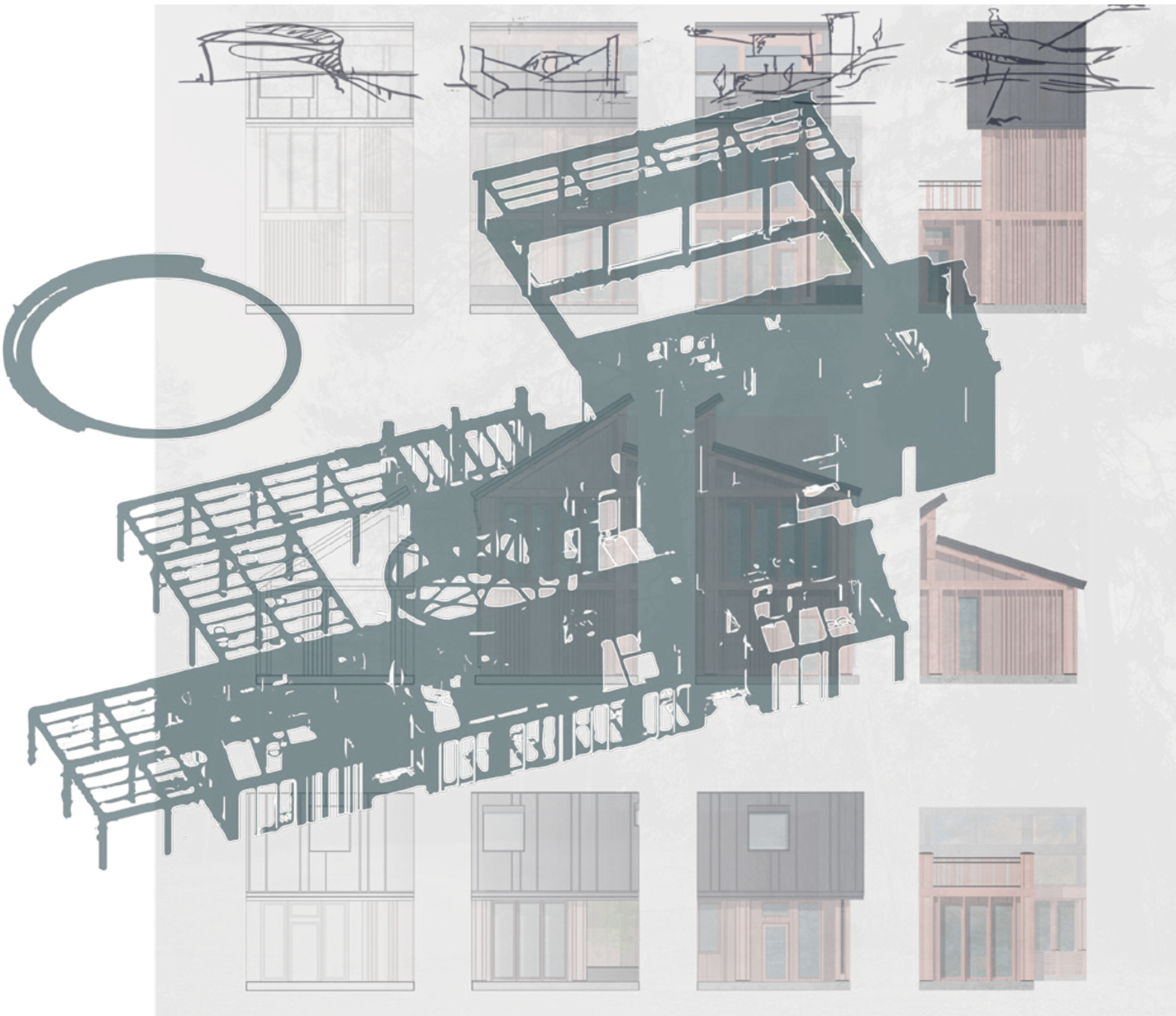

ARCHITECT'S DESIGN CODE

- Streamlining early-stage architectural workflow with parametric tools

Mattias Österman / MSc Architecture & Urban Design / Architectural Experimentation

Chalmers School of Architecture
Department of Architecture & Civil Engineering
2025

Examiner: Jonas Lundberg
Supervisors: Kengo Skorick, Shahin Sateei

Thank you,

Kengo Skorich
For supervising me through the process, with guidance, encouragement and valuable feedback.

Shahin Sateei
For supervision, encouragement and taking an interest in my journey through this thesis.

To my friends and fellow students
For being there, discussing ideas and creating an inspiring environment.

CHALMERS
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ABSTRACT

The Architect's Design Code aims to research, enhance and augment the architectural design process by improving efficiency through automated aid with the help of computational tools. The tools and research conducted in this paper serve as a framework for continued research through a selection of explorations and experiments, combined with a demonstration of powerful computational modelling aids.

Over the past decades, digital development has significantly improved workflows in the architectural design process through software's such as AutoCAD, Rhino, SketchUp and Revit. Despite these developments, the architecture field has been slow at adapting to emerging technical possibilities and the design process still involves a considerable amount of time on procedures that could be automated with parametric tools.

The aim of this thesis is to investigate how parametric tools, in the form of developed Grasshopper scripts, can streamline and automate aspects of an architectural design process and research how that affects the concept design workflow. Through development of scripts with different functions, designers can rapidly visualize ideas and allocate more time exploring and/or developing concepts while getting immediate feedback on their ideas. Tools created in this thesis were designed in a way to allow the user to have full control over the design without requiring prior computational experience.

In parallel to the tool development, a design-based project was conducted to evaluate the effectiveness of these tools. This project involves the design of an activity center for the elderly, located on an old boule-field in the small town of Knivsta, Sweden.

The expected outcome of The Architect's Design Code is not to deliver a flawless set of design tools, but rather to raise awareness and demonstrate the potential of computational methods. By integrating such tools, architects can reduce repetitive workload, allowing them to focus on other critical design tasks and better visualize their ideas.

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1.1. TERMINOLOGY/READING INSTRUCTIONS

The words "Parametric Design" or "Computational Design" might sound frightening and/or confusing to a big majority of designers. Hence, it will be important to define some key terms within these areas to establish an understanding of the explorations made in this thesis. In the article "Computational design in architecture: Defining parametric, generative, and algorithmic design", the authors Inês Caetano, Luís Santos and António Letão (2020) discuss and describe these key terms in more detail. First and foremost, it's important to understand the difference between digital design (DD) and computational design (CD) as design concepts. When we talk about DD, the most basic meaning would be using computer tools to develop design whereas CD uses computation to develop design. Therefore, CD and DD are separate concepts but commonly used to complement each other. DD is commonly used without CD. A famous example of using CD without DD is Frei Otto's experiments with minimal surfaces.

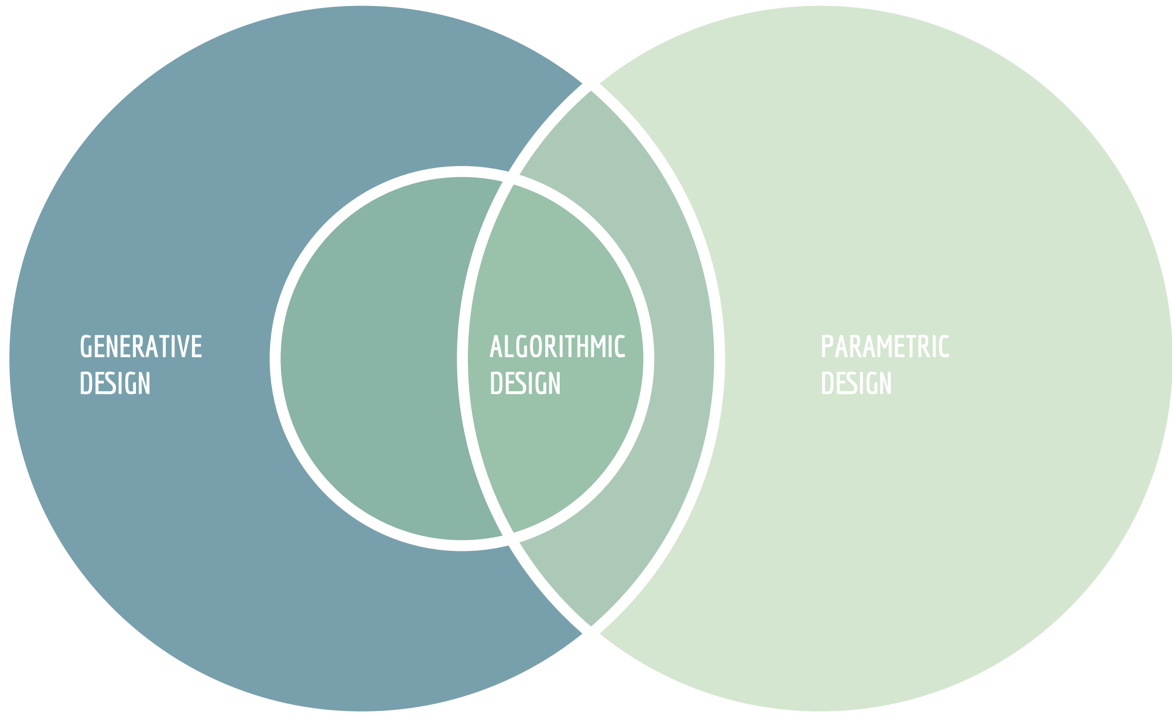
Computational design itself has a wider scope though, it includes a few more key terms that are important to acknowledge when talking about CD. The three most common terms would be parametric design (PD), generative design (GD), algorithmic design (AD) and Performance-based design (PBD) although PBD seldom replaces PD and GD and only has an overlap with performative design which is a term we use less than others.

The word **parameter** is described by Oxford Dictionary as "a numerical or other measurable factor forming one of a set that defines a system or sets the conditions of its operation," and **parametric** as "relating to or expressed in terms of a parameter or parameters". In other words, **parametric design** could be described as an algorithmic thinking design-based process that uses parameters as a constraint. An approach that describes a design based on parameters.

