BK7084 – Arcos

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Introduction

This report was created for the 'Computational Design Studio' project of the minor 'Spatial Computing for Architectural Design'.

Since the 1950s Rotterdam has been developing into an innovative modern city with new buildings being designed yearly. At the Schiestraat, next to Rotterdam Central Station, an old parking terrain and square seem old-fashioned compared to the more technologically advanced buildings surrounding the area. This allowed us to use the area as a base to create a new innovative building design, based on algorithmic generation, analyses, design requirements from the municipality and evaluation of building performances.

The process behind the creation of the building will be described in four different sections; 'Planning', 'Configuring', 'Growing', and 'Designing'. Apart from this, a codebook has been made to show all pseudocode and code used to construct building aspects computationally.

Planning

Process

Design Brief

The project objective is to develop a mixed-use building that is well-integrated into the surrounding area and connects to (already existing) infrastructure. The target audience for the program is students, the elderly, and starters. For each of the groups, different requirements have to be met. Besides the housing, several other program elements are integrated into the building. These can be found in the table of requirements.

Location Analysis

The designed building is located in the heart of Rotterdam, next to 'Rotterdam Centraal' at the Schiestraat. This location is known for its nightlife and adjacency to the train tracks, which creates challenges in preventing noise pollution. The large surrounding buildings create wind gusts, which also need to be taken into account. Since the building will be in the city centre, accessibility is a key factor in this project. The location is ideal for mixed-use developments for different groups with different interests and lifestyles. In the maps below, the position of the Arcos building in Rotterdam is shown. Two different scales are shown to illustrate where in Rotterdam the building is exactly located:

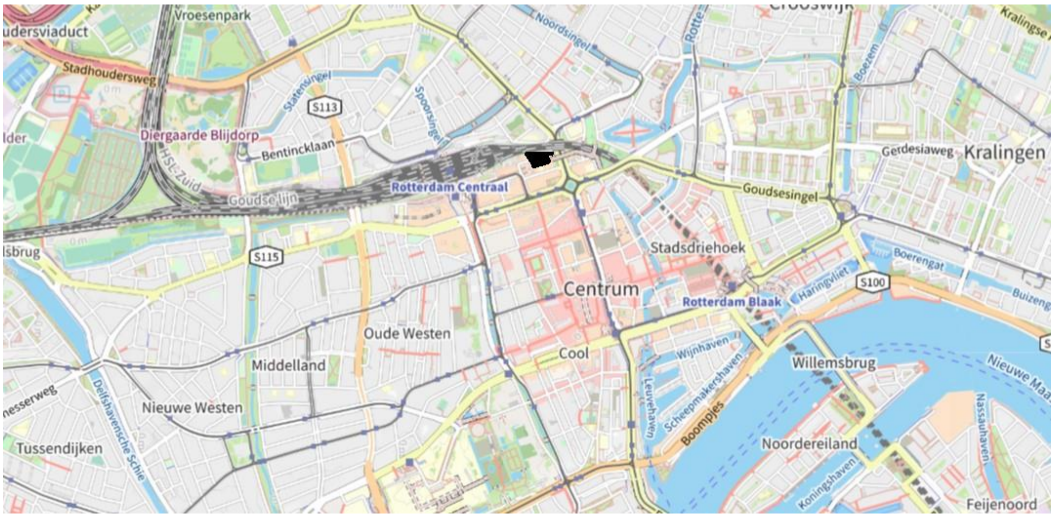


Figure 1: Scale 1; 50.000

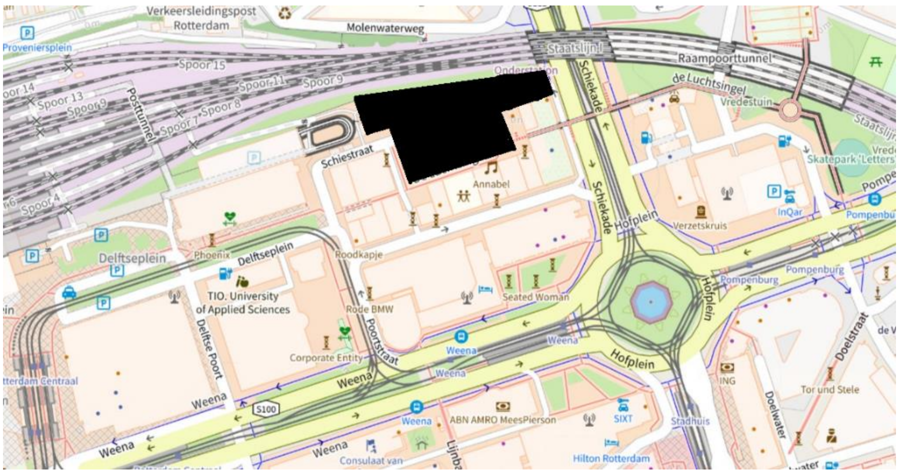


Figure 2: Scale 2; 5000

Our First Impressions

In the images below our initial impressions of the location are visually depicted.

