

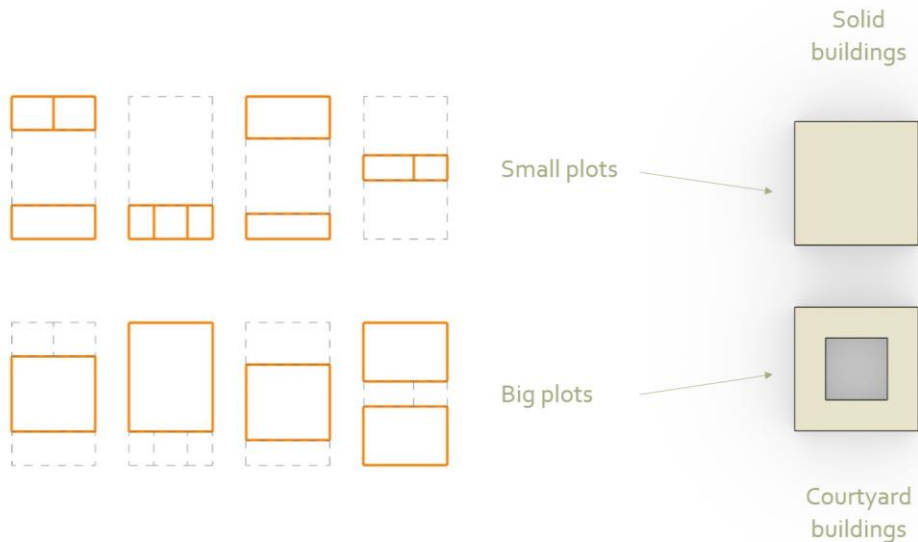


Figure 46. Suitability example of plot selection for new buildings.

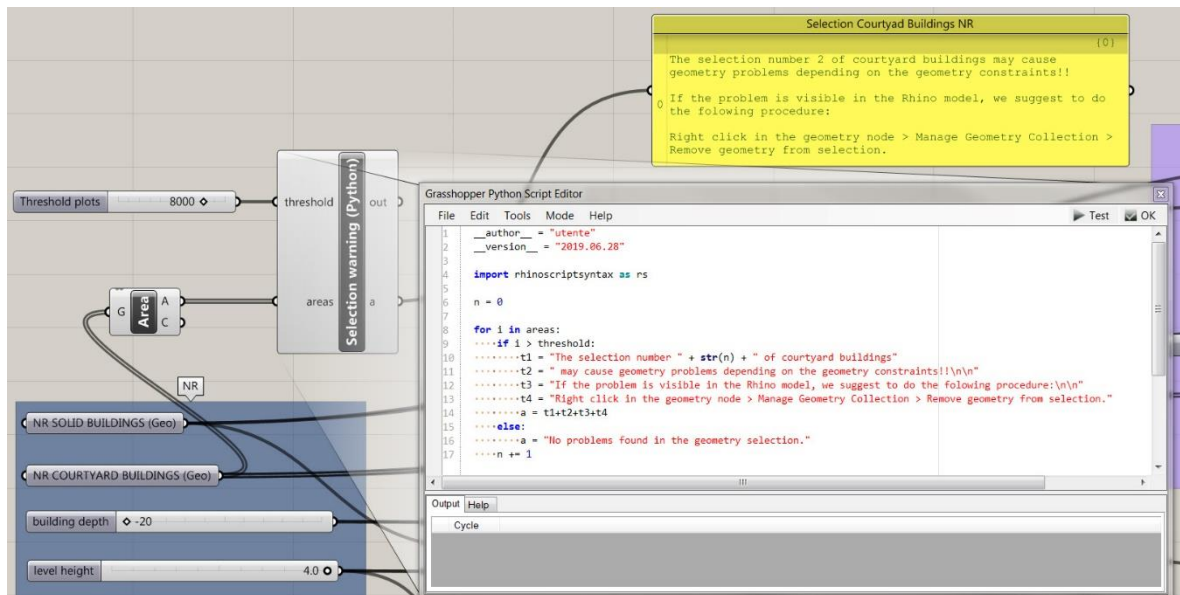


Figure 47. Screenshot of the Grasshopper interface. In the white box, the Python code inside of the GH nodes (grey) comparing the area of the plots with a threshold. The yellow box is the panel with information for the user.

Contextual information

The tool is provided additionally with extra information from the surroundings to help the user in the decision-making process during the interactive modelling. This contextual information are the buildings around the neighbourhood within 1.5 km distance, the non-residential functions in the same radius, the public transportation network and a topographic map.

The datasets are available directly in Rhinoceros as 'layers' that can be enabled and disabled when needed. Each layer was pre-processed before being loaded into Rhino. It is important that all the loaded data is harmonized using RD-New (28992) as CRS (Coordinate Reference System) to have a perfect match with the 3D model.

The sources and processing of information are:

- **Surrounding buildings:** these buildings we created using the same method as the LoD1 buildings in the indoor space calculation. The footprints were extracted from the Bouwjaar dataset and the heights of extrusion from the AHN3. The pre-processing stage was made in FME and exported as DWG format to load it into Rhinoceros (figure 48).

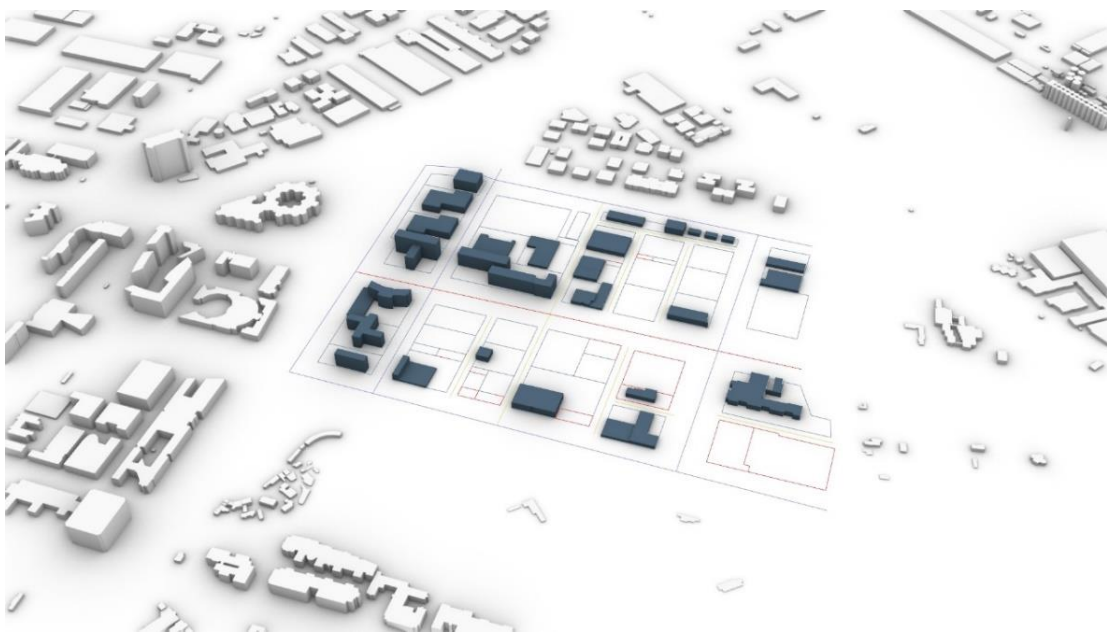


Figure 48. Surrounding buildings. Rhinoceros screenshot.

- **Public transportation network:** The metro, tram and train stations were downloaded as Shapefiles from the website <http://data.Amsterdam.nl>. The dataset is called *Tram-en metronet* and was pre-processed using QGIS. For the train station, it was calculated a buffer areas of 1500 meters for the metro stations a buffer of 500 meters. The dataset was enriched with the position of the bus stops from the *lijnenkaart2019-1*, the public transport network map provided by the GVB (administrator of public transport in Amsterdam) at <https://www.gvb.nl/sites/default/files/lijnenkaart2019-1.pdf>. The output is an extract from the interested area exported in JPG format and georeferenced directly in Rhino (figure 49).



Figure 49. Extract from the QGIS map. The yellow circle is the 1500-meter radius from the train station and the blue circles the 500-meter radius from the metro stations. The red dashed line is Sloterdijk One.

- **Topographic map:** This is an extract from the 'TOP25NL 2018 raster' downloaded from the Dutch geoportal (PDOK - <https://www.pdok.nl/downloads/-/article/basisregistratie-topografie-brt-historie>). A portion of the map was clipped and transformed into JPG format to reduce the size of the file. The image was loaded and georeferenced directly into Rhinoceros (figure 50).



Figure 50. TOP25NL loaded and georeferenced into Rhinoceros.

- **Non-residential functions of the surroundings:** This dataset is the same used to calculate the non-residential space in the second part of the methodology (*Functiekaart*). This time, the dataset was subdivided and coloured by function using FME. In Grasshopper, a label was added to each building based on the function name. This data is provided in Rhino as sublayers, so the user can isolate specific functions by enabling and disabling layers (figure 51).

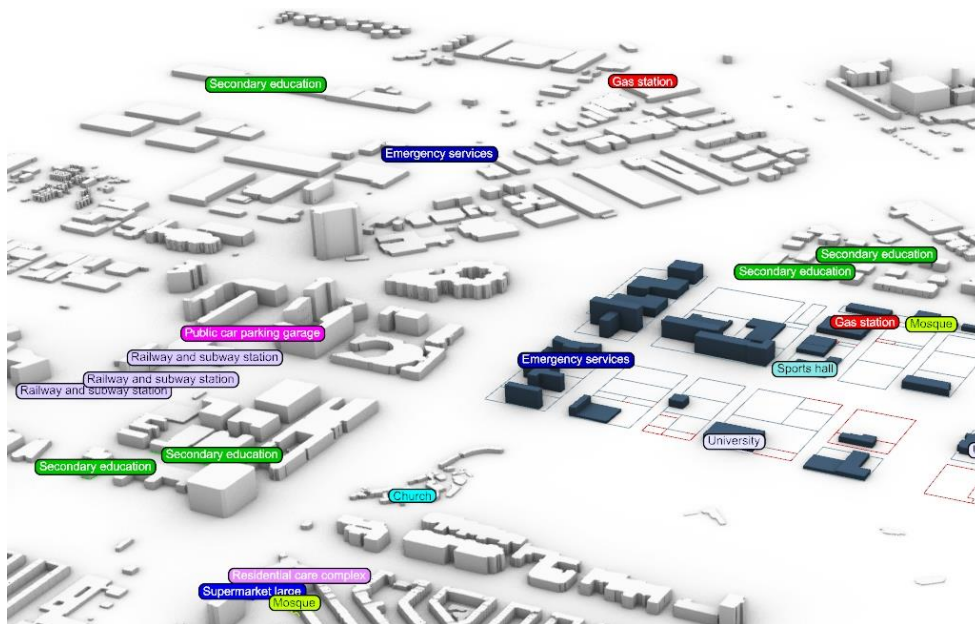


Figure 51. Non-residential buildings as labels in the 3D modelling tool.

Output

In the tool, two different types of output can be generated, the first one are screenshots from the 3D model itself, and the second one are reports containing the list of calculated parameters (KPIs, constraints, etc.). As the model is updated on the fly, the user can be export images at any moment of the design process (figure 52).

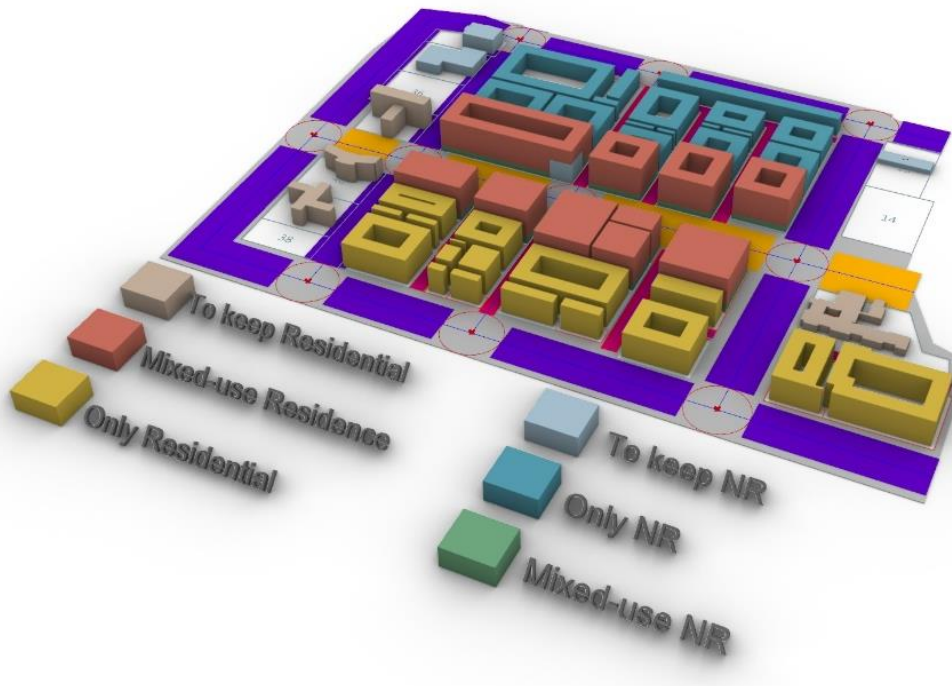


Figure 52. Screenshot of the 3D model.