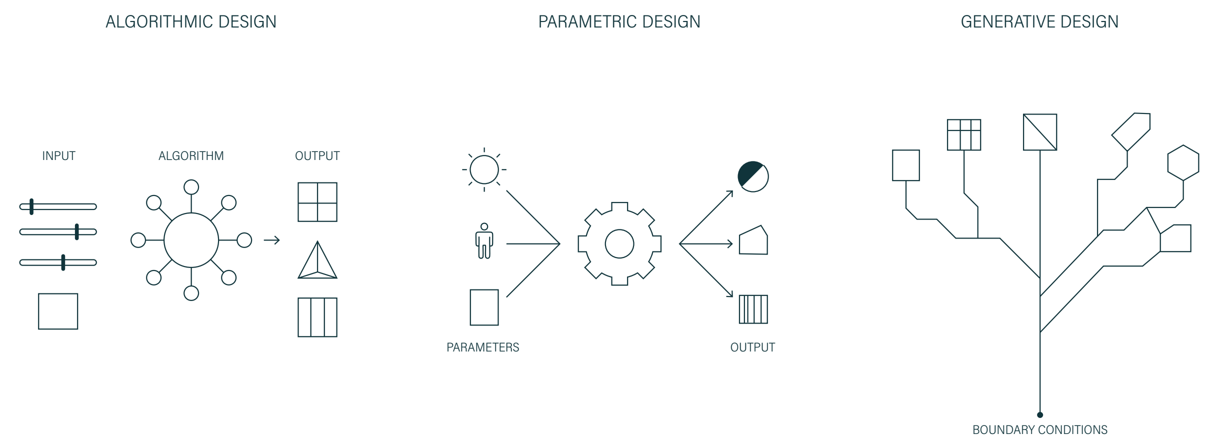
Generative as a word, is described by The Cambridge Dictionary as "capacity to produce or create something" and the Caetano, Santos and Letão defines **generative design** as a design paradigm that employs algorithmic descriptions, using a generative process where a system executes encoded instructions until a criterion is satisfied. In simpler words, GD methods can generate complex solutions to even basic algorithmic descriptions.

The Cambridge Dictionary describes the word **algorithmic** as a "set of mathematical instructions or rules that will help calculate an answer to a problem", which according to some might be hard to distinguish from GD. In this paper, **algorthmic design** is considered a design paradigm that uses algorithms to generate models and is therefore generative in a sense. The difference from GD would be that there is a correlation between the algorithm and the generated model, allowing the user to identify which parts of the algorithm to adjust to modify the output, hence a finer degree of user control in the process (Caetano et al., 2020).

*DD = *Digital design*
CD = *Computational design*
PD = *Parametric design*
GD = *Generative design*
AD = *Algorithmic design*
PBD = *Performance based design*



Conceptual representation of CD-terms



Parametic design: a design approach based on the use of parameters to describe sets of design.
Generative design: a design approach that uses algorithms to generate designs.
Algorithmic design: a GD approach characterized by an identifiable correlation between the algorithm and its outcome

1.2. BACKGROUND & DISCOURSE

The architectural design process has gone through a wide range of development, from the very first traces of architecture 10-12,000 years ago to today's highly technological advancements in the form of CAD (Computer-Aided Design) software's. In this paper, the focus will be on the technical advancements in a more modern era. From drawing analogically on paper to a completely digital design process and the future of architectural design.

Even though the vast electronic development took a charge in the early 1990s, constructions like the Guggenheim in Bilbao designed by Frank Gehry has design aspects that seems impossible to design or build today without the use of the digital tools available to Gehry's office. It was mainly a matter of fascination and inspiration that led architects to start believing that design should change at the beginning of the digital turn in the early 1990s. No one really knew how it would change, but many believed that activities and functions would move from a physical to a virtual cyberspace already back then.

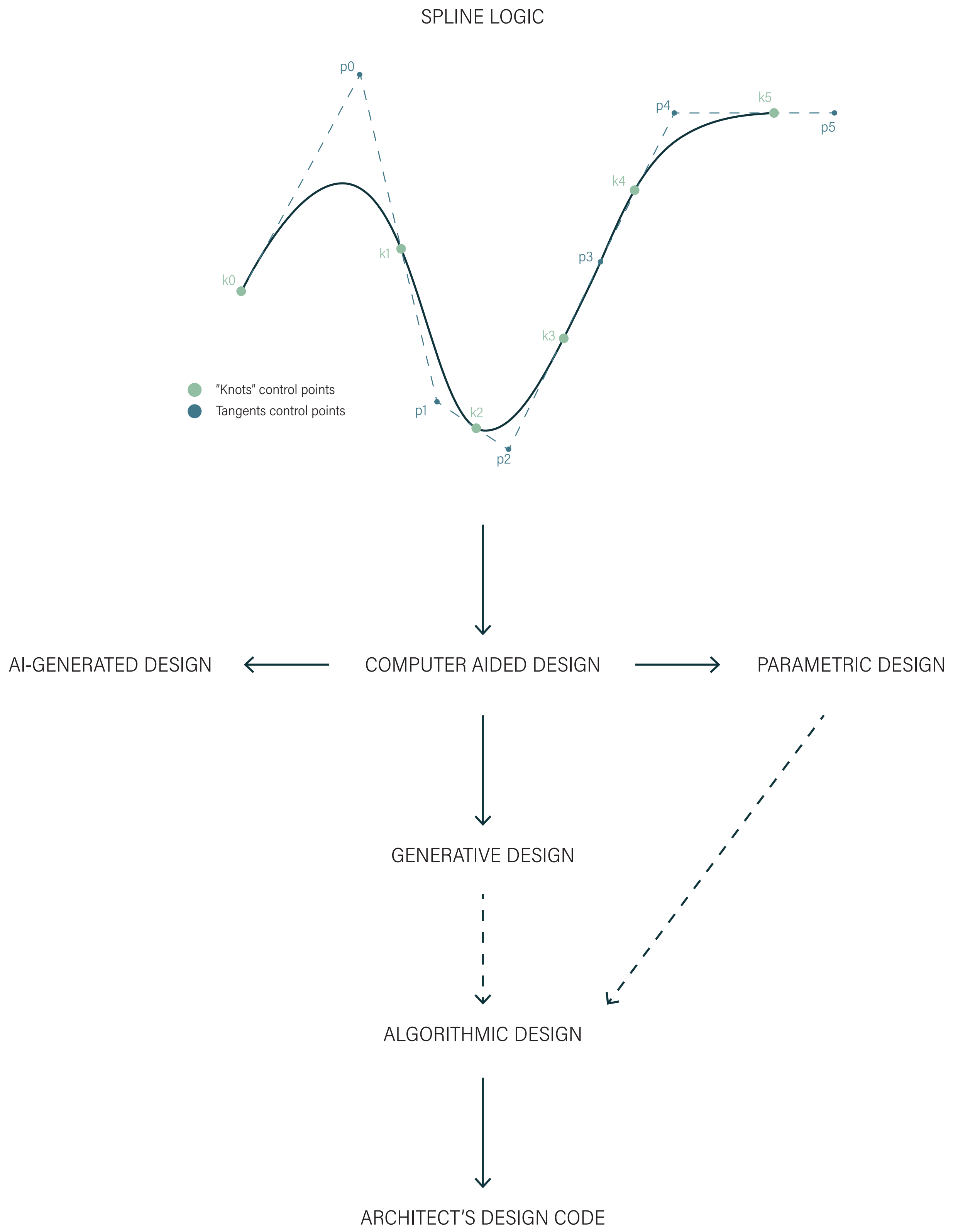
Parallel to the technological advancements at this time, the emergence of spline modelling sparked a new generation of software that took advancement of a general availability of cheap processing power. This allowed a new manipulation of curved lines, using vector technology and control points, creating the first thoughts of parametric development in architectural design. As a consequence of these new thoughts and innovations, CAD and BIM software's emerged to facilitate the cooperations of different stakeholders in construction and design (Carpo, 2012).

Today, architects have a wide range of digital tools to choose between in their preferred workflow and the productivity level has improved massively compared to just a couple of decades ago. From analogue drawing on paper, to the first digital drawing software and today's powerful 2D-and 3D-modelling tools. Some of the most popular ones might include AutoCAD, Rhino, SketchUp, Revit and ArchiCAD which all have different functions, advantages and flaws. These software's aids the users in understanding their designs, knowledge about geometry etc. but they are still just design-aids, the users are still limited to manual input and having to manipulate the geometry themselves. This design flow doesn't allow the user to go down the exploratory path that generative design tools might support (Chase, 2005).

Never has computational power been as accessible for architectural practice as it is today. Examples from other industries such as in agriculture, show how a harvester can sort and learn how a ripe tomato looks and only harvest those automatically. In the medical industry, they reconstruct 3d replicas of organs and injuries from X-rays. In architecture, the industry has been very slow at adapting and computational power is mostly used as an assistant for manual drawing (Sellberg, 2020).

However – there is a small community of people who share the same vision when it comes to taking advantage of computational power in architecture. There are examples of similar solutions to the vision explored in this thesis. A well-known example is that of Finch-3D, developed by Jesper Wallgren and his team. After researching several examples of developed parametric tools, there are a few things they have in common and one important aspect that I believe is missing.

The most developed tools are focused on generative, adaptive floor plan generation. These solutions give the designer an optimized floor plan that fits their outlined design. Even though these softwares are well developed and established in the computational community, they are more focused on generative, adaptive and optimized design. Thus, lacking full control of the designer aspect, the freedom of design that makes an architectural drawing unique to the designer and perhaps a sense of ownership of the design that they develop. A dilemma arises – If a computer generates solutions for the designer, how can we make sure the designer is responsible for the result? Most of the current generative tools are also in the form of third-party software, not connected to the media that most architects use for their design. This is where the explorations made in this thesis could fill in the gap.



Digital evolution

Figure 1: Guggenheim Museum, Bilbao, Frank Gehry.
Note. From E. Cuoghi, [Photograph], 2020. Unsplash.

Figure 2: Analogue design.
Note. From R. Ancill, [Photograph], 2020. Unsplash.

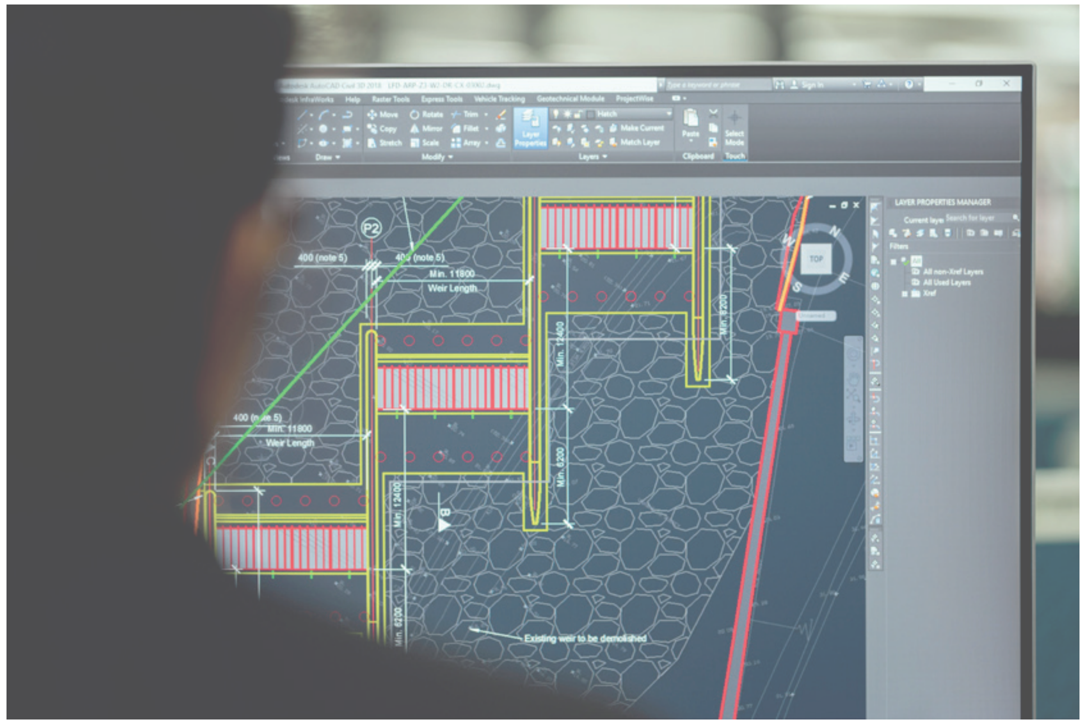


Figure 3: Computer-Aided Design.
Note. From ThisisEngineering, [Photograph], 2020. Unsplash.