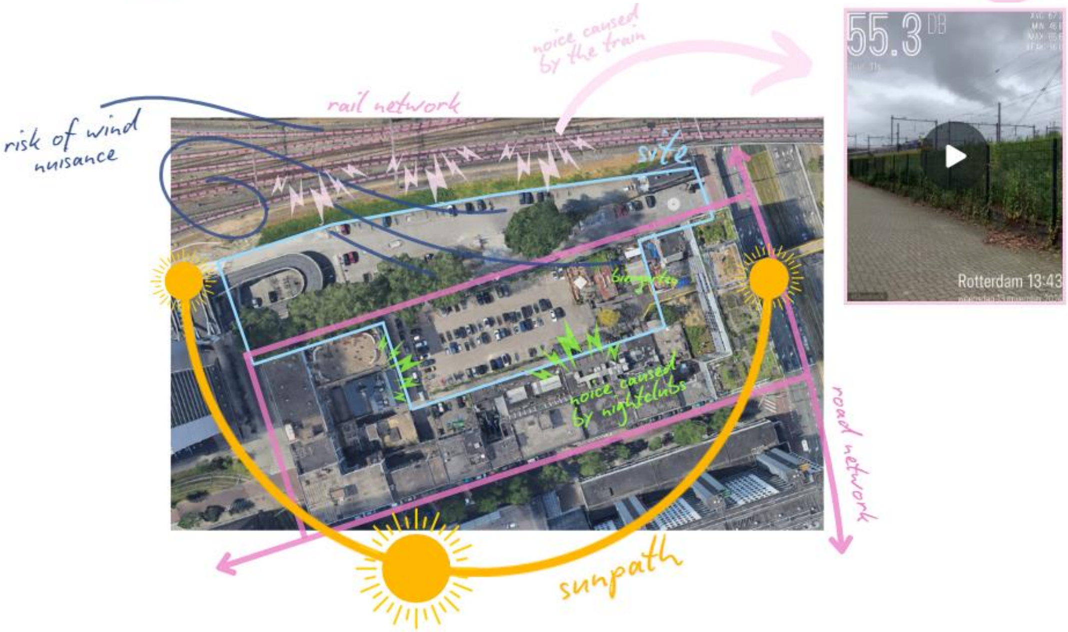
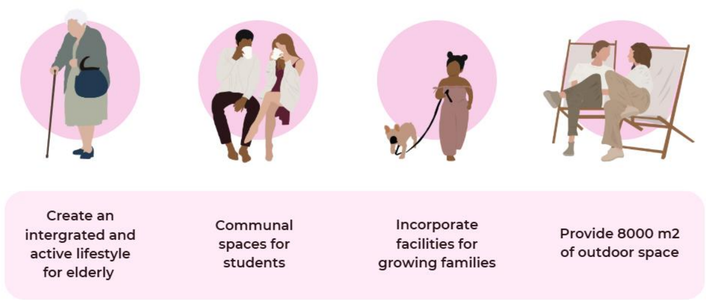


Table of Requirements

The table below shows the different requirements from the design brief. The first column shows the requirements. The middle column shows the needed area if applicable. The last column shows the exact definitions.

Student housing	400 units	Minimum of 25 m2 per student, windows with daylight, at least 5 m2 of outdoor space
Elderly units	200 units	Between 50 to 80 m2, single leveled, accessible by elevator and wheelchair, exterior space with sunlight of min 5 m2, assisted living units must be close to healthcare. Windows with daylight, housing larger than 40 m2 need at least 5 m2 of outdoor space
Start-up units	200 units	Windows with daylight, housing larger than 40 m2 need at least 5 m2 of outdoor space
Parking spots	car and bike	1.33 bike parking spot per resident, 0.8 car parking spot per dwelling (only accessible for residents) 10 bike parking spots and 4 car parking spot per 200 m2 of other programs (publicly accessible)
Greenery	Approx. 8000m2	equals to the total surface of the plot
System for rain harvesting		at least be able to collect and store rainwater from the site/neighborhood, part of stores water should be reused by the building complex
Solar power		enough capacity to light the public spaces
Public spaces		no blind facades on ground floor level, inner courtyards or corridors should be visible from at least a few dwellings

Design Goals



User Stories

Student: Charlie, a 22-year-old international student at the Erasmus University in Rotterdam

Charlie starts her day in her self-contained studio, by opening the windows so the first rays of morning sunlight enter the room. She makes breakfast in her own kitchenette. After her classes, Charlie stalls her bike in the private bike parking, at least not some weirdo will steal it! Haha. She has to finalise some work so the library is the place to be. Charlie is getting headaches from all the studying, luckily for her, the garden is next to the working spaces. While she walks back, she sees her friends who are playing a game of pool in the communal space. In the evening, Charlie goes to her friends at the café, whereafter they decide to go to the Biergarten. So glad they did not destroy it!