Another 3D model that can be captured with screenshots is the schematic representation of the building to compare with the analysed neighbourhoods in the first part of the methodology (figure 53).

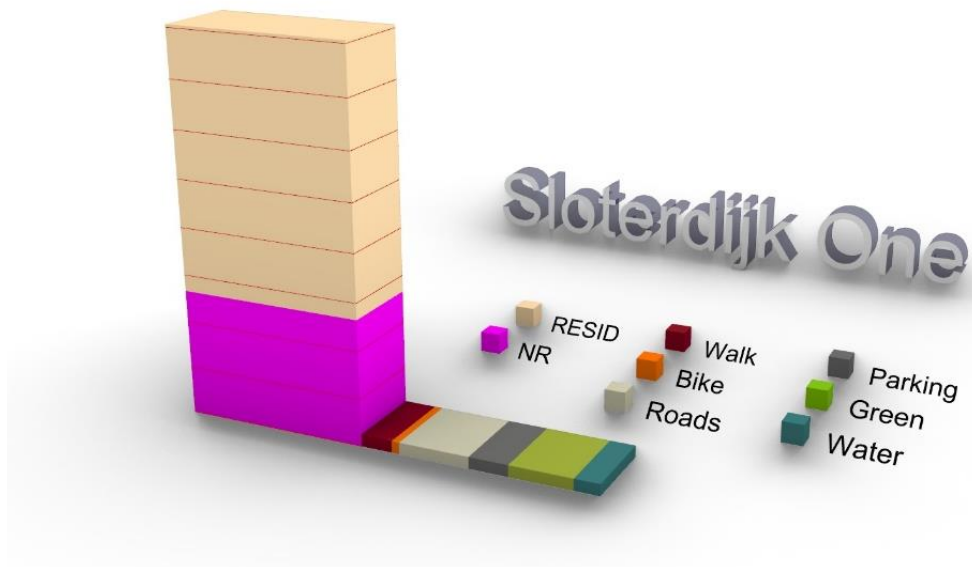


Figure 53. Screenshot of the comparison scheme.

The schematic representation of the road section models with the six functions of open spaces can be as well captured with screenshots (figure 54).

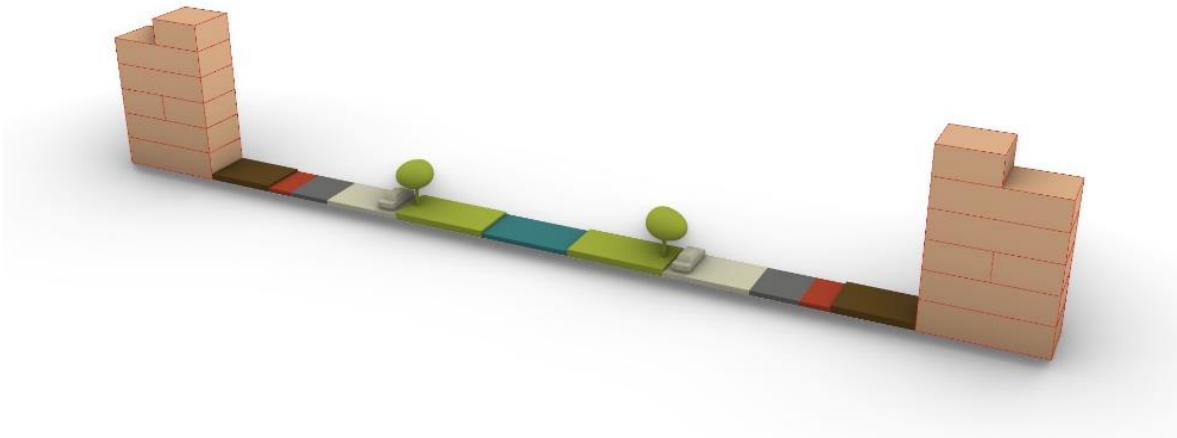


Figure 54. Screenshot of a 3D section model (The trees were not modelled in the overall model, only schematically for the 3D section model).

For transparency and communication purposes, a report containing all design parameters is also generated for each scenario. In the tool, there are two possibilities of generating reports, simplified or full, depending of the user needs. For this purpose, it is necessary to select a location folder for the output file, and the software automatically generate the log with a unique name based on the export date and time (YYYYMMDDHHMMSS).

For every line, the log contains an initial letter, this indicates if the information is a user input (I) or a calculated output (O) (table 3).

```

-----*
Saturday, July 6th 2019 (15:05:15)

FULL LOG

GENERAL OVERVIEW

O - GSI: 0.39
O - FSI: 4.21

O - Parcels area: 318729.86 m2

O - New construction: 1340800.0 m2
    O - Non-residential: 28.44 %
    O - Residential: 71.56 %

O - Density: 168.34 houses/Ha

RESIDENTIAL OVERVIEW

O - Total number of houses: 11250.86 homes
    I - New houses: 11220.0 homes

```

I - Houses in MIXED-USE buildings: 60.0 %
O - Houses in RESID buildings: 40.0 %

O - Existing houses: 30.86 homes

I - Average house size: 300.0 m3

NON-RESIDENTIAL OVERVIEW

O - Total number of working places: 12194.0

O - New working places: 9011.09

O - Working places in MIXED-USE buildings: 43.23 %

O - Working places in NR buildings: 56.77 %

O - Existing working places: 3182.48

I - Average working place size: 110.0 m3

O - NR space per house: 119.22 m3 (39.74 %)

NEW RESID BUILDINGS

O - Height: 40.29 m

O - Number of storeys: 12.0

I - Storey height: 3.5 m

I - Distance between sidewalk and building: -5.0 m (private space)

I - Building thickness: -19.0 m (only courtyard buildings)

Warning!!

The height of the Residential buildings is 10.286878 meters above the maximum allowed.

(Max height allowed is 30.0 meters)

NEW MIXED-USE BUILDINGS

O - Total height: 45.7 m

O - Total number of storeys: 13.0

I - Number of storeys in NR part: 2.0

I - Storey height in NR: 4.0 m

O - Number of storeys in RESID part: 11.0

I - Storey height in RESID: 3.5 m

I - Distance between sidewalk and building: -4.0 m (private space)

I - Building thickness: -20.0 m (only courtyard buildings)

OK!

The height of the Mixed-use buildings is 4.299273 meters below the maximum allowed.

NEW NR BUILDINGS

O - Height: 36.0 m

I - Number of storeys: 9.0

- I - Storey height: 4.0 m
- I - Distance between sidewalk and building: -14.4 m (private space)
- I - Building thickness: -20.0 m (only courtyard buildings)

OK!

The height of the NR buildings is 24.0 meters below the maximum allowed.
(Max height allowed is 60.0 meters)

OPEN SPACE OVERVIEW

- O - Water: 38289.19 m²
- O - Biking: 13913.82 m²
- O - Parking: 41323.02 m²
- O - Roads: 98587.62 m²
- O - Pedestrian: 77123.35 m²
- O - Green: 80368.2 m²

- O - Overall parking index per house: 0.29

- I - *Intersection radius: 35.0 m (considered as roads)

- O - Private open space: 122987.41 m²

ROADS - Type 1

- I - Road width: 80.0 m
 - I - Single bike lanes: 2.0
 - I - Bike lane width: 1.5 m

 - I - Parking lines: 4.0
 - I - Parking line width: 2.5 m

 - I - Drive lanes: 4.0
 - I - Drive lane width: 3.0 m

 - I - Water: 10.0 m (canal width)

 - I - Sidewalk width: 4.0 m (on each side)

 - O - Green areas: 37.0 m (width)

ROADS - Type 2

- I - Road width: 70.0 m
 - I - Single bike lanes: 2.0
 - I - Bike lane width: 1.5 m

 - I - Parking lines: 4.0
 - I - Parking line width: 2.5 m

 - I - Drive lanes: 4.0
 - I - Drive lane width: 3.0 m

 - I - Water: 10.0 m (canal width)

- I - Sidewalk width: 10.0 m (on each side)
- O - Green areas: 15.0 m (width)

ROADS - Type 3

- I - Road width: 20.0 m
- I - Single bike lanes: 1.0
- I - Bike lane width: 1.5 m
- I - Parking lines: 1.0
- I - Parking line width: 2.5 m
- I - Drive lanes: 1.0
- I - Drive lane width: 3.0 m
- I - Water: 1.0 m (canal width)
- I - Sidewalk width: 3.0 m (on each side)
- O - Green areas: 6.0 m (width)

OPEN SPACE PER HOUSE

- O - Water per house: 3.4 m²
- O - Biking space per house: 1.24 m²
- O - Parking space per house: 3.67 m²
- O - Road space per house: 8.76 m²
- O - Pedestrian areas per house: 6.85 m²
- O - Green areas per house: 7.14 m²

Table 3. Example of full log.

*An example of a simple log in the appendices section.

Finally, helped by the prof. Giorgio Agugiaro from the 3D Geoinformation group, each proposal was transformed from DWG format (Geometry + IDs as layers) and CSV format (Data + IDs) into a CityGML format using the safe software's FME (Figure 55). The generated CityGML models can be uploaded into web-based virtual platforms for visualization, for example, Google Earth or Cesium JS. This procedure is meant to facilitate dissemination and visual comparison of the different scenarios, and for potential inclusion of a wider audience in the evaluation or participatory processes. An example is given in the figure 56.

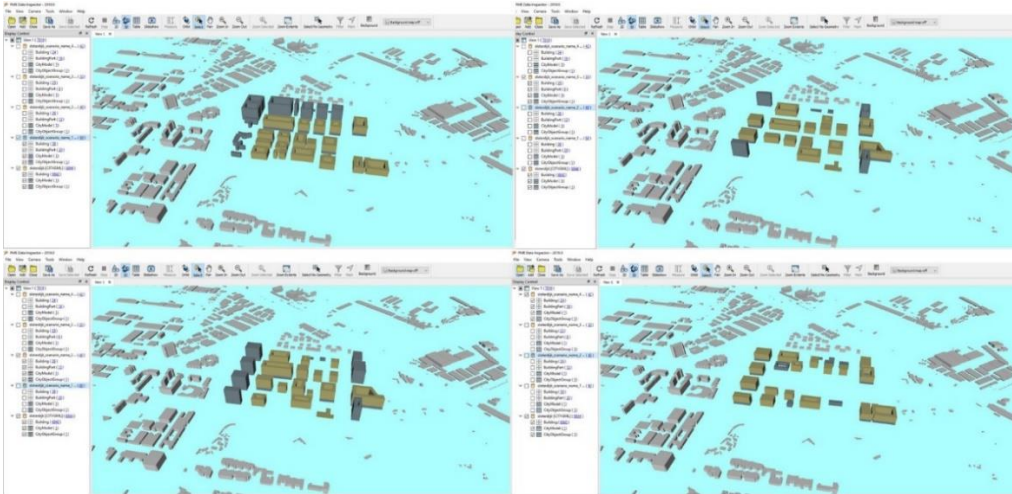


Figure 55. Four different design proposals visualized on the FME Inspector as CityGML models (G. Aguiaro).



Figure 56. Visualization of a CityGML model from a proposal loaded into Google Earth (G. Aguiaro).

5. Results and analysis

5.1 Neighbourhood selection results

Based on the generated KPI's, seven neighbourhoods were selected based on their similarity with *Sloterdijk One* (figure 57).

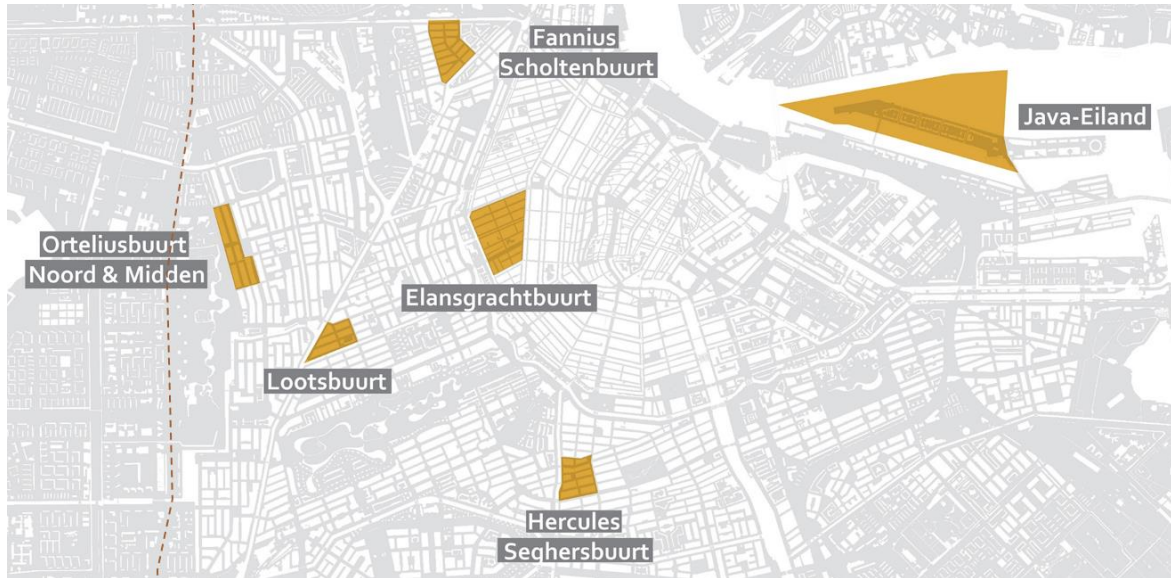


Figure 57. Selected neighbourhoods to analyse in Amsterdam.