1.3. REFERENCE STUDY

There are several similar research project and well-established companies exploring this common vision. The Swedish startup company Parametric Solutions came together 2020 as a group of designers with the same frustration with inefficient and monotonous processes within the design process. For them, parametric design is not only about sculptural shape exploration, but also about optimizing the use of resources. They have created tools that generate and evaluate early stage proposals, allowing designers to compare multiple solutions side-by-side and to depart from something more than a blank paper (Parametric Solutions AB. 2024).

Similarly, another Swedish startup company Digital Blue Foam shares the same vision. They state that urban design currently relies on outdated software from the 90s and aims to unite generative design and spatial analytics to create better cities for the industry and the future (Digital Blue Foam, 2023).

There are, of course, well established architectural software's like Revit and ArchiCAD that provide these easy-to-produce drawings. What these software's lack is the creative freedom achieved in programs like Rhino, where there are possibilities for parametric modelling.

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1.4. AIM & DELIMITATIONS

The aim for this thesis is to reduce time consuming design processes, automating them through a selection of parametric developed tools. By allowing the designer(s) to quickly visualize their ideas and get direct output response, they gain access to spend more time developing and/or exploring other design tasks that could improve the outcome of the project.

An important goal to achieve when developing the parametric tools is to make sure they can be used by everyone easily without much training and still maintain full control over the design, despite how much earlier computational experience they might have.

Parallel to the tools being created, a design-based project in the form of an activity center for the elderly is carried out. To both show the power of the computational tools in the form of input and output comparisons and diagrams, but also to stress-test them and get user input to see what works and what needs to be improved further.

While augmenting architectural design workflows, there's opportunity to allocate more time on evaluating the design proposal. One form of evaluation can be done in first person, immersive virtual reality. This thesis explores how this form of evaluation can be supported by the parametric toolkit.

The aim is to raise awareness for architects to always keep adapting to new technological opportunities. If an architect student can prove that we can drastically improve our design process efficiency in a master's thesis, the possibilities for developers are huge if enough resources and time are allocated to the cause. It should be noted that this thesis does not aim to develop a perfectly complete set of design tools without flaws. Instead the focus is to show how accessible and user-friendly parametric developed tools can reduce overall lead time in the early phases of the design process.

An important strategy during the development of the toolkit was to design around a generic, rigid style of architecture. Meaning architecture built with vernacular building elements such as vertically straight walls, squared windows and doors and a column-beam structure. This decision ensured reliable and consistent performance but also meant that more complex geometry, such as organic 3D-shapes or structures angled outside the XY-plane, may not be fully compatible with the current setup of geometry generation tools included in this toolkit. Additionally, aspects like building materials and tectonic detailing also remained generic to avoid case specific solutions. While the toolkit substantially improves efficiency and precision in high resolution, traditional building- and designing techniques, it only grasps the surface of what is possible integrating computational tools into architectural workflow.

The motivation behind this thesis is not to create a perfect, complete set of tools that will change the world, but to showcase and raise awareness about the possibilities most of us ignore in the design process. It is also a way to show where in the computational, generative tool-creation business there is currently a gap.

Not all tools created in this thesis are supposed to be used in later design stages, as they are built to fit a concept design workflow.

1.5. THESIS QUESTIONS

> HOW CAN VISUAL PROGRAMMING BE USED AS AN AUGMENTED ENHANCEMENT TO AN EARLY-STAGE ARCHITECTURAL DESIGN PROCESS?

> HOW CAN PARAMETRIC TOOLS WITH SUPPORT FOR FIRST PERSON, IMMERSIVE VIRTUAL REALITY HELP EVALUATE A DESIGN PROPOSAL IN THE CONCEPT PHASE?

1.6. METHODS & TOOLS

The development phase of this thesis is based on both personal previous experience with computational design, as well as research of similar case studies/articles with the same vision. Research through design was used while developing the parametric tools since they were put to the test with different geometry and the design-based project, making sure they are generic and work with all types of cases. To make sure the tools were developed as proof and lag efficient as possible, further computation theory, python programming and optimizing methods was studied. This was crucial since lag and bugs prevent efficiency.

For the design phase, it was important to not create a design project that only serves the purpose as a proof-of-concept. The development of tools and the design project should serve as two equal main phases of the thesis, cooperating to make the most out of each other. The parametric tools acted as aid to designing the final project, and the design project served as a demonstration emphasizing the power of the parametric tools.

As for representation methods, the thesis represent the outcome in both well-designed architectural drawings combined with diagrams and schematics to showcase the process of the parametric tool development. These diagrams and schematics include, for example, input/output diagrams and experiments showcasing time variations using different methods.

Theoretical research help formulate a framework of academic purposes for the thesis. By researching historical architecture practice and current practice, concrete arguments build the thesis. By studying computational terminology, a better description of the work help the audience who might not be as familiar with some of the key terms understand the thesis better.

By looking at **case studies** and learning about different studies where they have used parametric/generative design, a deeper understanding for when and where the architectural practice needs parametric aid was clearer..

There is a small, but very helpful and experienced **community of computational designers** who are more than happy to share their work, visions and problems. This was a big inspirational source, as well as a guide through what to do and not to do.

The main environment of the development of said tools was **Grasshopper**. It was crucial to evaluate personal skills to see where the limits were to this thesis. **Python and C# programming** was also explored, since it adds another dimension and new possibilities to visual programming in Grasshopper. **Artificial Intelligence** was used as aid in discussing logic and structure of these implementations.

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1.7. SUSTAINABILITY

The architecture industry (and the rest of engineering and construction industries) is slowly adapting to a ground-breaking software type called Building Information Modelling (BIM), Revit would be an example of software within this domain.

One major reason why it has become so successful is the availability to plan and develop projects in a virtual environment from the building's construction all the way to its demolition. The possibility to acquire this information early in the design process is crucial in a sustainability aspect, since most of a building's life cycle impact are based on decisions made in the early design phase (Carvalho et al., 2020). If we can integrate functions in our softwares about the building's energy demand, carbon emissions and raw material consumption, we can take important decisions that can impact the overall green footprint of the design. Especially if we can see the information in real-time respond to the design decisions we make.

Tools created in this thesis are meant for concept based design and early iterative work. Thus, it would not be realistic to provide a full LCA-report as an automatic function in these tools as a complete set of material choices are most likely not decided at an early design phase. However - in the tools where geometry creation is the function, the scripts will provide an immediate list displaying the bill of quantities. This function can of course be turned off, but it provides information to the user allowing them to be aware of how the choices they make might affect the sustainable footprint in further development.

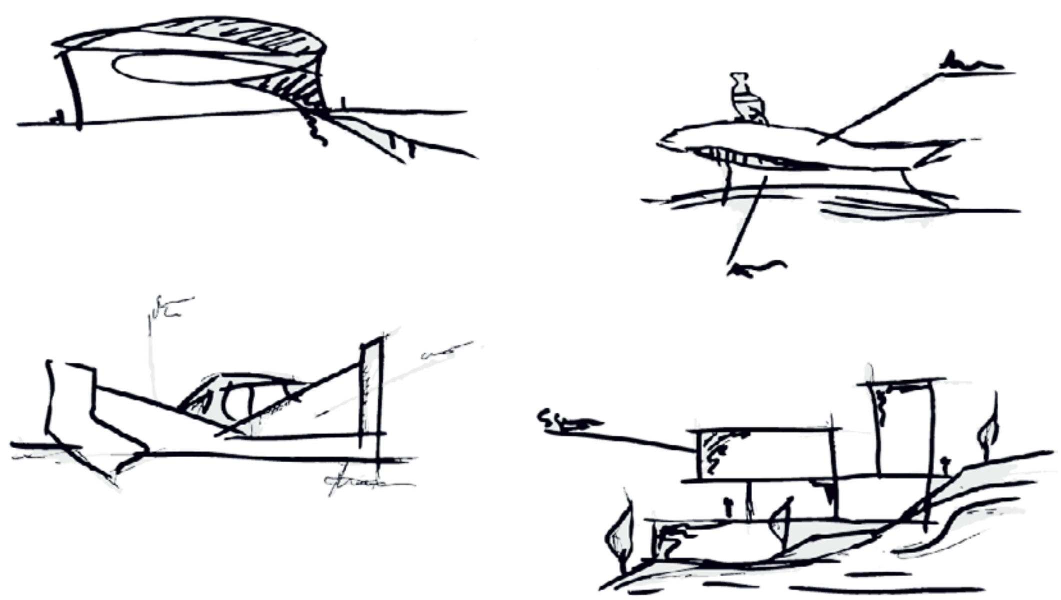
1.8. THE CONCEPT PARADIGM - WHAT IS A CONCEPT SKETCH?

When starting a project design, the most traditional way of initiating the process is to brainstorm. Spilling out ideas on how to approach the task and forming a concept. For ages, designers have done this by making simple sketches with a pen on paper, capturing the essence of their ideas in simple, low-resolution drawings. These quick sketches communicate flexibility, leaving room for interpretation and further refinement in. Serving as a universally understood design language between designer, clients and/or colleagues.

But what happens when/if this way of delivering ideas is challenged by other media and ways of representing? Is there a reason why this pure form of concept sketches has stayed analog and untouched the whole time? Despite the digital revolution in architecture and design, these concept sketches have stayed rooted in traditional methods. Is it because digital alternatives lack spontaneity and openness, like hand sketches, or have we simply not explored their full potential?