Starter: Bas, a 32-year-old working in the port of Rotterdam, with his wife Lisa and 4-year-old daughter Tess.

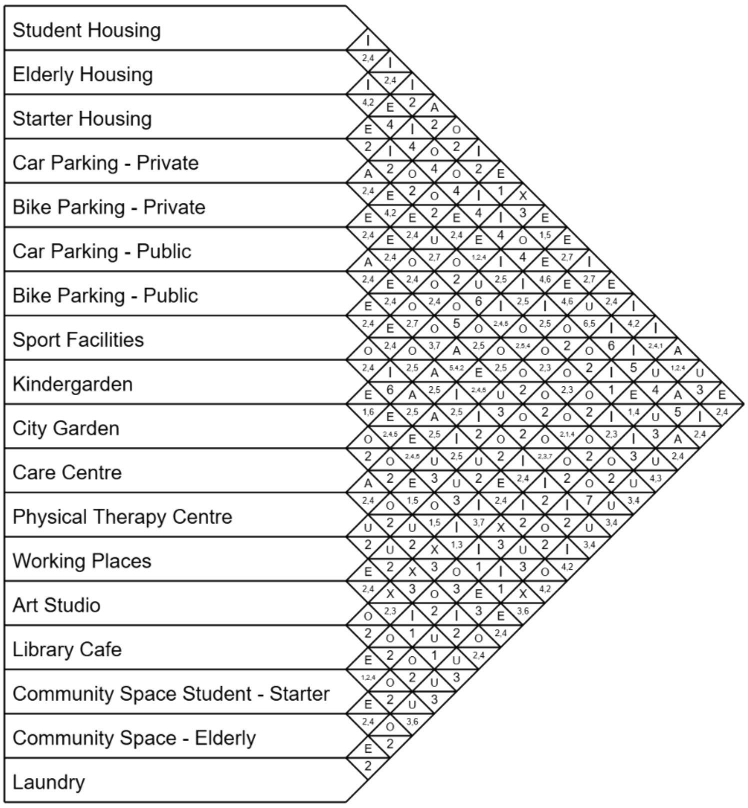
Bas starts the morning in his 2-bedroom studio. He has slept a little longer than his daughter, who is playing in her bedroom, because the walls isolate the noise she is making. Bas has to work at the port, and Tess has a day off school, so Lisa brings her to the Kindergarten on the ground floor. After work, Bas decides to go to the physio, which is located in the building. Immediately afterwards, he picks up Tess, who had a great day and has spent all afternoon playing in the garden and in the Kindergarten. In the evening, when their daughter is asleep, Bas and Tess decide to go to the communal space to see their friends, who live in the same complex! The perfect time for Lisa to tell their friends about the progress she has made in drawing after taking lessons at the Art Studio in the building!

Elderly: Jan, a 75-year-old retired teacher living in an assisted living unit.

Jan wakes up at 9:00 and makes breakfast in the kitchen, which is at the same level as the bedroom. After his breakfast, Jan walks to the laundry, which is very close to his apartment, to collect his dried clothes. In the afternoon Jan has an appointment with the doctor at the Care Centre downstairs because his knee is getting a bit weaker each day. In the evening Jan attends a yoga class, which is only a 50-metre walk because his apartment is only one floor above the Sports Facilities. After the yoga class, Jan goes to bed. He is glad that his apartment is far from the Café and Biergarten! Good night :)