Orteliusbuurt Noord and Orteliusbuurt Midden will be considered as a single neighbourhood because of their location and similarity. Because of this, in total, six areas were analysed to calculate the size of the living space. In the table 4, the full list of attributes for the selection.

Neighbourhood	Density (h/Ha)	Price Index per sq. meter	Quality of life	Year Index
<i>Java-Eiland</i>	97	€ 4,885.00	8	1996
<i>Elandsgrachtbuurt</i>	151	€ 6,738.00	9	1593
<i>Orteliusbuurt</i>	203	€ 5,442.00	4	1931
<i>Lootsbuurt</i>	214	€ 6,422.00	7	1918
<i>Hercules Seghersbuurt</i>	221	€ 6,207.00	7	1920
<i>Fannius Scholtenbuurt</i>	235	€ 6,151.00	4	1930

Table 4. Characteristics of selected Neighbourhoods.

In the list, four attributes were taken into consideration for the selection: housing density, price of the household, quality of life and year index.

Four neighbourhoods are denser than 200 households per hectare, which is close to the demand in *Sloterdijk One* (192). The other two, are less dense but are in the list because of their interesting characteristics: Elandsgrachtbuurt is the most expensive neighbourhood in the list. It belongs to the old part of the city and is the one with the highest quality of life. In contrast, Java Eiland is the cheapest and newest, besides a good rate in quality of life. This neighbourhood can be considered as part of the new expansion of the city and containing an important project of social housing on its north façade (<http://stadseilanden.nl>).

Returning to the densest four, they share similar characteristics: all of them were built at the beginning of the XX century and their prices are slightly above the average (more than 6000 euro/sq. meter). Fannius Scholtenbuurt is the densest neighbourhood in the city, with a weak score in quality of life but located close to the city centre. Orteliusbuurt and Lootsbuurt have similar characteristics with a modernist style similar to the New West area and they are in the nearby to the Haven-Stad project. Finally, Hercules Seghersbuurt is situated in the southern part of the city and it is a modern gentrified area close to the business district of Zuidas Zuid.

5.2 Space calculation results

For each neighbourhood, all living-space values were normalised and referred to one *prototypic* average building (in our case, composed of three households, with additional non-residential and outdoor spaces) to facilitate comparison. This schematic building, is 5.4 meter wide (front facade) by 12 meter deep, which are standard dimensions for residential buildings in the Netherlands. In the scheme, the non-residential space is situated in the lower storeys and the three households above of it. It was decided to represent the results using this building because it allows a better comparison among neighbourhoods with regard to heights.

In the front façade, proportionally, it was represented the distribution of open spaces for the three households.

It is important to remark that the building and open spaces are proportionally drawn for three households but the written data in the scheme is referred to a single household.

Besides the 3D model and information, four extra calculations were added to the prototypic buildings:

- **The average price per household:** This information was calculated with the average volume of the household and considering a storey height of 3 meters. Then, the resulting square meters multiplied by the ANPI (Average Neighbourhood Price Index).
- **Number of inhabitants per household:** Calculated by dividing the number of inhabitants by the number of households (*Wijken en Buurten* dataset).
- **Distance to the Amsterdam Central station:** This distance was measured from the main entrance of the station in a straight line to the centroid of the neighbourhood polygon.
- **The average size of a working space:** This parameter was calculated by dividing the volume of non-residential spaces by the number of working people in the neighbourhood (gebiedinbeeld.amsterdam.nl)
- **Parking index per household (PI):** This is the amount of parking spaces in the streets per household. One parking space is assumed as 2.5 meters x 5 meters (12.5 sq. meters).

In the figures 58 to 63, the resulting panels of space calculation.

Java-Eiland

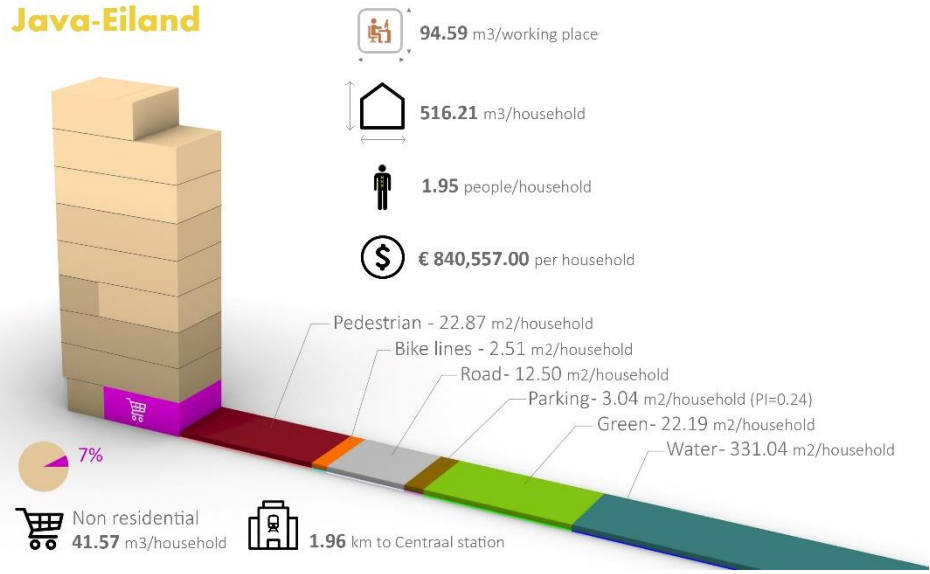


Figure 58. Java-Eiland panel.

Elandsgrachtbuurt

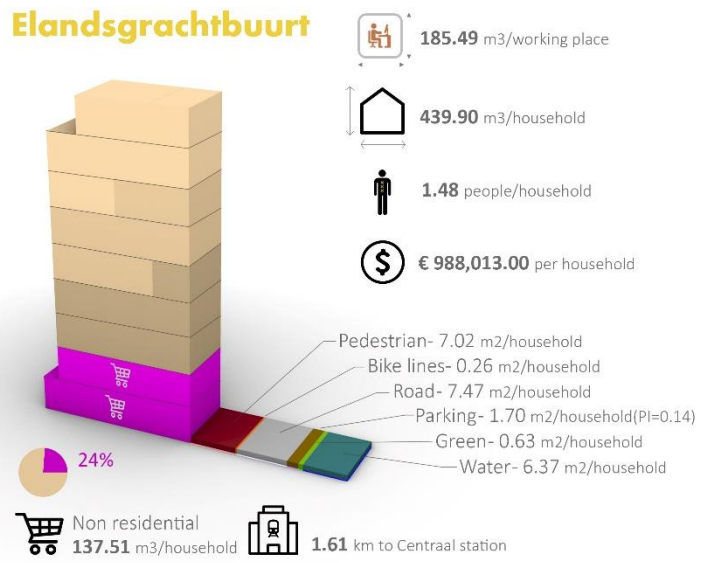


Figure 59. Elandsgrachtbuurt panel

Orteliusbuurt

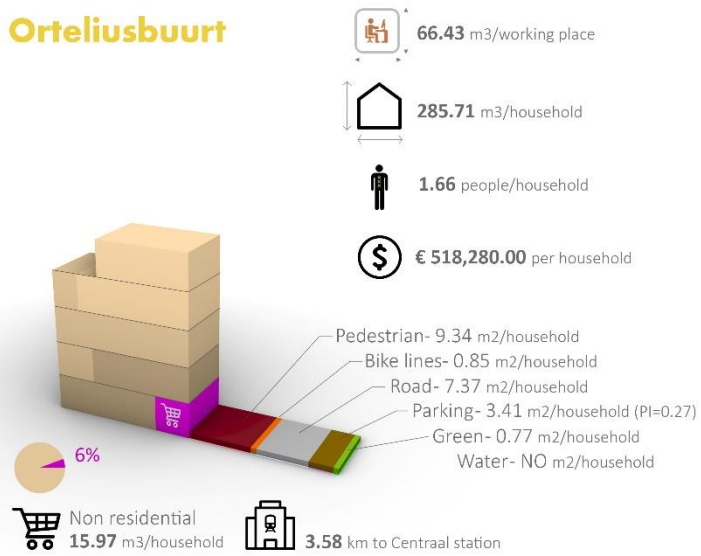


Figure 60. Orteliusbuurt panel.

Lootsbuurt

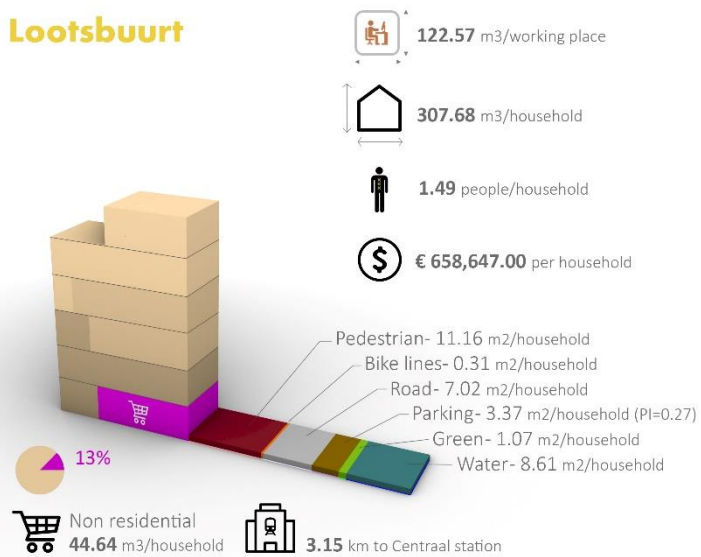


Figure 61. Lootsbuurt panel.

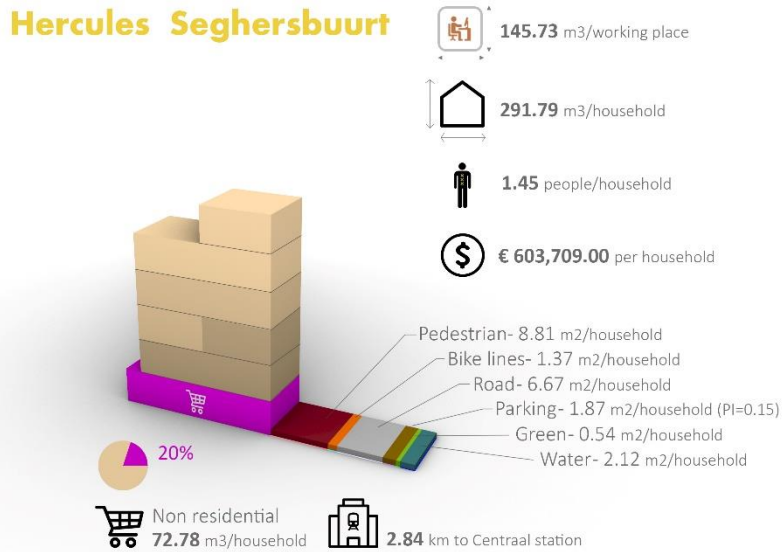


Figure 62. Hercules Seghersbuurt panel.

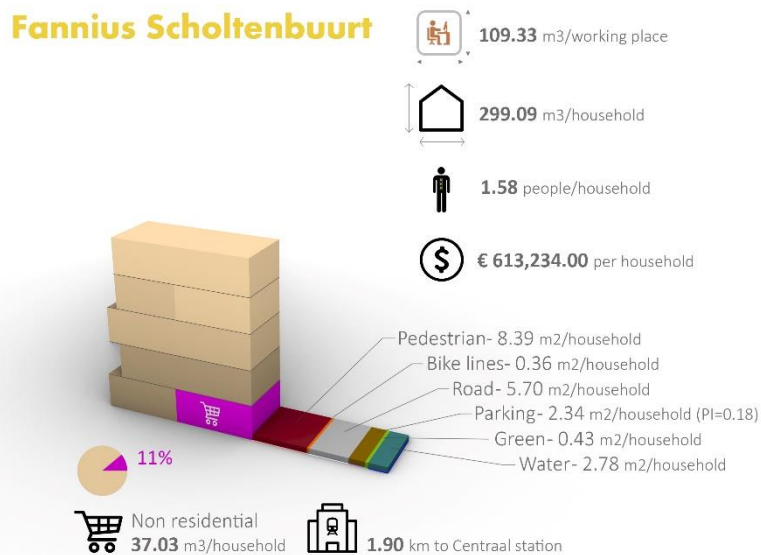


Figure 63. Fannius Scholtenbuurt panel.

Results of calculations demonstrate that exist a strong relation between the size of the household and the density. While denser is the area, the size of the living space decreases (tab. 5).

In this table, it is also shown the no-relation between the price and the size of the households.