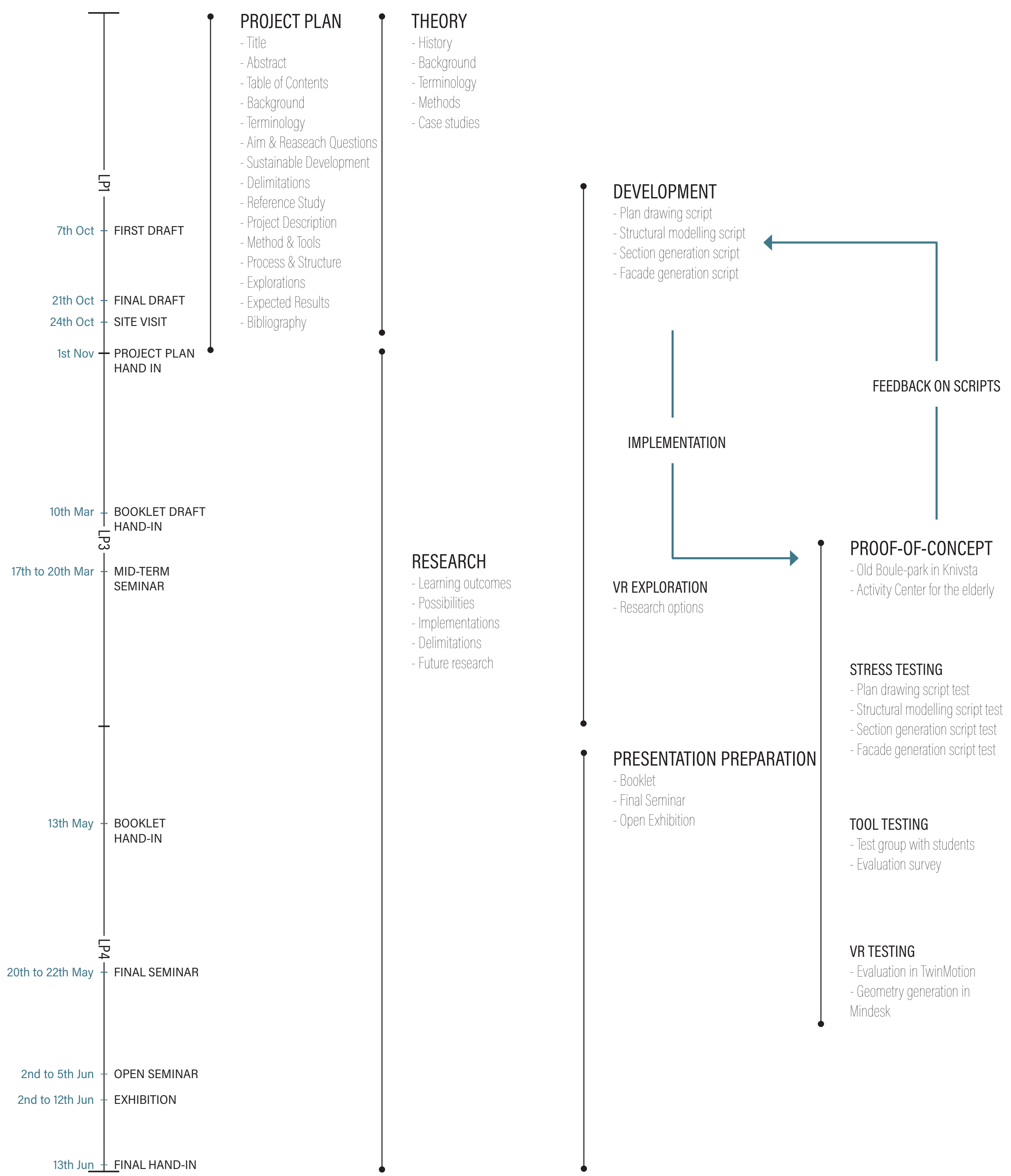
This thesis challenges the way we approach concept design by introducing the designer with rapid development tools and enables high resolution concept ideas to be created in a short amount of time. While hand sketches emphasize flexibility, these digital tools allow designers to explore ideas with depth and clarity from start.

Can these high-resolution concept representations be as effective in the eyes of a client? Do they maintain the same sense of flexibility as simple sketches, or are they too advanced and would be seen as too rigid and finalized for the receiver?



Conceptual sketches

1.9. PROCESS & STRUCTURE



2.1. EXPLORATIONS SETUP

Prior to starting the development of the tools, a strategy to frame the explorations had to be set up in order to structure it appropriately. The strategy written before the start of the explorations is listen below:

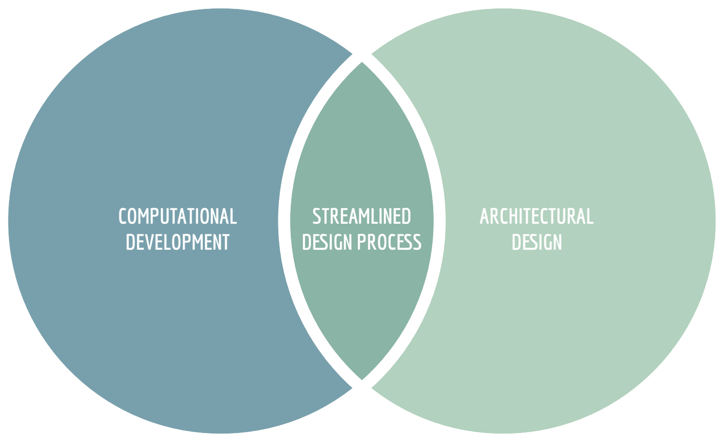
RULES:

- Start small and build
- Divide into parts & functions
- Simple geometry to complex geometry
- No lag!

REPRESENTATIONS

- Diagrammatic scripts
- If Python code, annotated code
- Schematic input/output
- Document learning outcomes in unsuccessful experiments

1. Line weights in Grasshopper
   - If successful, length domain to line weight
2. Custom planes to length domains
3. Alternatives in line weight output and export
4. BRep to wireframe to section
   - Look for previous work
   - Move from simple to complex to direct input
5. BRep to wireframe to facade
   - Look for previous work
   - Move from simple to complex to direct input
6. Structural modelling
7. Bill of quantities in Grasshopper
8. Python development/learning
9. Python streamlining through implementation in Grasshopper
10. Plan drawing script



Computation meets architecture

2.2. TECHNOLOGICAL NETWORK

To make the Grasshopper scripts interactive and maximize its user-friendly potential, it is important to make sure anyone (who has basic CAD-experience) can use it comfortably without any computational training. This will be made possible thanks to a generic theory, or framework that all tools will be based on.

It builds on a few key principles, namely the component "Geometry Pipeline", the tab-option "Remote Control Panel" and the layer structure within Rhino. These will all function as a direct link between Rhino and Grasshopper, making sure the user does not have to make any adjustments in the Grasshopper window. One reason so few architects have adapted to parametric design is the unfamiliar format and logic that extensions like Grasshopper use.

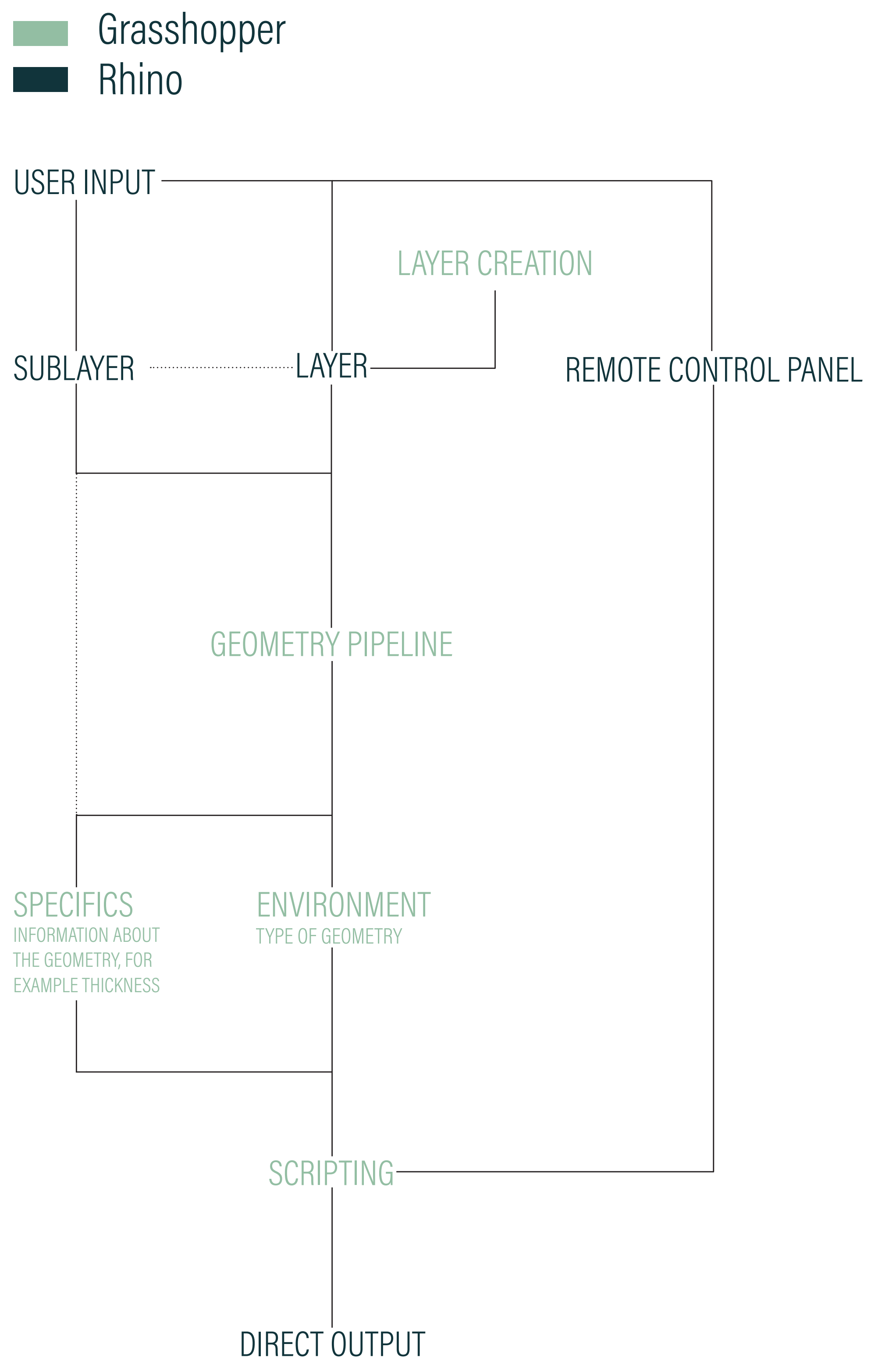
The component Geometry Pipeline acts like a direct reference link between Rhino and Grasshopper. It reacts on layer-input and references geometry created in a layer directly into Grasshopper and can handle information from full layer-path, meaning it can extract both geometry and written information from both main layers and sub-layers.

The tab Remote Control Panel (RCP) collects parameters, buttons, and panels from Grasshopper and makes them accessible in a Rhino format as simple controllers. This feature allows the user to make parametric adjustments without having to open the Grasshopper window, in a pedagogic manner.

Layer structure in the scripts will be tailored to each tool, giving the user the different types of geometrical input possible in the said script. It will give the user examples of sub-layers within the main layers with preset information about the geometry. For example, a preset sub-layer to creating external walls could be named "0.300x2.8" meaning the creation of external walls with 300 millimeters thickness and a height of 2.8 meters. The user can then alter and create their own layers with the desired dimensions to the geometry they want to create. The layer structure works directly with the Geometry Pipeline component.

Editing through this layer structure also makes sure the user maintains a well-organized layer structure throughout the project.

These main principles all work in symbiosis and are key functions to giving the user the direct visual response to their input, which is the reason why tools like these are so powerful and useful.