REL Chart

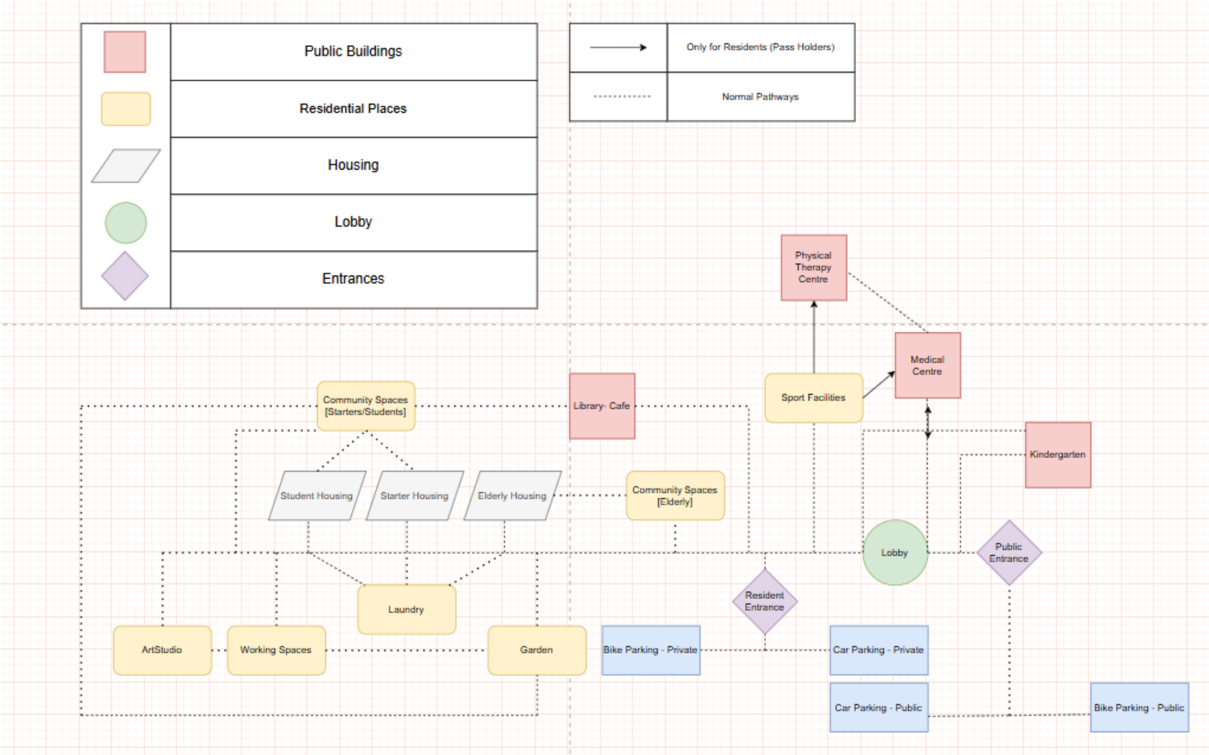
A REL Chart, also known as an activity-relationship chart, is used to depict relationships between certain building aspects. In our building, it is used to outline all outliers and main building aspects. The REL Chart is needed to create a metro network to see which functions need to be placed where.



Code	Closeness Rating
A	Absolutely Necessary
E	Especially Important
I	Important
O	Ordinary Closeness
U	Unnecessary
X	Avoid Closeness

Code	Reasoning
1	Social
2	Efficiency
3	Noise Pullution
4	Function
5	Healthcare
6	Aesthetic
7	Safety

Product
Metro Network



1) Residential Entrances and Public Entrance differ so residents do not have to go through the lobby to reach their homes. An entry pass will give them access to the building.
2) Residents can use the entry pass to access the sports facilities as well. These facilities are not for the public, but the medical centre and therapy centre are. For this reason, there are certain pass-holder pathways that only residents can use.
3) Community Spaces have a direct connection with the garden and the student/starter housing. This means that fresh air is always easy to reach.

Configuring

Voxel Size

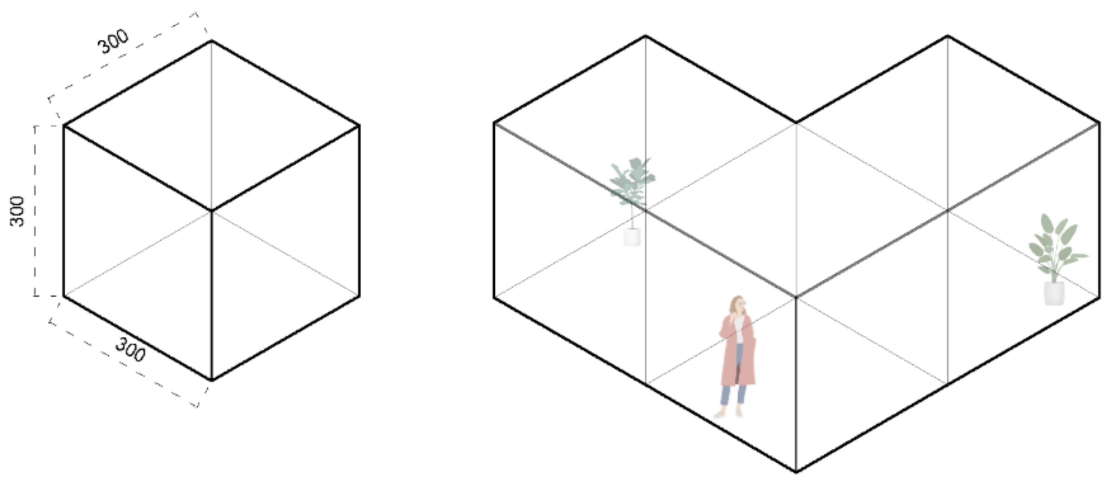
We did not create the final building by hand. Instead, we made a procedural model that uses our input to create the building for us. The main benefit of using a system like this is that it can be easily extended to take a lot of environmental factors into account. It also makes it much easier to test different settings of variables, compared to doing everything manually.