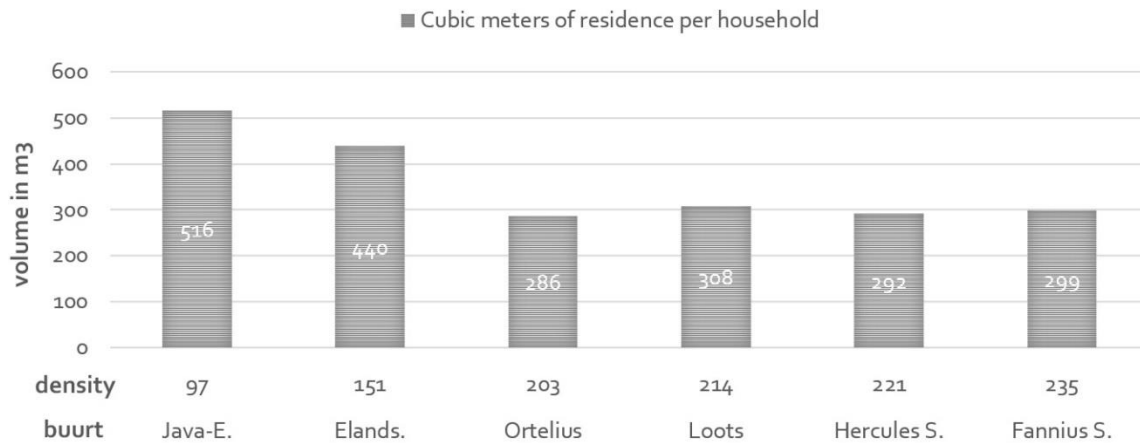


Table 5. Cubic meter of residence per household. Bottom of table: Price index and housing density (Ordered from left to right by ascending density).

Another relation found in the resulting tables, is the one between the price per sq. meter of the household and the percentage of private space (plots) in the neighbourhood. While more expensive are the households, the amount of public space decreases (tab.6).

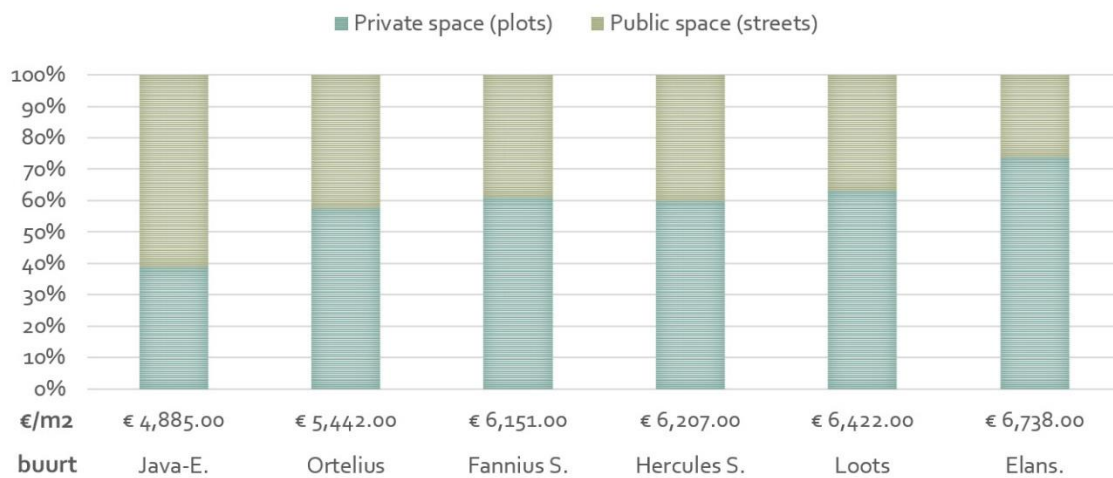


Table 6. Public space and price of the household (Ordered from left to right by ascending price).

The amount of shops and commercial spaces is also related with the liveability index. In the table 7, it is possible to see that, while more NR space, the quality of life index increases.

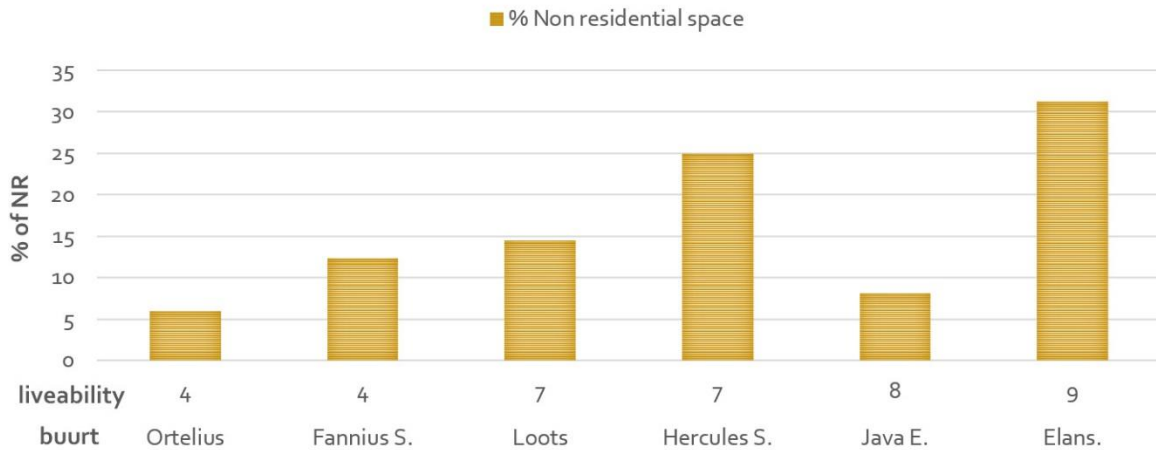


Table 7. Amount of NR space and quality of life (Ordered from left to right by ascending liveability scores).

The distance from the neighbourhood to the central station, as well, seems to have a direct relation with the quality of life. In the table 8, it is possible to see that the closer to the station, the higher the quality of life.

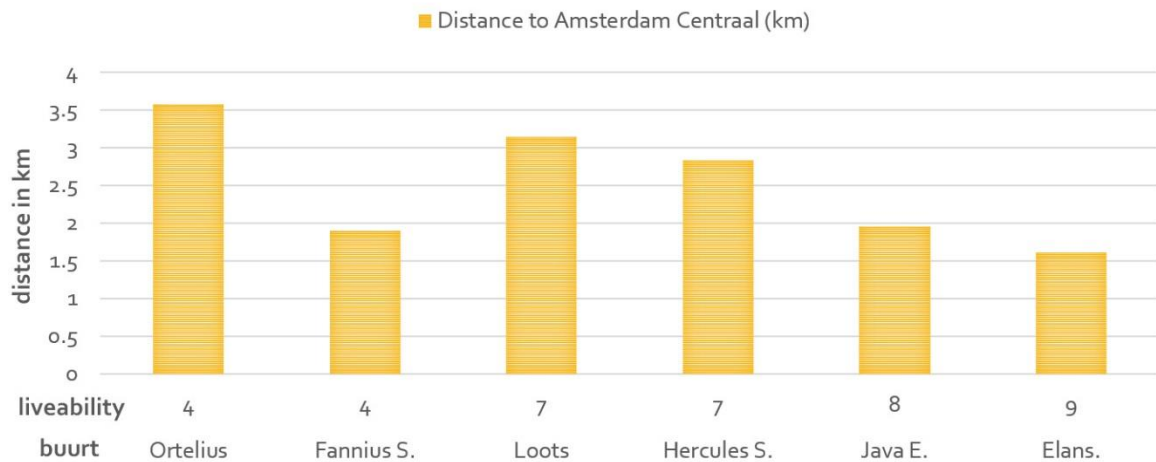


Table 8. Distance to Amsterdam Central Station and quality of life (Ordered from left to right by ascending liveability scores).

The four neighbourhoods with higher densities have similar characteristics regarding building heights, open spaces, green areas and price of the households, excepting Orteliusbuurt, coinciding the cheapest and the furthest of the central station.

Java-Eiland and Elandsgrachtbuurt seem to be the oddest in the list, both contrasting in size of open spaces and density but very similar in household size.

5.3 Creation and comparison of design scenarios

Regarding to the last part of the methodology, several design proposals (also called scenarios) were created to test the tool. In order to understand the importance of the household size and to compare the six neighbourhoods among each other using the tool, a scenario was generated using the same configuration for all of them, only the size of the household and the number of storeys in the NR buildings as changed to have comparative models with similar number of working places. Two specific cases were selected to make a punctual comparison: Elandsgrachtbuurt and Orteliusbuurt (the other four scenarios created for the remaining analysed neighbourhoods can be found in the appendixes section).

As described before, the modelling process was carried out using exactly the same constraints and design parameters for both proposals: 11,220 households, around 8000 working places and the same building distribution for each category. In the Orteliusbuurt model, the number of working places is more than 12,000 because the non-residential buildings must have at least 1 storey (the minimum available in the tool), so for this configuration, this is the minimum amount of working places. In the figure 64, the screenshots of both proposals.

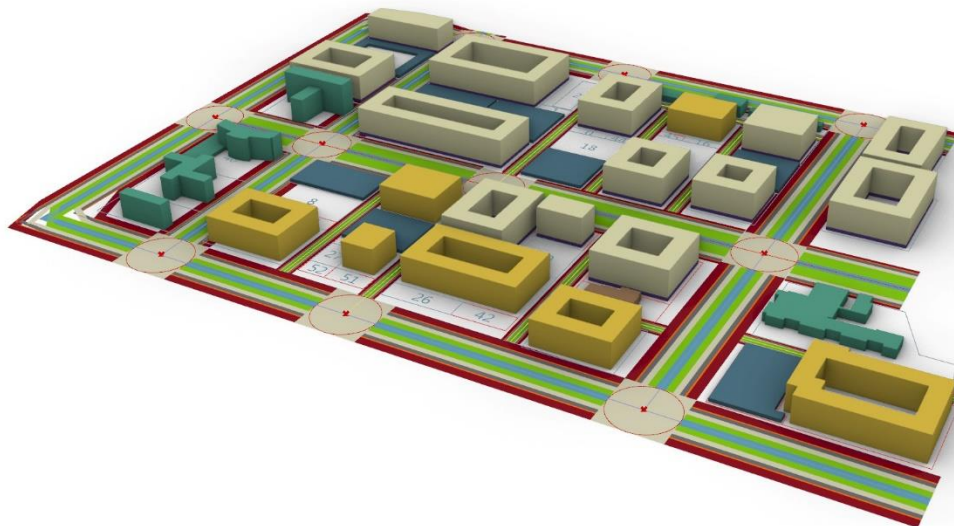
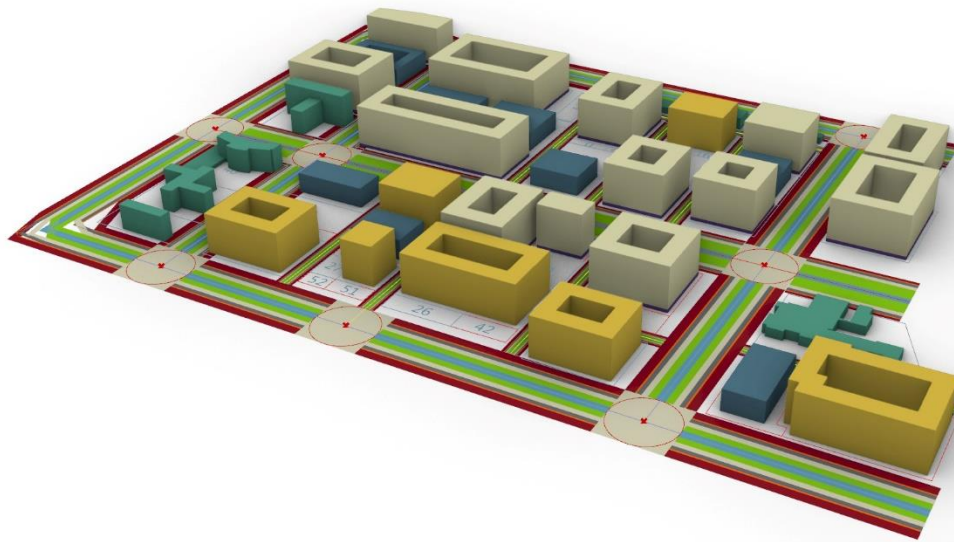


Figure 64. Top, screenshot of the 3D model generated with the Elandsgrachtbuurt space sizes. Bottom, screenshot of the 3D model generated with the Orteliusbuurt space sizes.

The contrast between the two proposals it is clearly visible by observing the screenshots, nevertheless, to make a specific comparison among projects, selected information from the logs is displayed in the table 9.

Goal:

11220 households	Java E.	Hercules	Elands.	Orteliusb.	Lootsb.	Fannius
<i>Household size (m3)</i>	515	290	440	285	310	300
<i>Working space (m3)</i>	95	145	185	65	125	110
<i>Working places</i>	8,692	7,785	7,524	12,703	7,930	11,250
<i>FSI</i>	5.8	3.8	5.51	3.57	3.92	3.79
<i>m2 of construction</i>	1,848,000	1,212,200	1,754,700	1,136,400	1,247,900	1,206,500
<i>Storeys Residential</i>	16	9	13	9	9	9
<i>Storeys Mixed-Use</i>	17	10	15	10	11	11
<i>Storeys NR</i>	1	3	6	1	2	1

Table 9. Data extracted from the logs of each proposal.