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2.3. PLAN DRAWING SCRIPT

The first and most advanced tool is the plan-drawing script. This tool is very useful and gives the user big creative freedom while enabling for quick visualization and export-options.

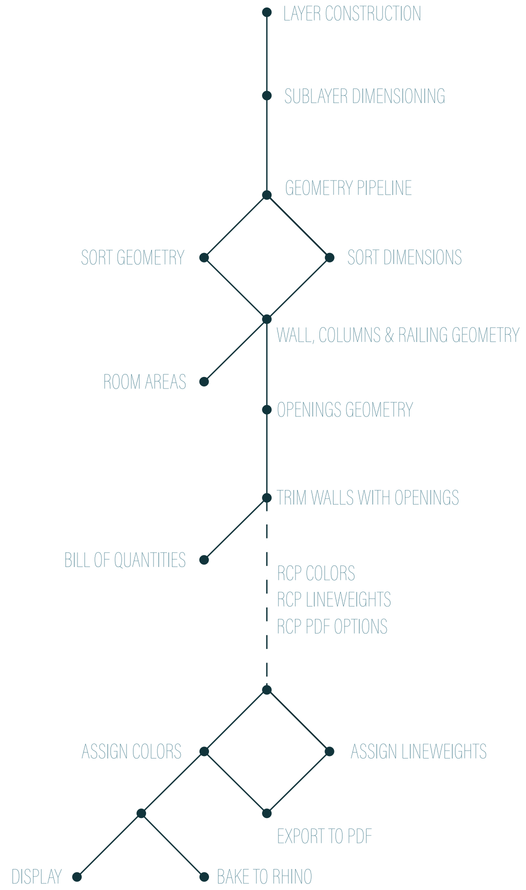
While the input consists of only centerlines and points in Rhino, the layer-structure enables the user to design with precision and showcase a wide variety of different design options. All this while saving a huge amount of time.

The Remote Control Panel (RCP) makes sure the user doesn't have to be in the grasshopper environment at all, since the panel offers all the parametric options inside Rhino. In the RCP, the user can control colors, line weights etc. If the RCP is not enabled from default, go to the grasshopper window > View > Remote Control Panel. The panel should now be visible in Rhino.

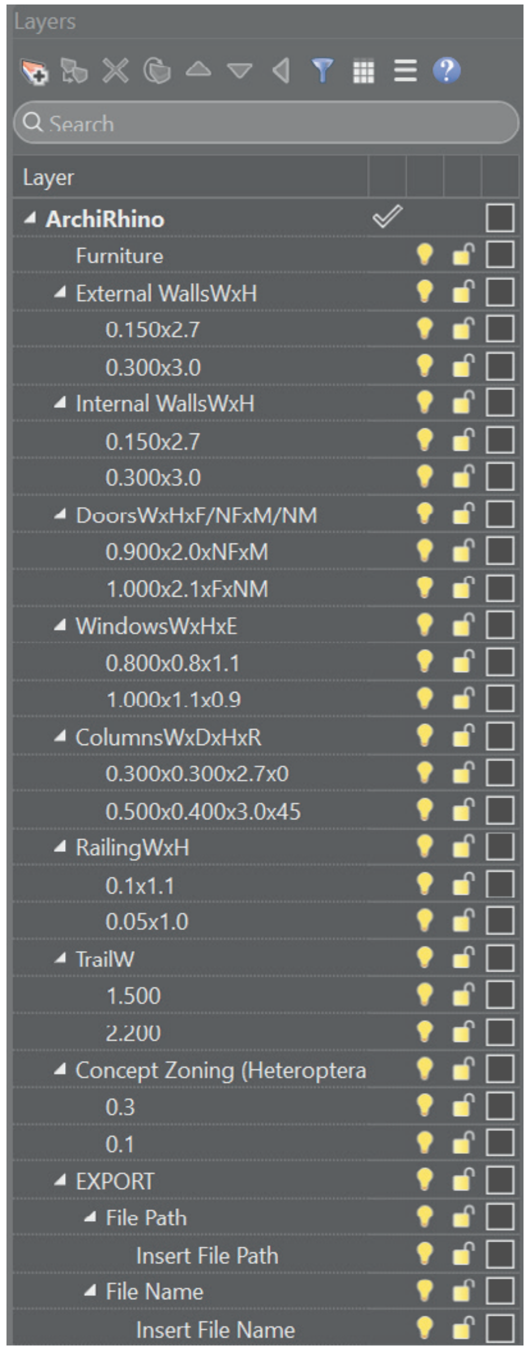
After setting up the layer-structure and the RCP with the users' desired properties and parameters, the design can be instantly visualized and/or exported as high-quality drawings. What makes the tool so powerful lies in the way the user can iterate and make changes to the design while getting the instant visualization during the process.

The tool comes with a preset layer-structure to showcase examples of how the sublayers should be constructed. If the user wants to change/expand the sublayers, they can simply add another layer with the instructions in the RCP.

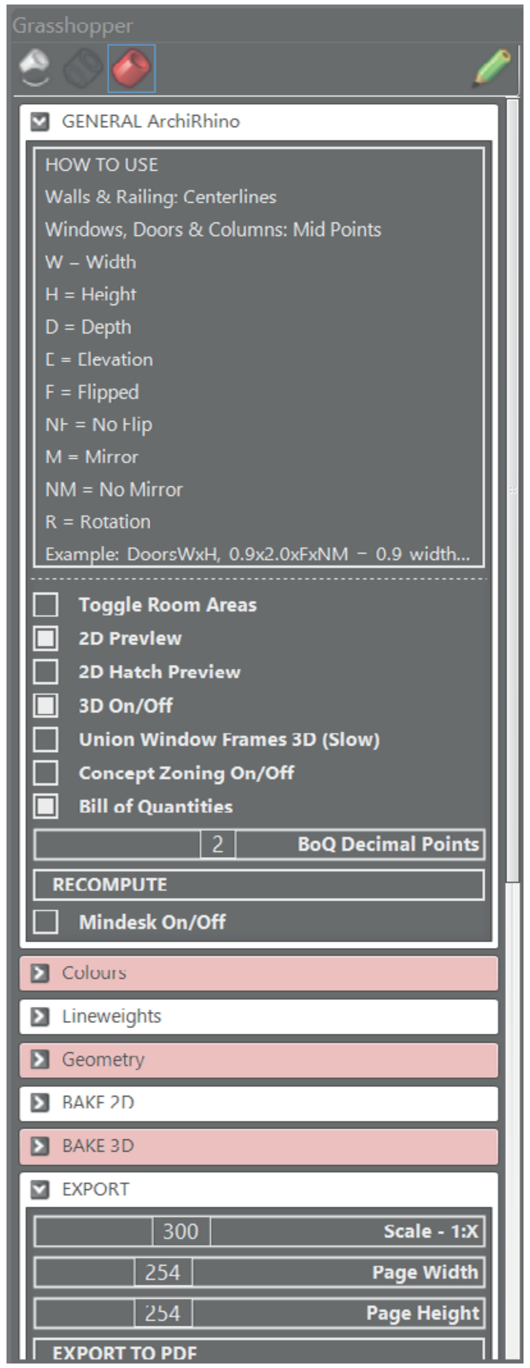
The tool also includes an option for 3D modelling of the user's floorplan, by simply checking the "3D On/Off" box in the RCP. The user can also turn on the function displaying a bill of quantities, allowing them to be aware of how choices they make will affect the sustainable footprint.