The model we made works by making a grid of big cubes called voxels, followed by removing voxels based on analyses, and then deciding which spaces in this so-called envelope have which specific function. This last phase is called the growing stage.

To start this process, we needed to decide how big one of these cubes would be. We decided on a voxel size of 3x3x3 meters. This size is small enough for detailing, but not so small it becomes computationally infeasible. It also lines up nicely with the height of one single floor, which makes floor planning significantly easier.

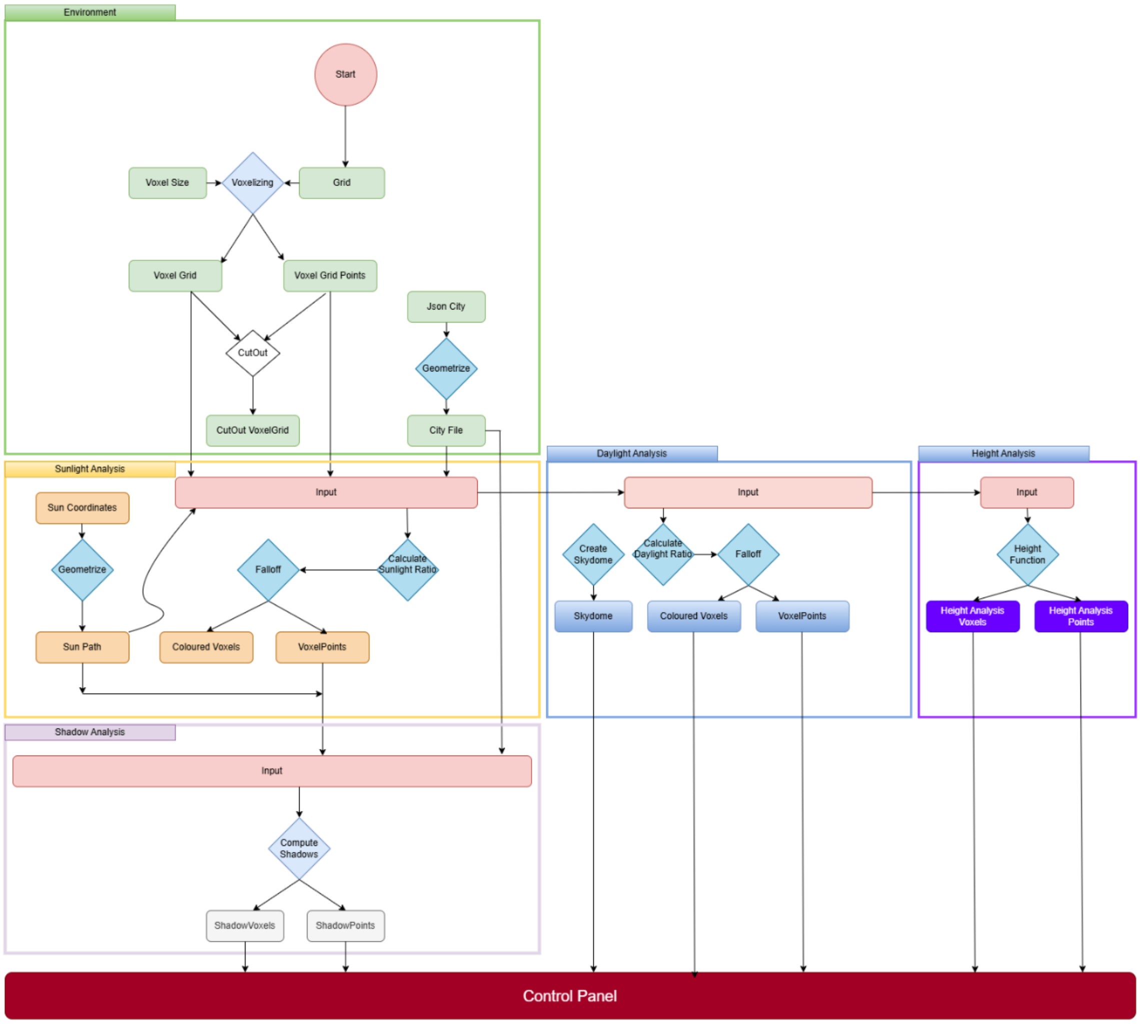
This voxel is then positioned in a grid formation and copied upwards to give the outline of the building.