These two proposals can host the same amount of households with different characteristics regarding indoor spaces. This can be considered as a demonstration about the importance of using the size of the living space for urban development projects.

6. Conclusion and future work

6.1 Conclusion

In this thesis, the *city of the present* was analysed from the open data perspective. The resulting of this analysis are key elements containing the essence of selected areas in Amsterdam to create the *city of the future*.

This *city of the future*, is thought to be planned from a multidisciplinary perspective, specifically for the methodology of this thesis, in three main steps: starting from the 'Geo' domain with spatial data analysis, passing through the urban 'planning domain' with design and parametric modelling and closing with the 'Geo' domain by storing the design proposals in international geo-databases.

In this methodology, the size of the living space as a unit of measurement plays the major role and contrary to what was personally expected, the results of the first analysis demonstrate that the size of the households and open spaces in Amsterdam have no relation with the socio-economic status of the neighbourhood. The personal thought was, while more expensive the households, bigger the spaces related to it, but in Amsterdam it seems the opposite.

Another outcome in relation with the preliminary assumptions is the relation between the *leefbaarometer* scores and the amount of services in the neighbourhood. Before this thesis, it was thought that in quiet neighbourhoods with less NR functions, the liveability was higher. Nevertheless, if we interpret these scores as an indicator of happiness, the major part of the citizens are definitely happier in equilibrated mixed-use areas.

Regarding the 3D modelling tool, even if it is still a prototype made with simplifications and assumptions, it contributes to demonstrate the importance to consider the size of the living space, in particular the size of the households, in future urban developments. Furthermore, the exporting process allows making the design process more transparent and public.

A missing element that might contribute to reduce the number of simplifications, assumptions and increase the overall accuracy of the results in this thesis, could be a semantic 3D model provided by official sources in which reliable information about the size of the living spaces is available.

6.2 Future work

For this thesis, the non-residential spaces were used to calculate size of the individual working space. This was estimated by making assumptions regarding the number of storeys for each non-residential activity. Having said that, an interesting topic for future research could be the definition of an accurate method to calculate the size of the working space, maybe by making a differentiation between amenities and working space.

Another topic for future implementations could be the creation an automated method to calculate the size of the living space for every neighbourhood in Amsterdam.

Once this process is completed, the following step could be every *buurt* in the Netherlands as the Dutch datasets are well harmonized for the entire country. This characteristic of open data, theoretically, allows upscale the process.

Once the size of the living spaces are known and harmonized in a dataset, the next level for the tool could be the ability to compare automatically the own designs with any other neighbourhood in the Netherlands. Alternatively, the opposite way, load the exact same characteristics from a specific *buurt* in the tool and use it as default parameters to start a new scenario.

The idea could be to connect the tool with a living space size dataset or, better, a size generator to keep the information up to date.

Another implementation could be the development of the 3D modelling tool in an open source software. The development in Rhinoceros and Grasshopper was a preliminary test but the methodology is based on open data.

Regarding to specific elements of the 3D modelling tool, the connection between indoor and outdoor spaces can be made by calculating an ideal road width based on the height of the buildings. This procedure, unfortunately, remained out of the scope of this thesis because of the limited time of implementation.

As the heights of the buildings are known, the width of the road can be an average percentage of the building heights along the road (figure 65). In order to implement this constraint, a topology checker should be introduced in the tool to understand which plots influence each road. With this procedure, the user could be provided with information to create an adequate road infrastructure based on the design of the buildings.

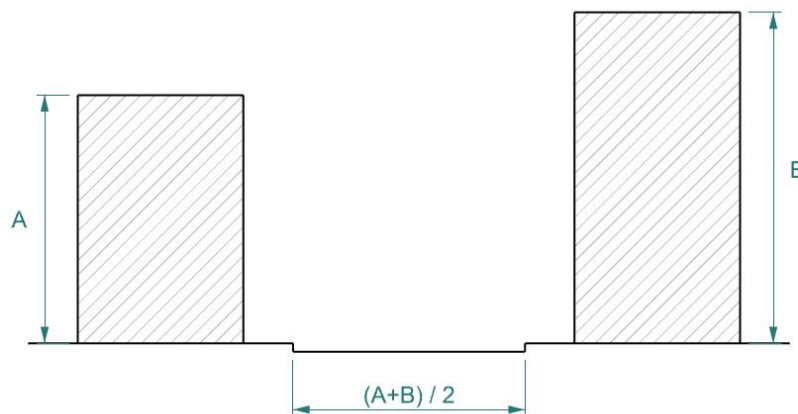


Figure 65. Calculation of the road width based on the building heights.

Following this idea of the topology checker for roads, knowing which plots are situated along roads is not only beneficial for open space design but also to give more flexibility to the buildings design.

If the side of the plots facing the road is known, the possibilities of detaching or attaching the building to the streets gives more flexibility to the building design. This is useful to create row houses, different street cross sections, courtyard buildings with different heights, etc.

For example, with this information, it could be possible to have corner buildings on the side of the road but not attached to the neighbour buildings (left figure 66). Another example is the

creation of row houses with a front yard garden or single buildings close to the road but separated in the other 3 sides from their neighbours (Right figure 66).

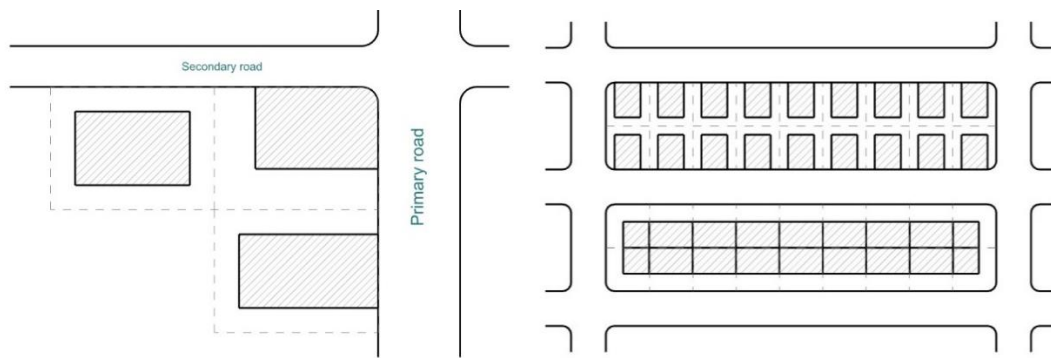


Figure 66. Design possibilities by applying a topology checker to the plots.

7. Reflection

The work in this MSc thesis was realized within the *Stad van de Toekomst* graduation lab in the Faculty of Architecture and the Built Environment. This is a multidisciplinary group of students and professors with the scope of designing the 'city of the future' from the perspective of different disciplines: architecture, urbanism, building management, transportation engineering, geomatics, etc.

From a personal point of view, the 'city of the future' is a projection of the data we are collecting at every second from our current cities. The problem is, in most cases, these data is not clearly readable for future makers or, in this specific case, urban planners. For this reason, it was decided to create a mechanism to make this projection as clear as possible for designers.

The main goal of this mechanism is inspired from one of the recurrent ambitions of the Municipality of Amsterdam: reproduce the current 'successful' urban areas in future expansion projects of the city (A10 ring). In contrast to traditional methods, in which scientific theories were used to analyse the current situation of the city, on this research, the city of the present is analysed based on open data. This alternative method is one of the main proposals of this thesis to design the 'city of the future'.

The 'city of the future' proposed by this thesis, is based on the size of the households as principal unit of aggregation for future developments. As demonstrated, this dimension can be crucial when the space is limited. Recently in Amsterdam, because of the housing needs of the city, the first question that comes out when talking about new developments is *how many households can be allocated in the project?* and, as shown in the results of this research, the answer can widely vary depending on the taken reference for the project, despite the same given constraints.

Other elements widely researched when designing the 'city of the future' are cross section modelling for roads, the shape of the buildings and the spatial analysis of the current situation with GIS tools. For each of these three topics, several scientific documents can be found as a reference but it is rare to find these topics combined in a single research. This is the reason why in this thesis, all these topics were combined to understand the relation among them.

In my experience as an architect, many the design proposals often end up 'forgotten' or locally stored somewhere and, eventually, become inaccessible or lost. On this thesis, the use a standard format like CityGML to store the generated design proposals, might help to share the work of designers. For one, the possibility to easily publish the results in web-based digital platforms can contribute to the welcome beneficial 'side effect' of further valorising the use of (open) datasets for design purposes.

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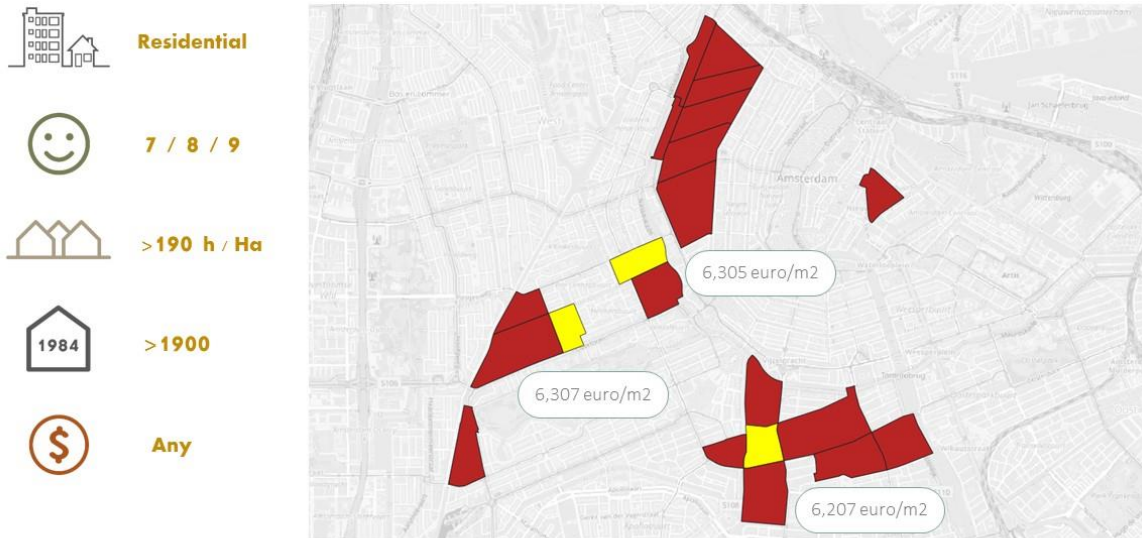
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9. Appendices

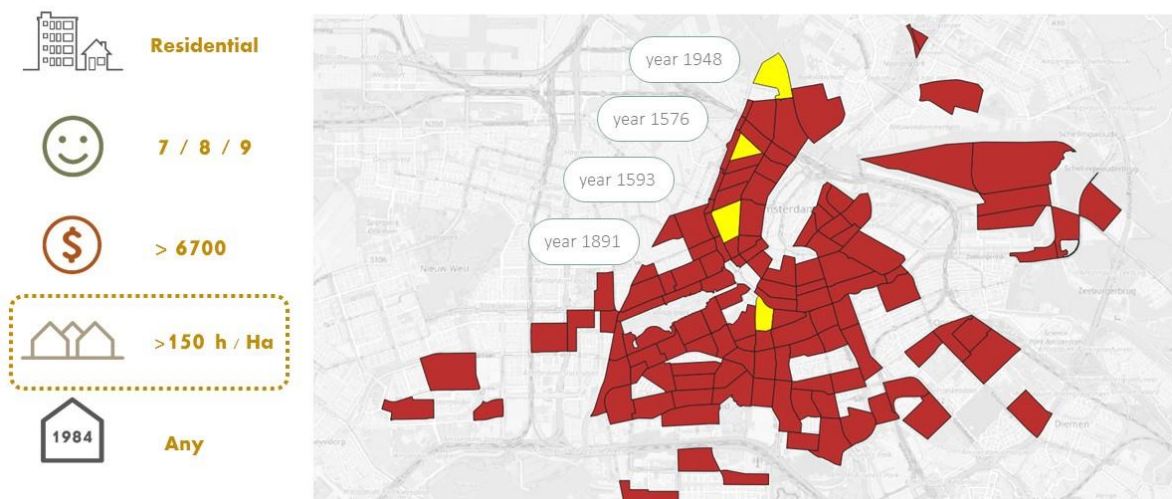
DEMO VIDEO: https://www.youtube.com/watch?v=cPYT5_cFlgw