LAYER STRUCTURE & PARAMETERS

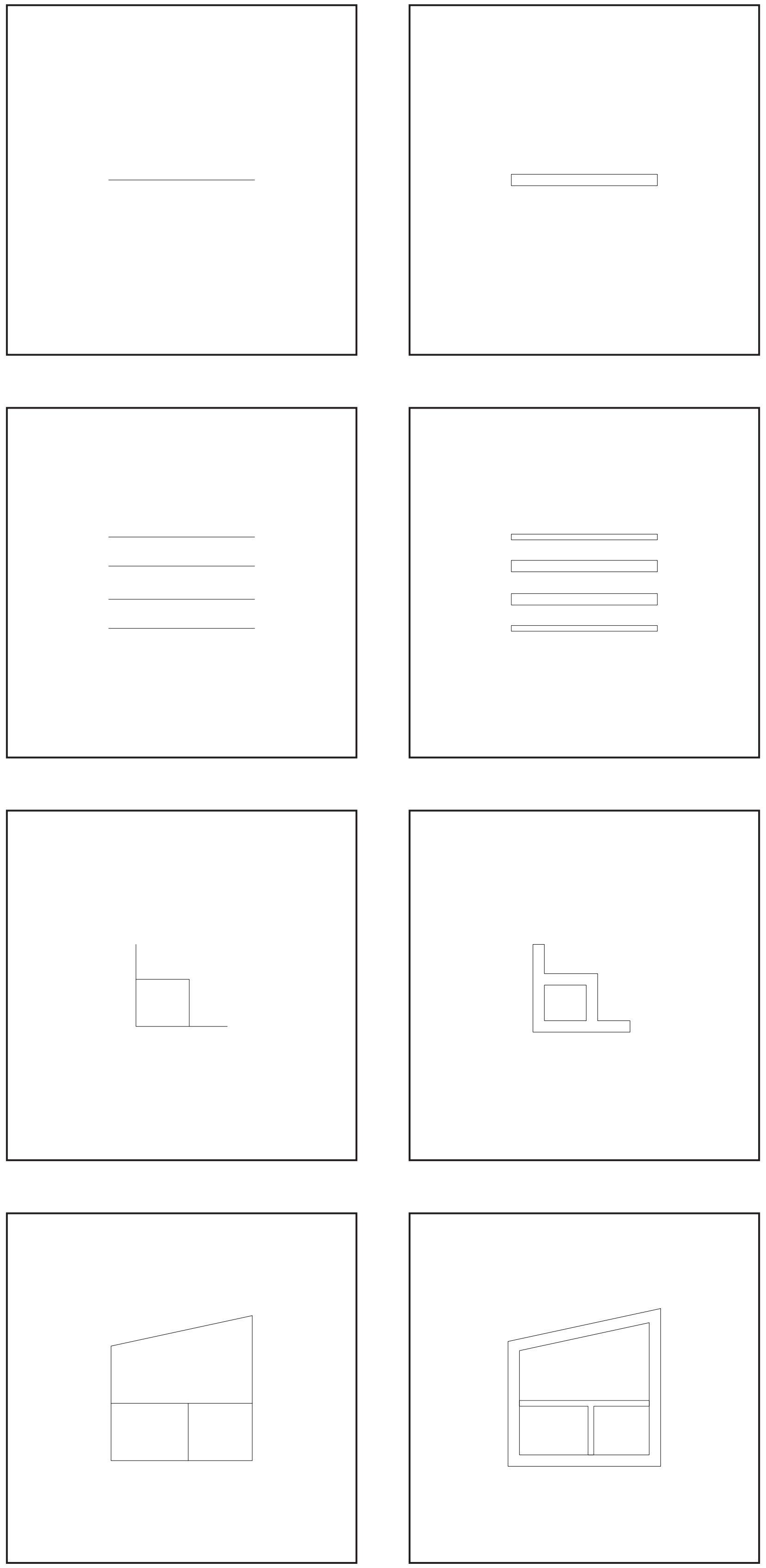


Preset layer-structure



Remote Control Panel

INPUT | **OUTPUT**



SINGLE WALL

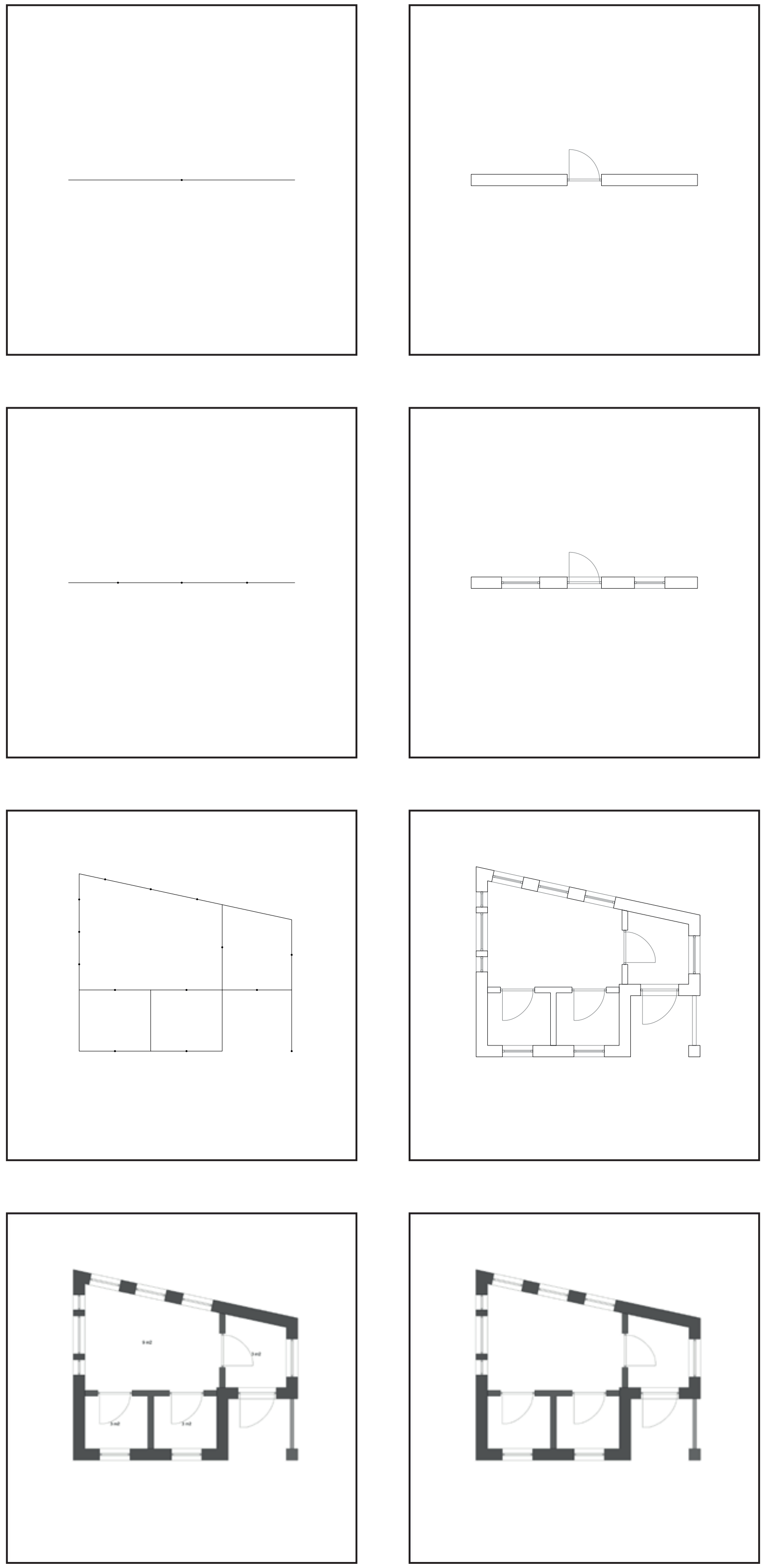
MULTIPLE WALLS

WALL INTEGRATION

EXTERIOR & INTERIOR WALLS INTEGRATION

Examples of script functions

INPUT | **OUTPUT**



DOOR SIMPLE

DOORS & WINDOWS

COMBINED FUNCTIONS

ROOM AREAS & HATCH

Examples of script functions

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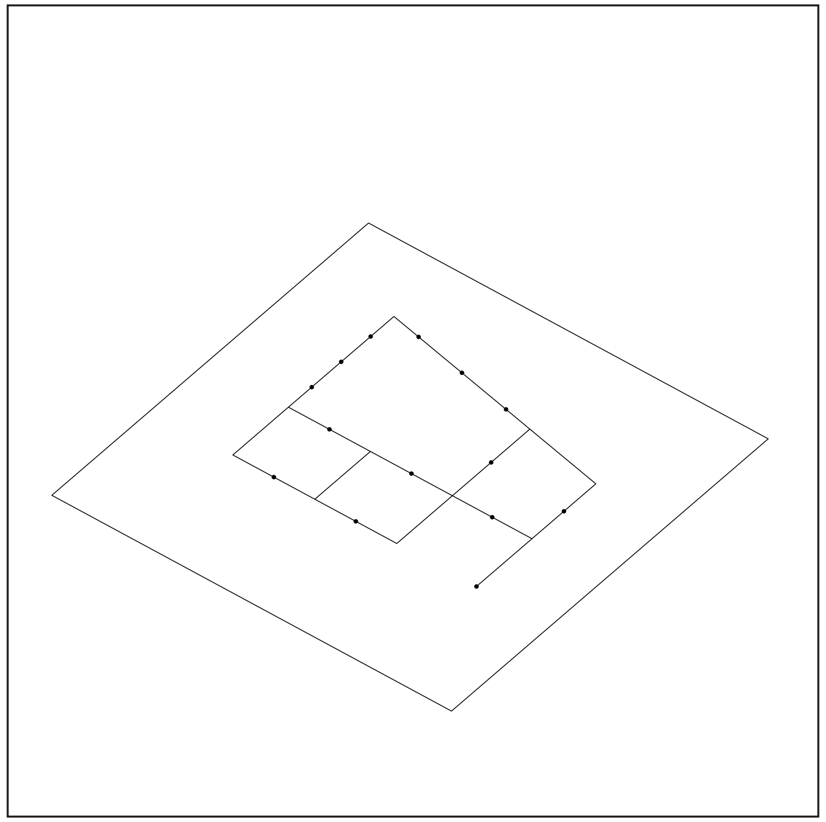
REFLECTIONS

The development of this tool went great. An important goal for the script was to minimize lag and bugs, since lag contributes to inefficiency, and no one wants to use a tool that is slow and has lots of bugs.

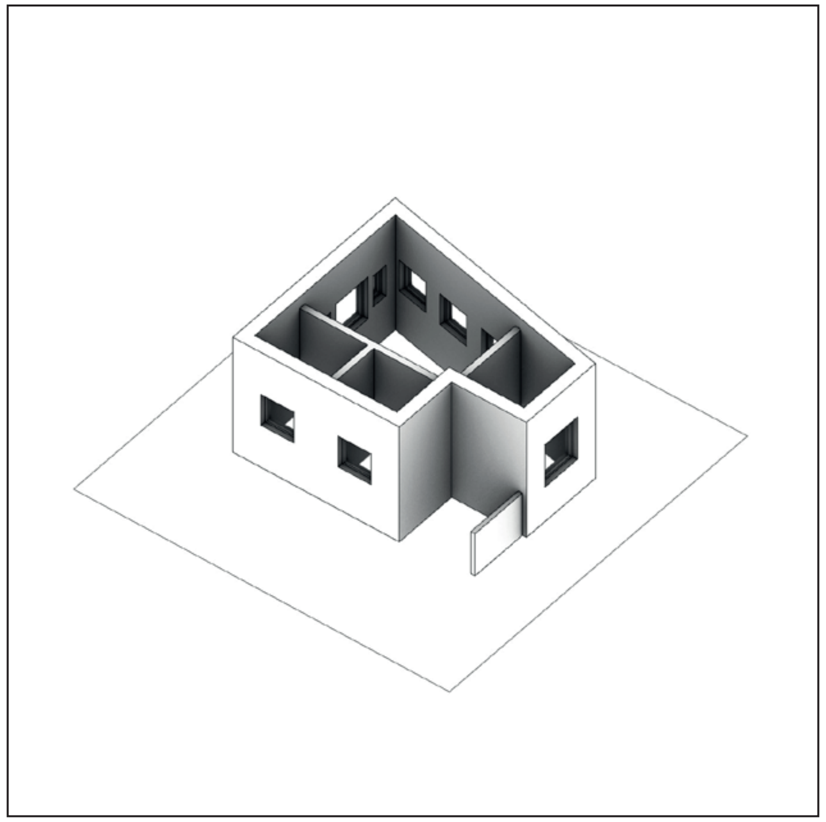
It was very important to be in control of the data structure while scripting, since a lot of different data is translated into different forms but still must remain in control to being able to apply the correct properties to them.

The tool still has a couple of small bugs, mostly in the 3D modelling section of the script. These are small enough to pass as OK in this thesis, since they mostly occur in extreme conditions. For example, the door and window geometry can get a little bit messed up in some places if the geometry is very curvy, conditions we very rarely see in architecture.