Example of aleatory configuration of a room
(27m2)



Houdini Configuration Flowchart

After the voxelization is completed, the project is implemented in Houdini. The following chart gives a basic depiction of the procedural implementation of our model in Houdini.



Analyses

The voxelization step is followed directly by the analysing step. This step entails the execution of four analyses. These are discussed in detail below.

The first is the height analysis. This adds the height of the voxel as an attribute. It also caps the building on a certain parameterized amount of floors. This analysis both influences the shape of the building and the growing phase.

The second analysis is the shadowcasting analysis. This checks if a ray cast through the voxelpoint, from a sunpoint, hits a building on its way out of the scene. If it does, this means the voxel casts a shadow on a building and therefore receives a penalty point. This analysis only influences the shape of the building.

The third analysis is the sunlight analysis which influences only the growing algorithm. It checks if a ray cast from the sunpoint hits a building before it hits the voxel.

The last analysis is the daylight analysis, which works similarly to the sunlight analysis. However, instead of using sunpoints, the ray is cast from points uniformly distributed along a sphere.

The Growing Algorithm

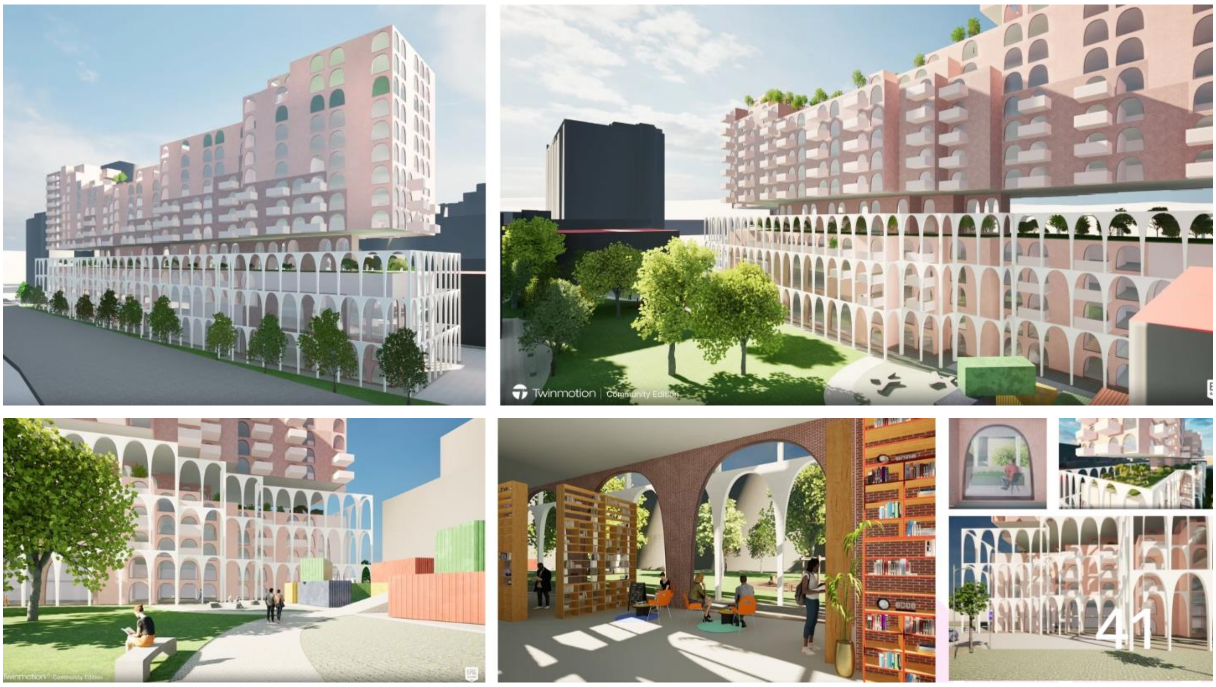
The algorithm should slowly fill the voxels with functions, based on the values of the analyses. This is why we call it growing. The key part of this process is determining how good a voxel is for a specific function. We call this value the fitness. In our project, the fitness is calculated by a weighted sum of the analysis values, and the weights we determined in the functions table. In simpler terms, if we decide in the input that something is important the fitness goes up, and if the score from the analysis is higher it also goes up.

The first points during growing are determined by taking the best point for each function. After that, all voxels that share a face with the respective function are checked, and the algorithm grows to the best one. The growing for a function stops once it has reached the required area for that specific function.