SEARCH FOR CANDIDATE NEIGHBORHOODS MAPS




Search for major similarity with Sloterdijk One

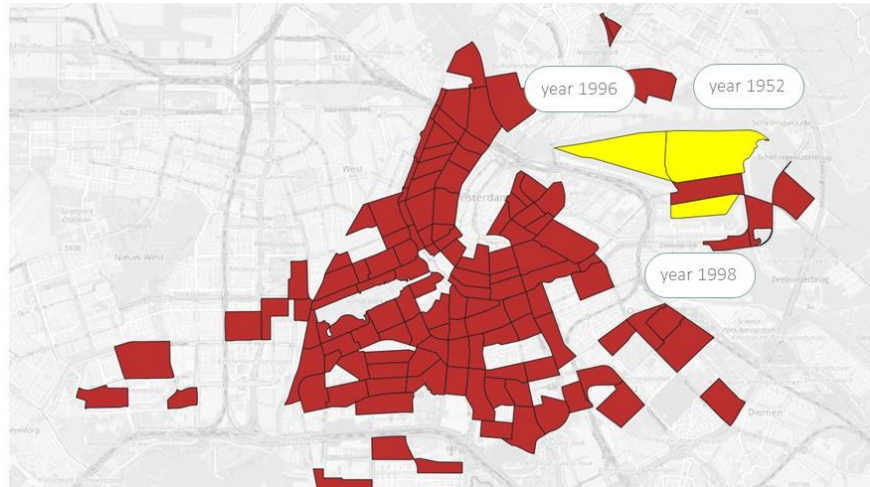


Search for HIGH LEVEL HOUSING



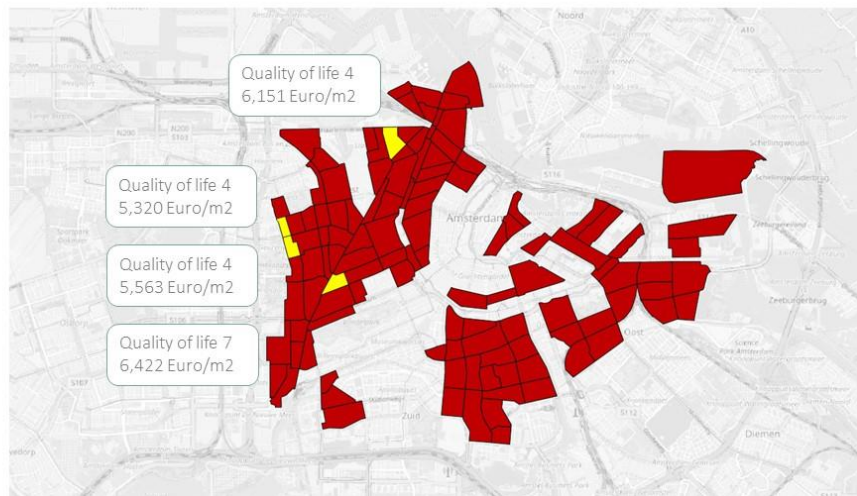
Search for SOCIAL HOUSING

-  **Residential**
-  **7 / 8 / 9**
-  **< 5000**
-  **> 90 h / Ha**
-  **1984** **Any**