INPUT



OUTPUT



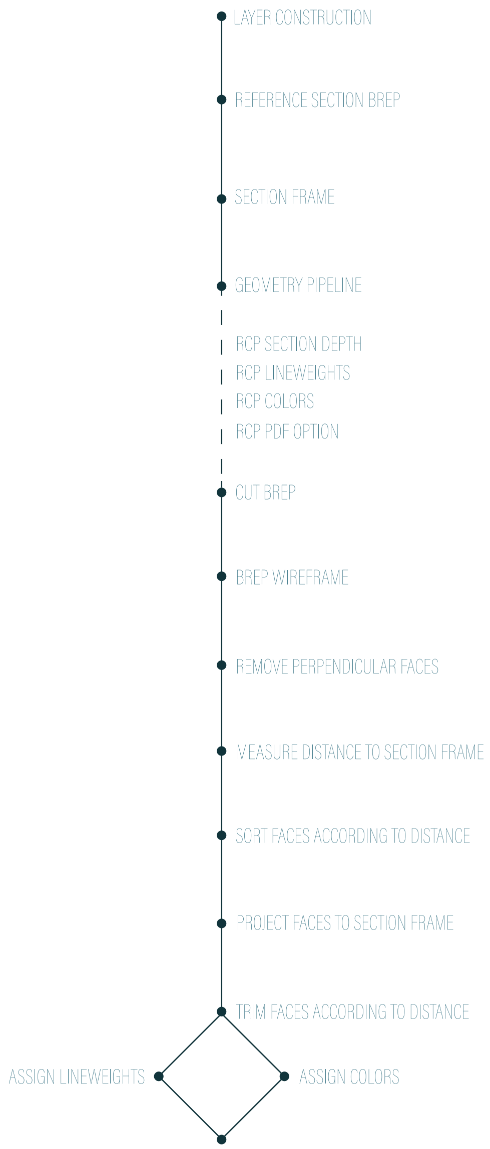
Examples of script functions

2.4. SECTION GENERATION

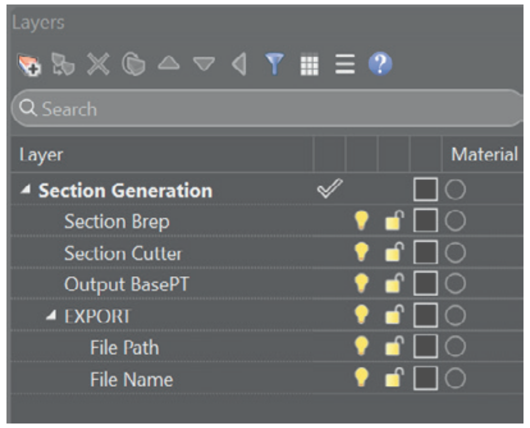
A section drawing serves both a representation tool, to help the reader understand function, movement and scale, and as a valuable design tool, offerings the designer another perspective on space, lighting and spatial relationships. It serves as a good compliment to the floor plan and volume by showcasing aspect that might otherwise be hard to grasp.

However, section drawings can be quite tedious and time-consuming to create and as the design developes, so does the section drawing. Each iteration of the design requires manual updates, making the process repetitive. This tool eliminates that tedious and repetitive task while maintaining the full control to the designer. By referencing the building volume in the input layer in Rhino, the user can simply select where the section should be drawn with the "Section Cutter" and the drawing is automatically computed, drawn and displayed with preset colors and lineweights depending on the depth of the section.

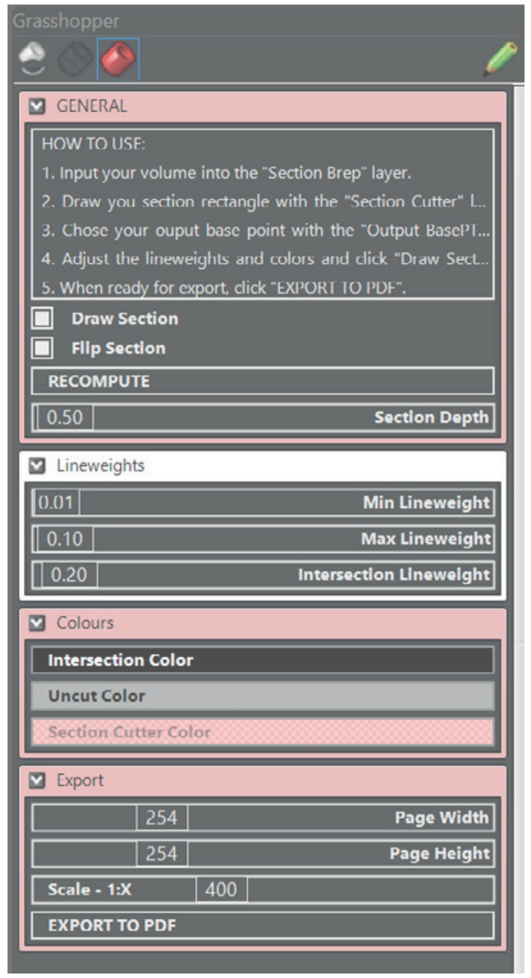
Once computed, the drawing can, with a push of the export-button be exported instantly to a PDF, ready to be edited in other softwares if desired. This workflow streamlines the process, ensuring that section drawings remain an integral part of the design development without slowing it down.