One feature we added to this growing algorithm is that it can never get stuck. Normally a function could get stuck if it is completely surrounded by other features and has nowhere to grow. In this case, our algorithm will find the next best position, similar to when finding the seeds.

Product

The final result from the growing algorithm can be seen in the following pictures.

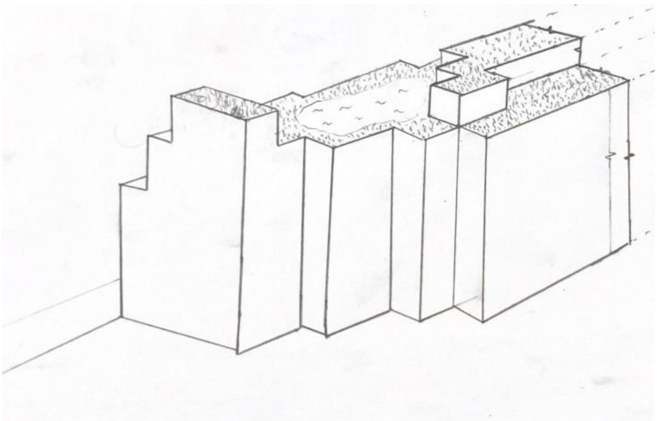


Designing

Planning

Water Harvesting System

Toilet use **-** According to the CBS, a person uses 30,2 litres of water daily to flush the toilet. Toilet water is the only type of water for which lightly filtered rainwater can be used. With a quick calculation, the daily needed toilet water can be estimated:

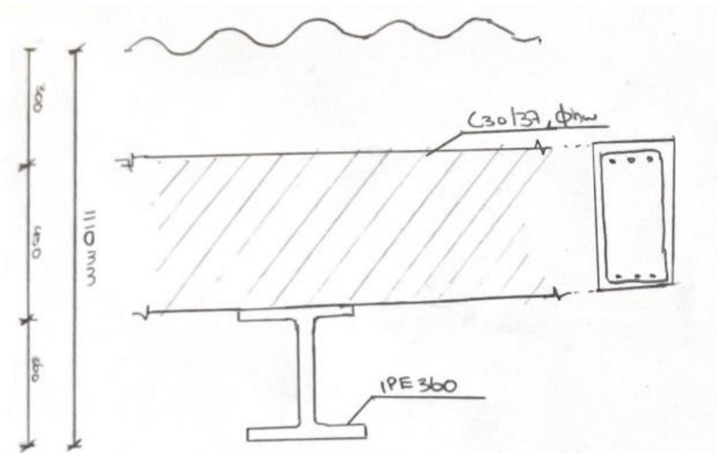


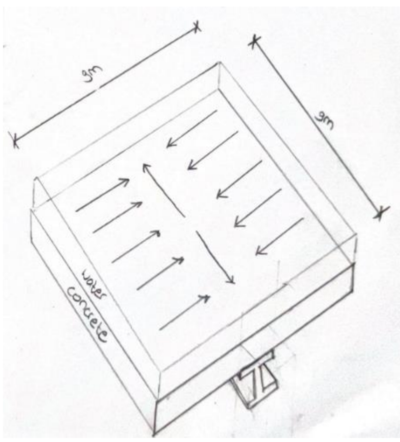
Student Homes = 400 persons
Elderly Units = 200 * 1,5 = 300 persons
Starter Units = 200 * 2,5 = 500 persons
-- +
Total Amount of People: 1200

1200 * 30.2 = 36.240 litres of toilet water per day

Plant Retention - We have to take into account that not every drop of water will reach the tank, due to plants placed on the roofs. According to the European Federation of Green Roof & Wall Associations this factor for medium-sized vegetation is 0,6 (this is the percentage of the water that is being held by the plants).

Tank Storage **-** The tank storage needs to be tested since it must be able to contain a lot of water after excessive rainfall. In the last 5 years, the peak daily rainfall in Rotterdam was 34.7 mm/day. 95.56 m^3 can be captured by the tank and the plants. When put in an equation this equals 95.56 * 0.4 – 36,24 = 2.0 m^3 of water. This equations shows that there are no problems with overflows of the water reservoirs. For this reason, we have chosen to create artificial ponds on the roofs, in which water is stalled. If water is needed, water will be drained from the bottom of the ponds and will be distributed through the building. These ponds, however, will be located on the roof. Because of the weight increase a beam unity check is used to make sure the roofs will hold the water.





Unity Check

- Ponds are in this example made out of a 9x9 grid with water, with depth d = 0.3 meters.
- IPE360 S355 is used to create the beam structure of the building.