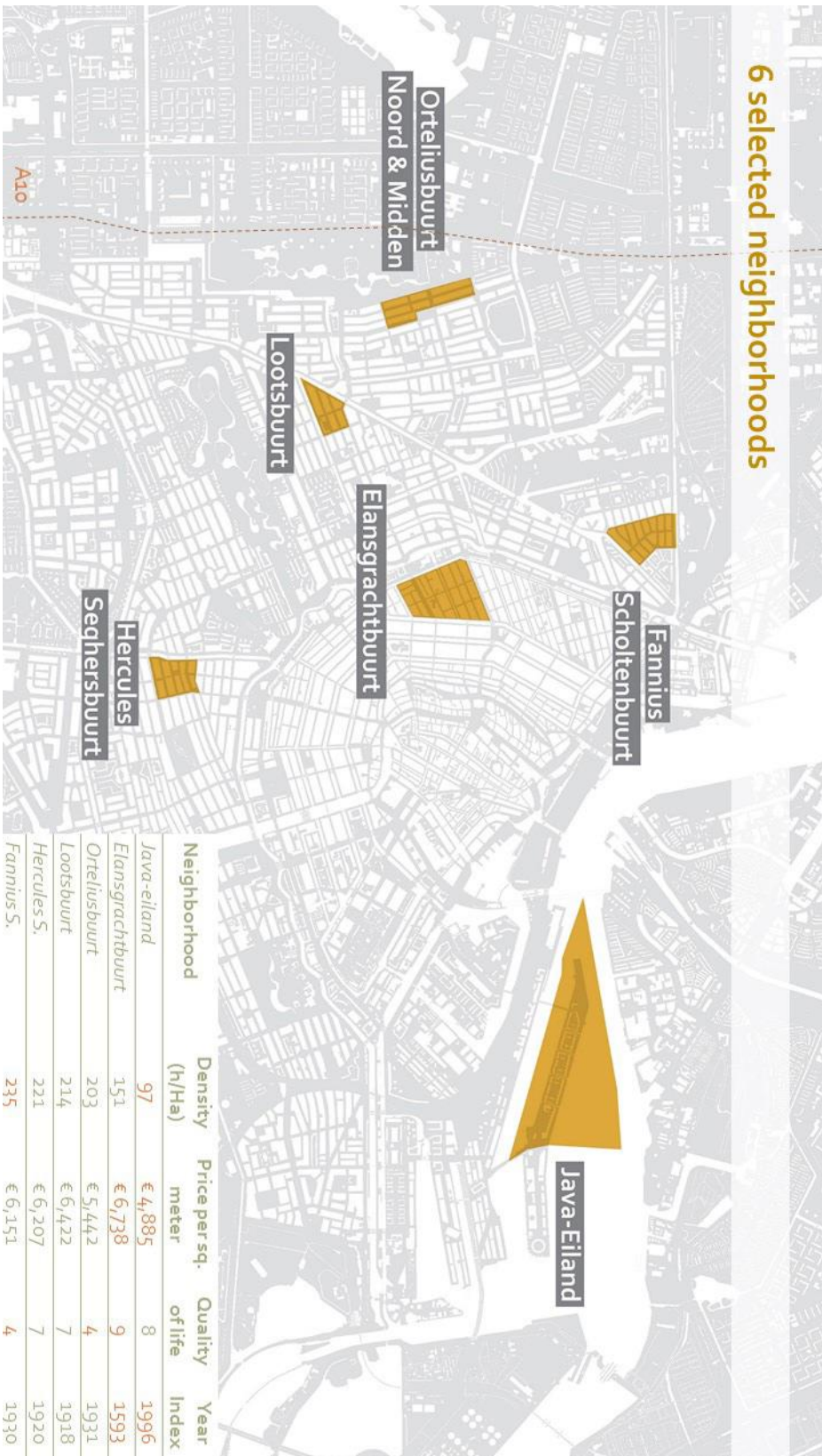
Search in WEST areas

-  **Residential**
-  **Any**
-  **Any**
-  **> 190 h / Ha**
-  **1984** **Any**



SPACE CALCULATION REFERENCES

6 selected neighborhoods



Java-Eiland – land ownership



1996



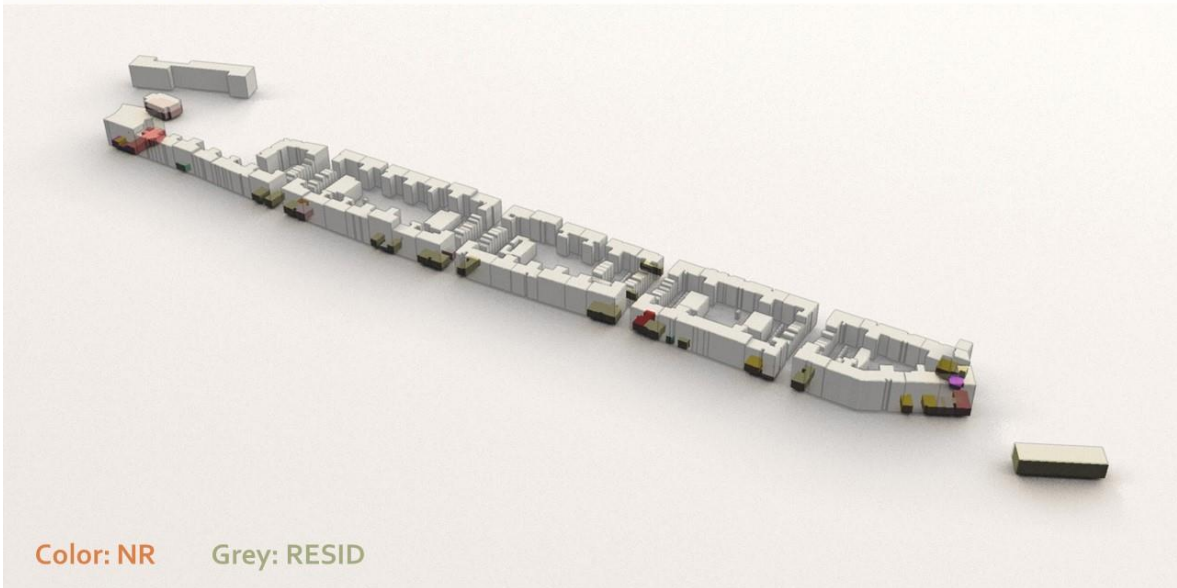
Java-eiland



1996



Volume calculations _ Java-eiland



Hercules Seghersbuurt – land ownership



Hercules Seghersbuurt



1920

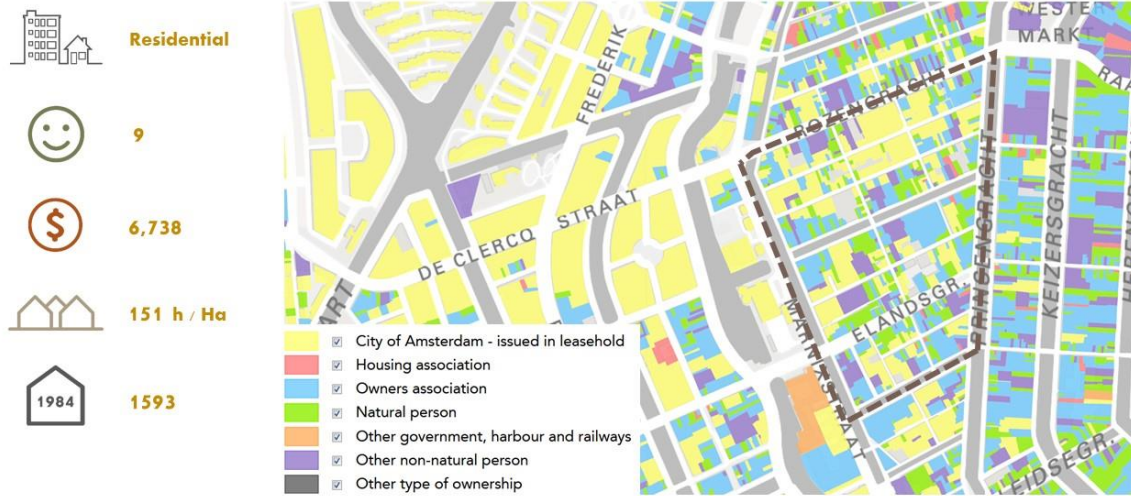


Volume calculations _ Hercules Seghersbuurt



Color: NR Grey: RESID

Elansgrachtbuurt – land ownership



Elansgrachtbuurt



Volume calculations _ Elansgrachtbuurt



Color: NR Grey: RESID

Orteliusbuurt – Land ownership



Orteliusbuurt



Residential



4



5,442



203 h / Ha

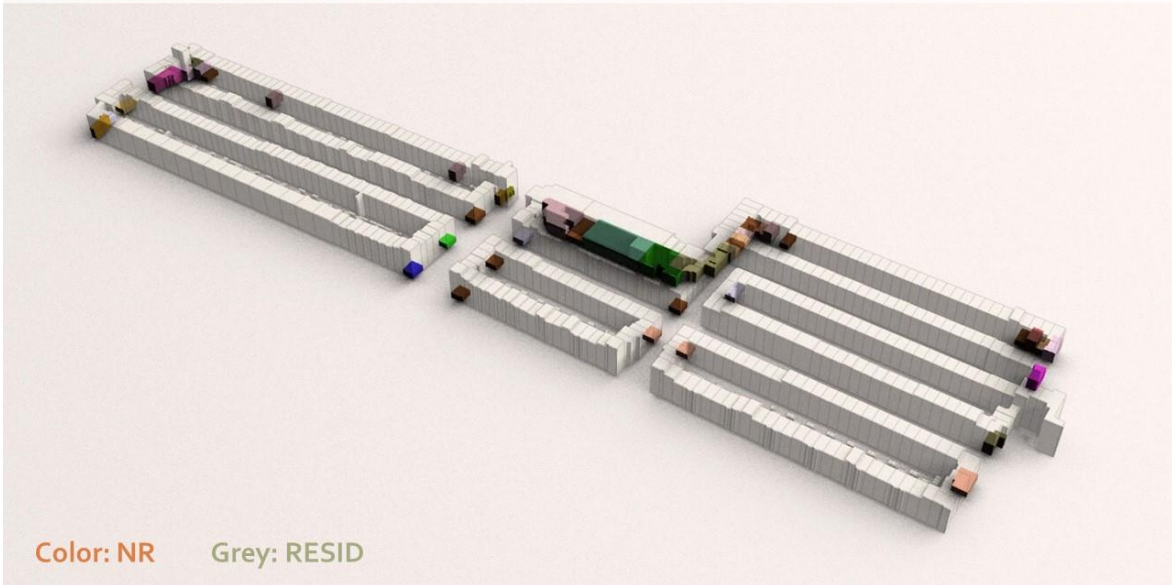


1931



17

Volume calculations _ Orteliusbuurt



Lootsbuurt – Land ownership



Residential



7



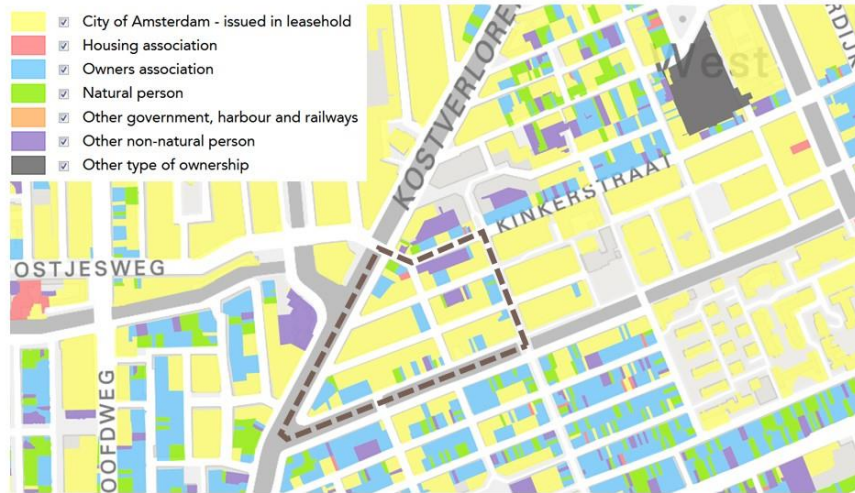
6,422



214 h / Ha



1918



Lootsbuurt



Residential



7



6,422



214 h / Ha



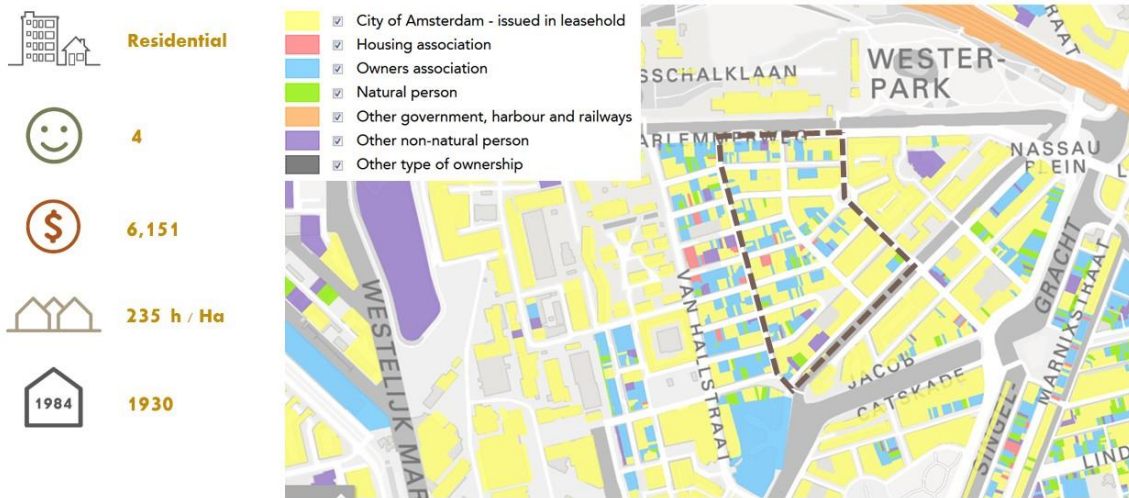
1918



Volume calculations _ Lootsbuurt



Fannius Scholtenbuurt – Land ownership



Fannius Scholtenbuurt



Residential



4



6,151



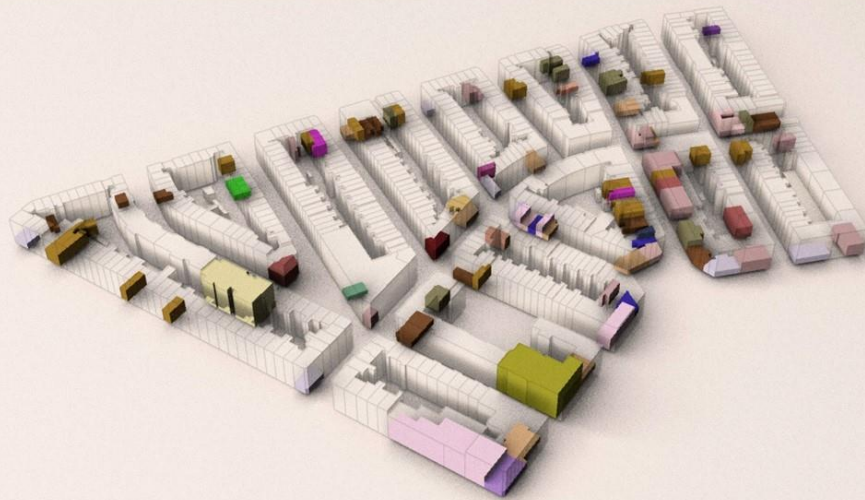
235 h / Ha



1930

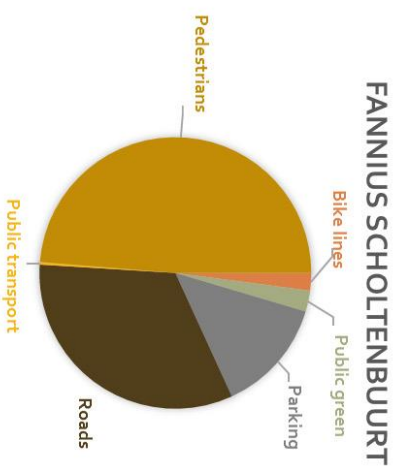
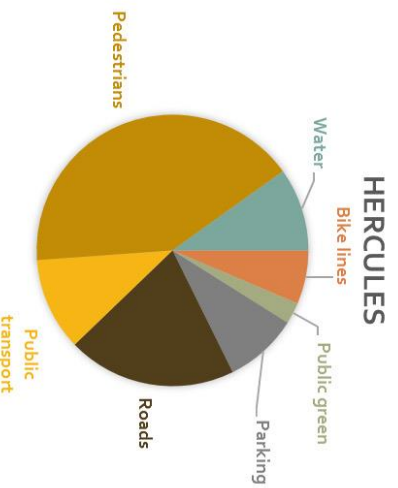
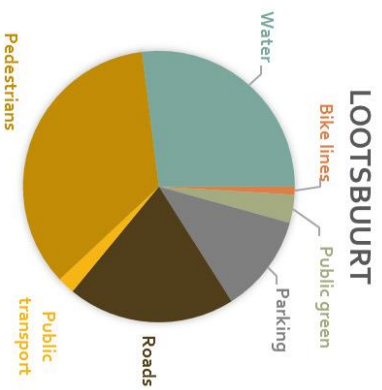
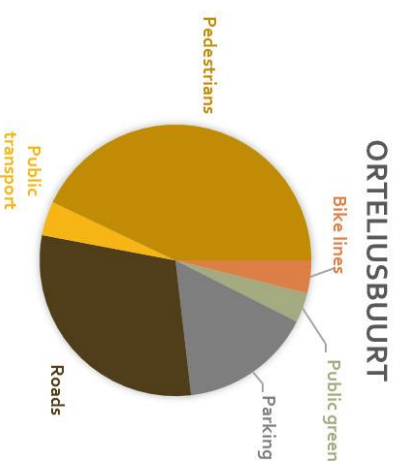
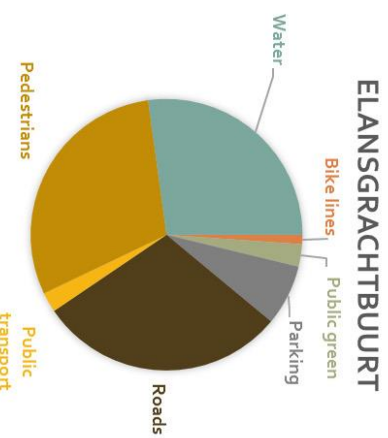
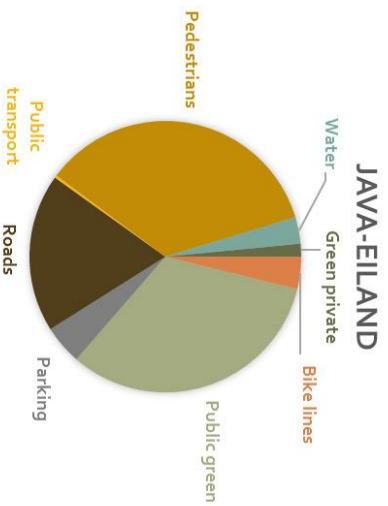


Volume calculations _ Fannius Scholtenbuurt

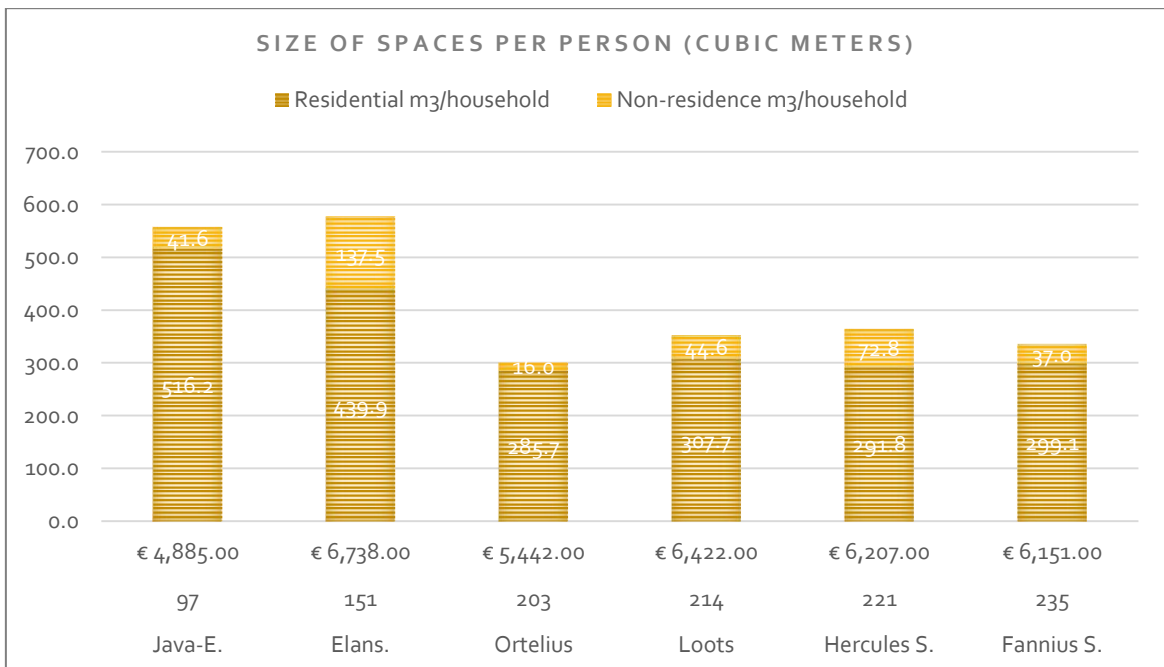
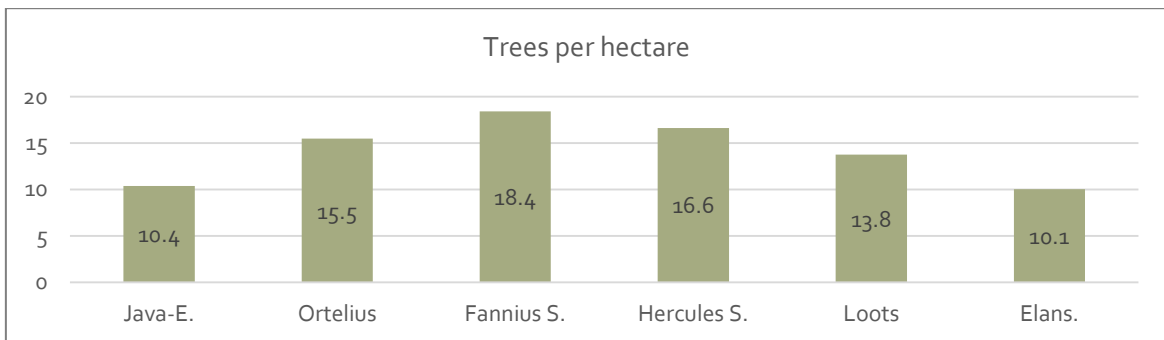
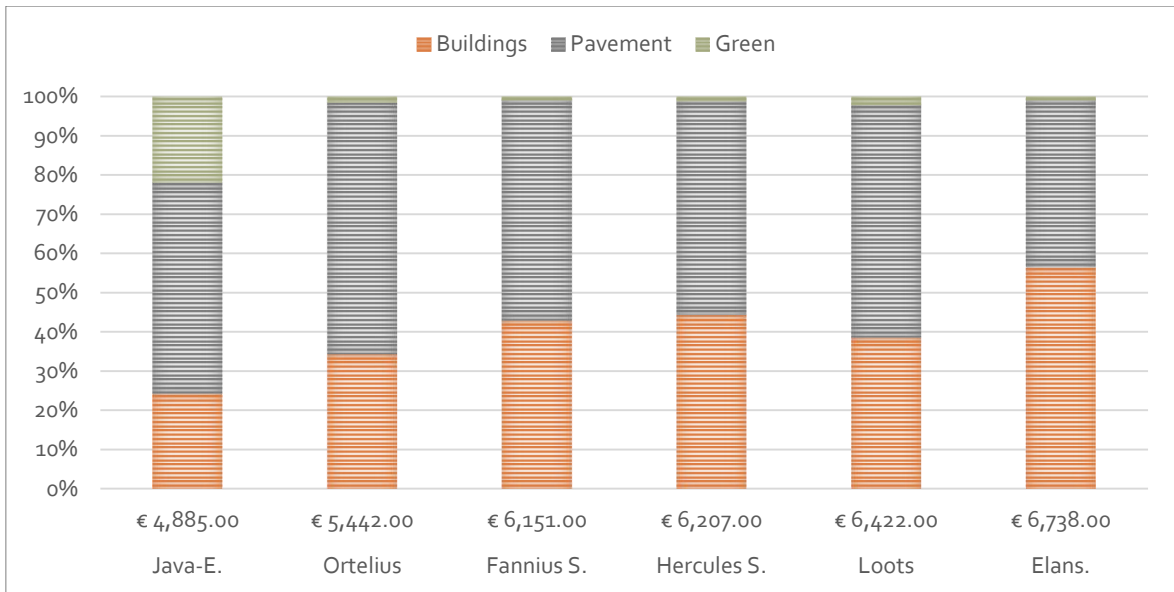


Color: NR Grey: RESID

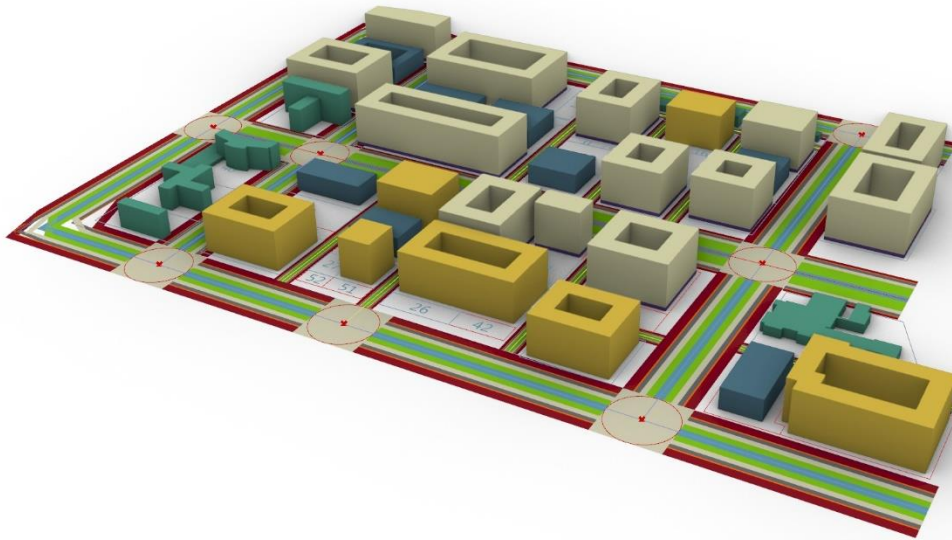
Outdoor space statistics



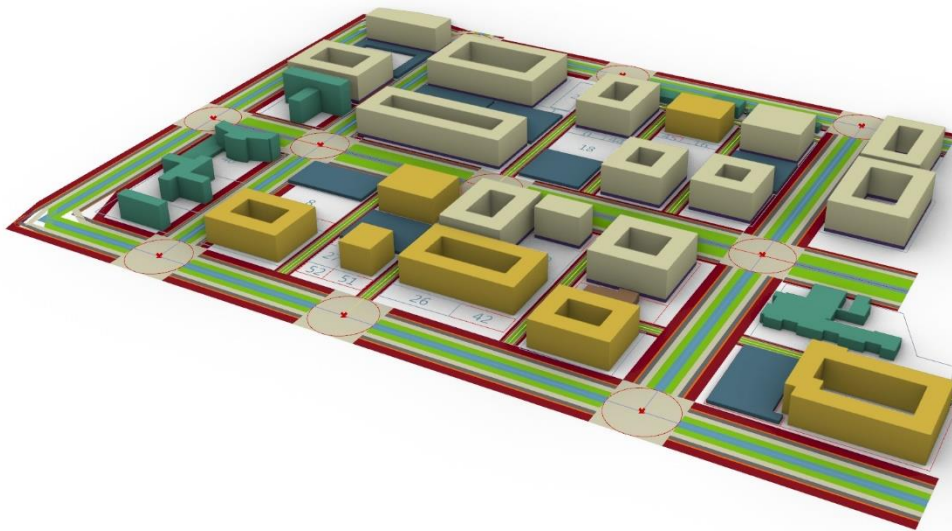
FURTHER SPACE ANALYSIS



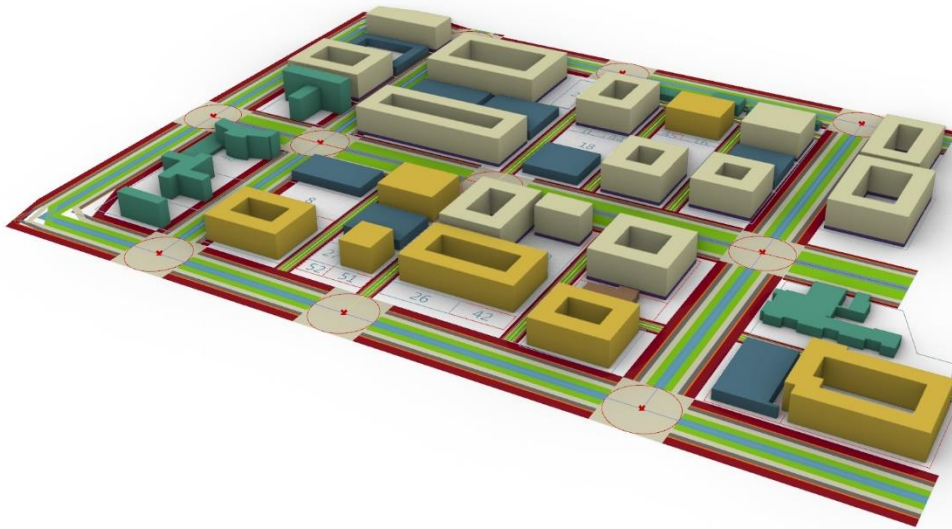
SCREENSHOTS FROM 3D MODELS USING SAME CHARACTERISTICS (chapter 5.3)



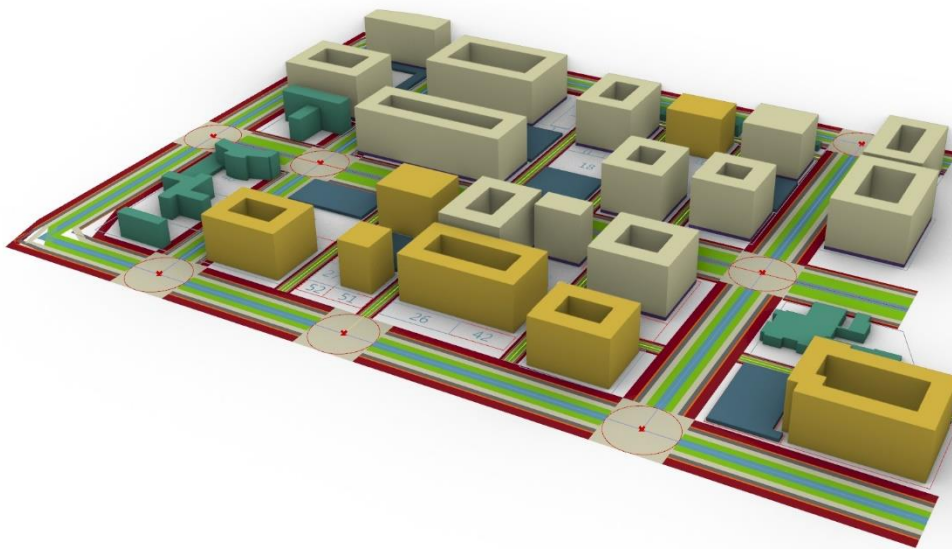
Elandsgrachtbuurt



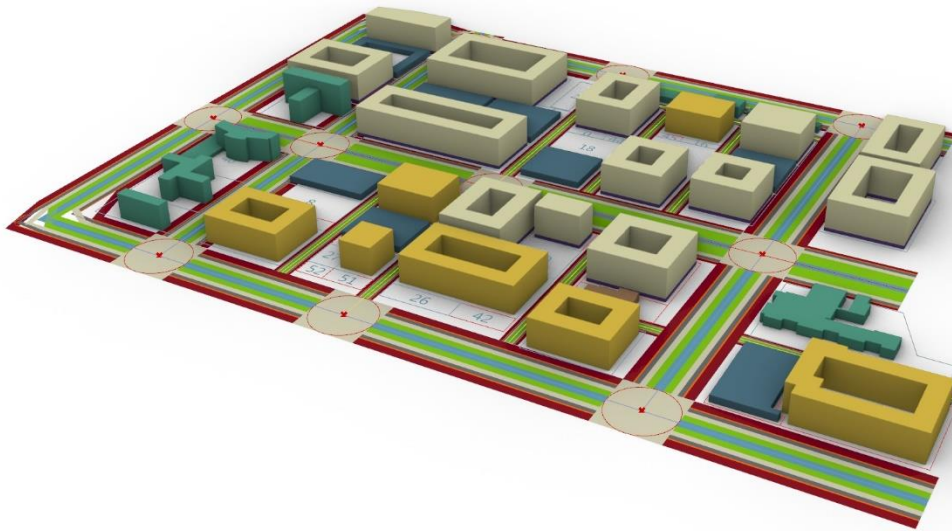
Fannius Scholtenbuurt



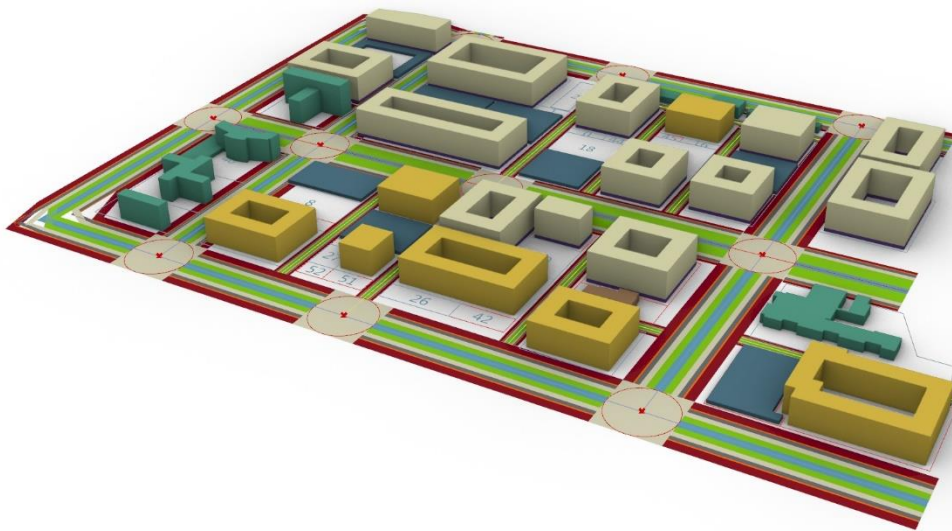
Hercules Seghersbuurt



Java Eiland



Lootsbuurt



Orteliusbuurt

SIMPLE LOG EXAMPLE

Saturday, July 6th 2019 (15:09:22)

SIMPLE LOG

GENERAL OVERVIEW

O - GSI: 0.39

O - FSI: 4.21

O - Parcels area: 318729.86 m2

O - New construction: 1340800.0 m2

O - Non-residential: 28.44 %

O - Residential: 71.56 %

O - Density: 168.34 houses/Ha

RESIDENTIAL OVERVIEW

O - Total number of houses: 11250.86 homes

I - New houses: 11220.0 homes

I - Houses in MIXED-USE buildings: 60.0 %

O - Houses in RESID buildings: 40.0 %

O - Existing houses: 30.86 homes

I - Average house size: 300.0 m3

NON-RESIDENTIAL OVERVIEW

O - Total number of working places: 12194.0

O - New working places: 9011.09

O - Working places in MIXED-USE buildings: 43.23 %

O - Working places in NR buildings: 56.77 %

O - Existing working places: 3182.48

I - Average working place size: 110.0 m3

O - NR space per house: 119.22 m3 (39.74 %)

OPEN SPACE PER HOUSE

O - Water per house: 3.4 m2

O - Biking space per house: 1.24 m2

O - Parking space per house: 3.67 m2

O - Road space per house: 8.76 m2

O - Pedestrian areas per house: 6.85 m2

O - Green areas per house: 7.14 m2