- C30/37 Concrete with reinforcement with d = 0.45 meters. This height is chosen from the following Eurocode formula: h = L / (20 to 25) = 9 / 20 = 0.45m.
- Every column gets a 9x9 grid of water weight + self-weight of concrete.

Water: $9 \cdot 9 \cdot 0{,}3 = 24{,}3\ m^3$ water $= 24300\ kg = 238{,}98\ kN$

Concrete: $\rho = 2600$ (reinforced concrete)

$h = L/(20 \text{ to } 25) = 9/20 = 0{,}45\ m$

$0{,}45 \cdot 9 \cdot 9 = 36{,}45\ m^3 = 94{,}770\ kN$ +

$\sum \text{Weight} = 333{,}75\ kN$

• $M_{ED,max} = \frac{1}{8} \cdot q \cdot l^2 = \frac{1}{8} \cdot (333{,}75/9) \cdot 9^2 = 375{,}5\ kNm$

• IPE 360

$I_y = \frac{1}{12} \cdot 170 \cdot 360^3 - \frac{1}{12} \cdot (170-8) \cdot (360 - 2 \cdot 12{,}7)^3 = 155 \cdot 10^8\ mm^4$

↳ strong axis, where force will act on

$M_{y,Rd} = W_{y,el} \cdot f_y = \frac{I_y}{(h/2)} \cdot f_y = 439\ kNm$

$UC = \frac{375}{439} = 0{,}85 < 1$ ✓

$V_{z,Rd} = (h - 2 t_f) \cdot t_w \cdot f_y / \sqrt{3} = 549\ kN$

$V_{z,Ed} = 333{,}75\ kN$

$UC = \frac{333{,}75}{549} = 0{,}61 < 1$ ✓

Sunlight Calculation

In the program of requirements, it is stated that there needs to be enough capacity for solar power to light public buildings. The following public buildings with their areas are placed in the building:

Building	Area
Car Parking Private	16000
Bike Parking Private	2533.3
Car Parking Public	39.8
Bike Parking Public	99.5
Kindergarten	200
Care Centre	230
Physical Therapy Centre	60
Working Places	550
Art Studios	60
Library/Café	900
Community Spaces	800
Laundry	100
Total	**21572.6 m^2**

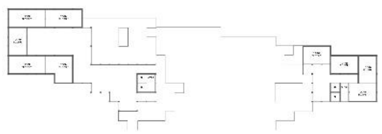
Operational Light Hours = 12 hours.
Led Bulb in a room needs 5 W of light for 1 m^2 (UPSHINE, n.d.) = 21900 kWh/year/m^2
Sun panels convert circa 500 kWh/year (Essent, n.d.) =
Area Sun Panel according to Essent: 110mm * 175mm.
Sun Panels convert 259.75 kWh/year/m^2.
21900 / 259.75 ≈ 84.31 m^2.

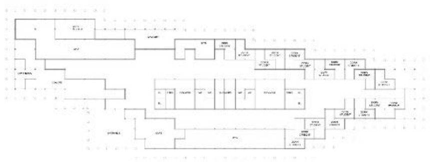
This 25m^2 of solar panels will be placed on the roof, placed next to each other at a location where no greenery is located.

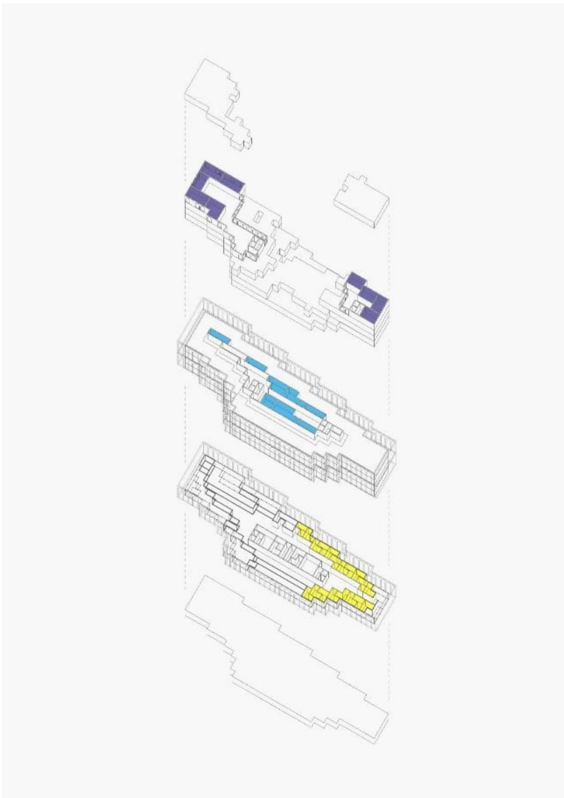
Area plan

Final result

Floorplans







Renders