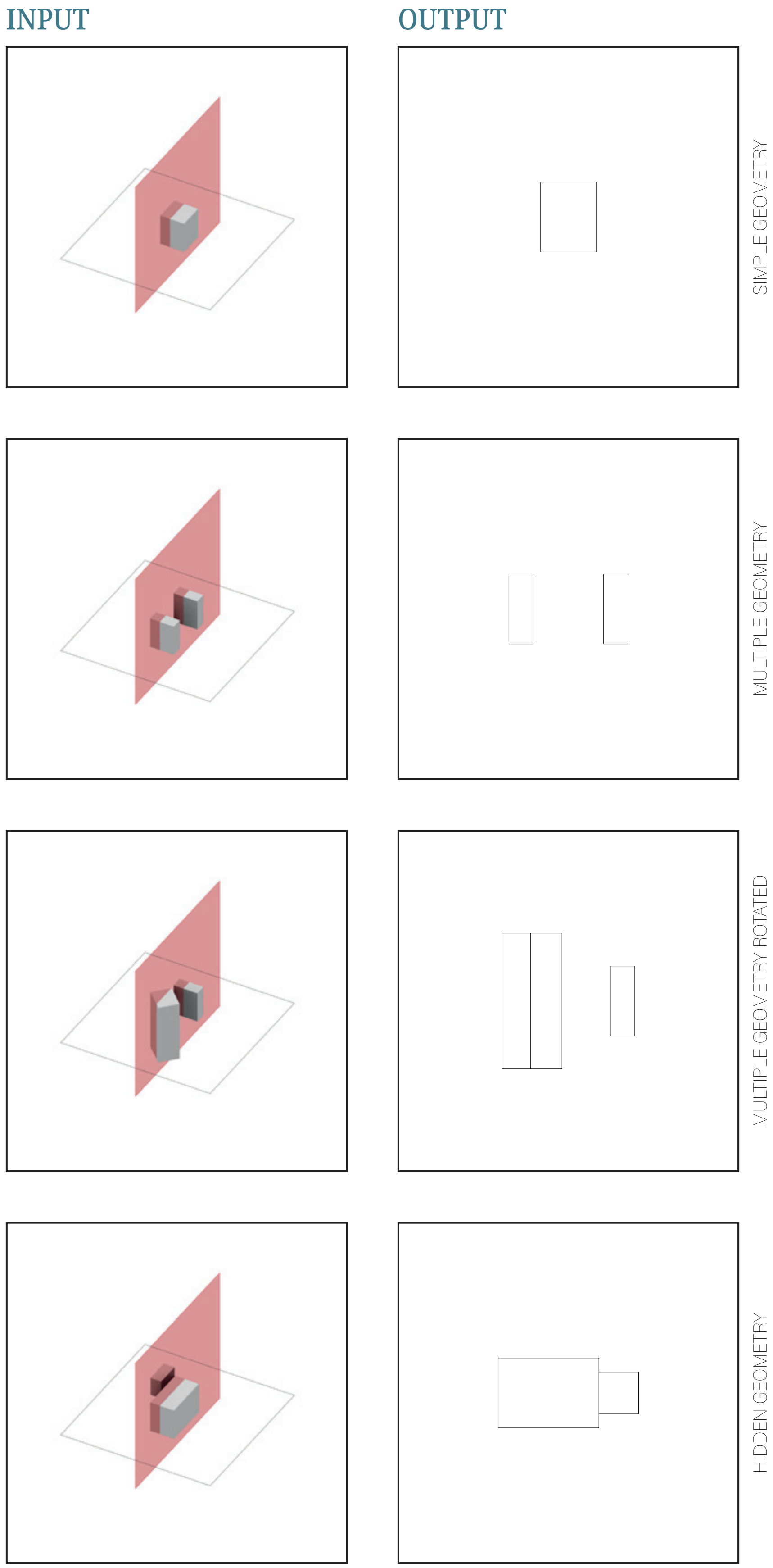
LAYER STRUCTURE & PARAMETERS



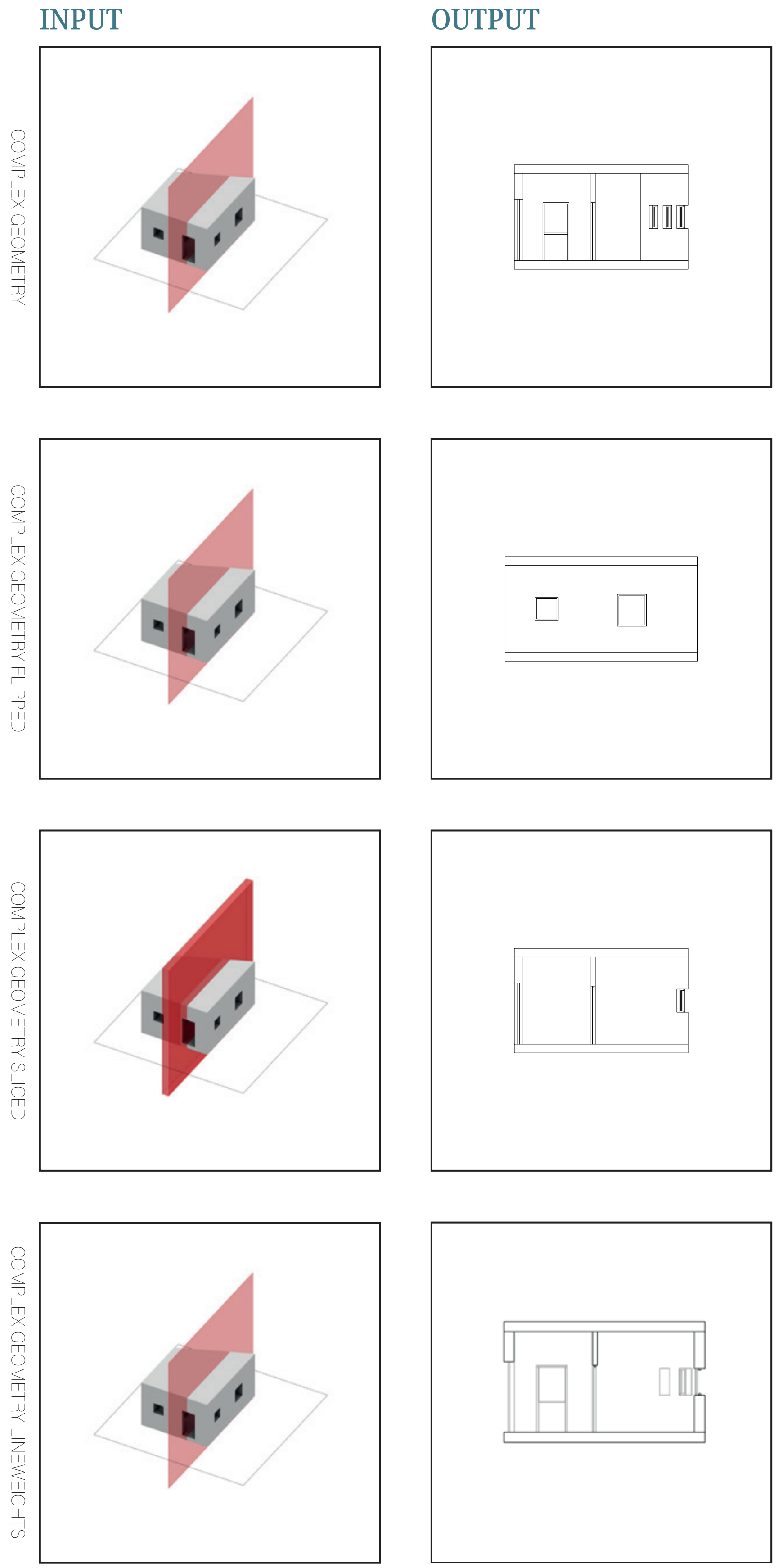
Preset layer-structure



Remote Control Panel



Examples of script functions



Examples of script functions

THESIS BOOKLET - 2025

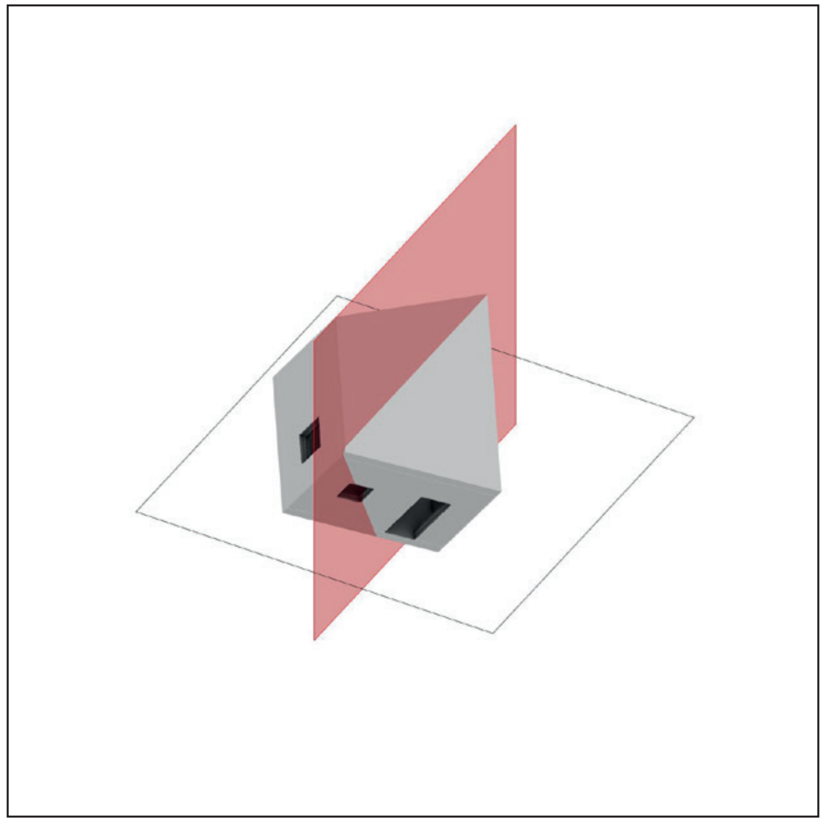
REFLECTIONS

This tool handles a seemingly quite simple task: To cut the input volume and display its interior content and surroundings. It revealed however to be a quite intricate and complex challenge to make sure the data stays in tact in order to allow the code to assign lineweights and colors correctly.

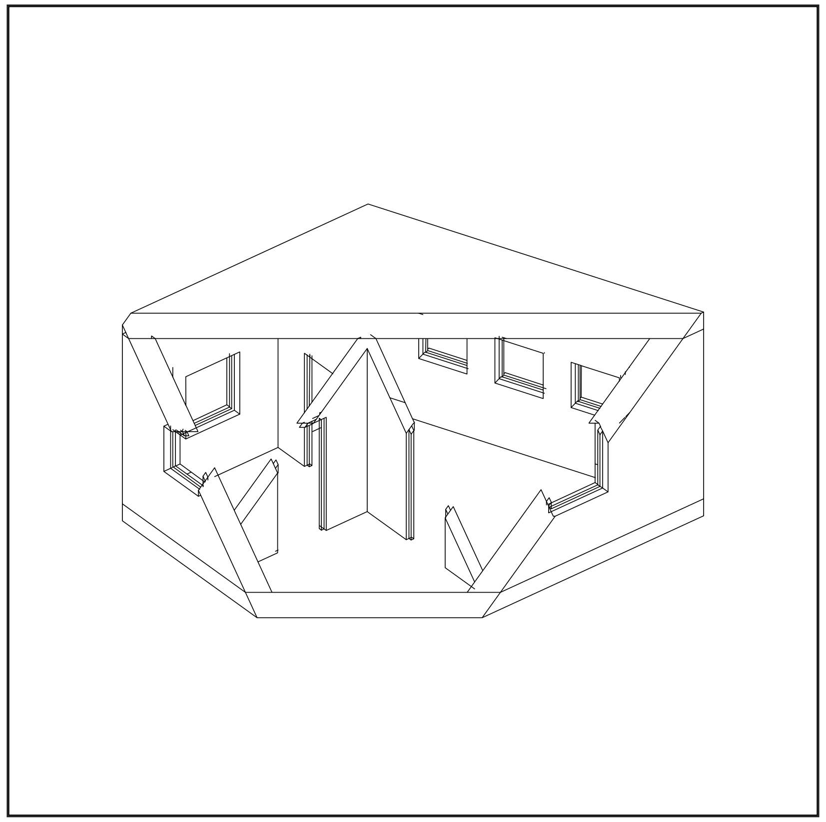
To achieve this, a custom Python code had to be implemented as there seemed to be no good way to handle this with built-in grasshopper components. One could use the regular "Make-2D" component but it lacks the essential functions that would make it valuable, such as depth and color differniation. The key motivator behind this script roots in frustration over the "Make-2D" function in Rhino not working very well.

The custom built Python code performs quite well overall, with only minor bugs, and serves its purpose showcasing the value of such functions. It proved to be a little bit slow when applied to more complicated geometry. It does however significantly enhance the manual workflow as parallell tasks can be done while the script computes.

INPUT



OUTPUT



Examples of script functions

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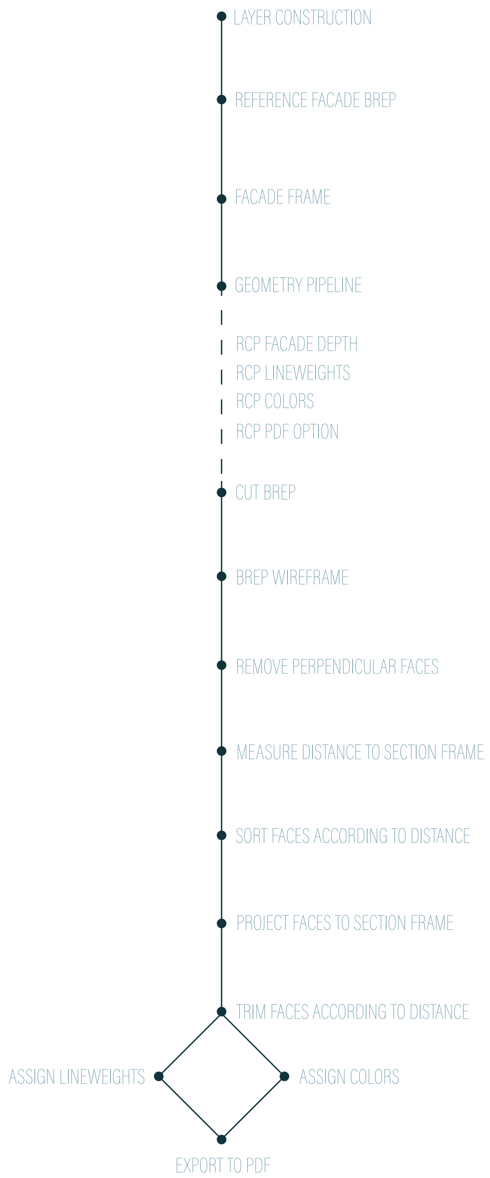
2.5. FAÇADE GENERATION

Similarly to section drawings, façade design is a very important key aspect to an attractive design. Just like sections, these transform during the iteration process and making these over and over again manually can be a massive time consuming task.

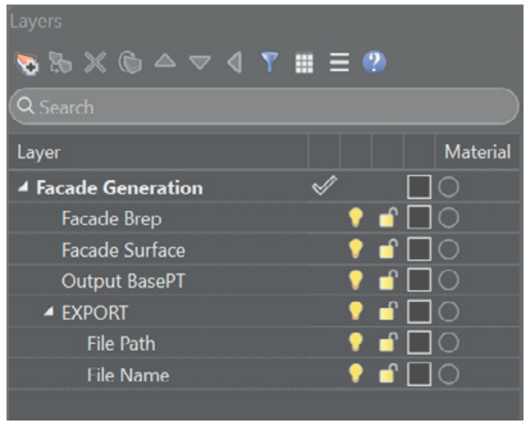
This tool automates that process, leaving the designer free to allocate time on other aspects while always being able to keep track of the façade expression.

The logic behind the functions are basically the same as the section generation script, except that the target frame is outside the building instead of cutting it. The script computes the linework of the façade and displays it with appropriate lineweights according to the user's choice.

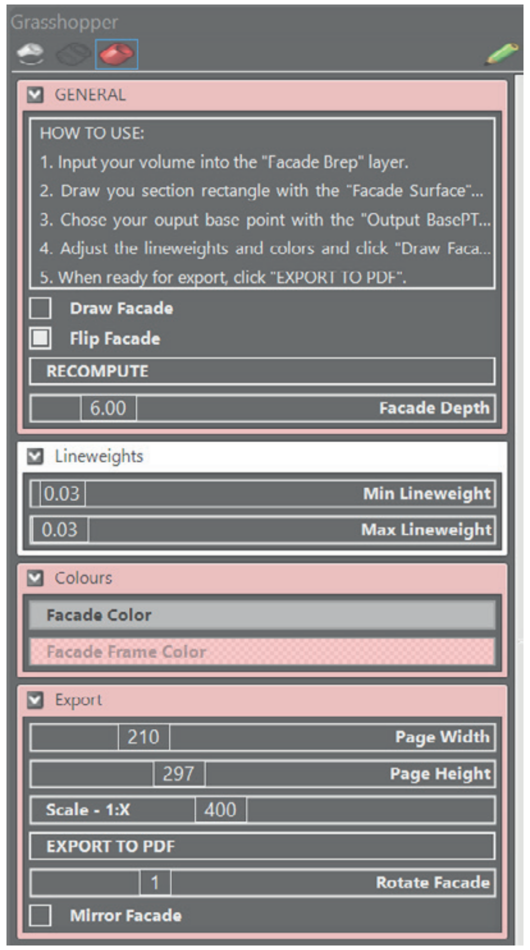
When ready, the drawing can be exported instantly to a PDF with a single button press. The user can then, if desired, edit it further in their choice of software.



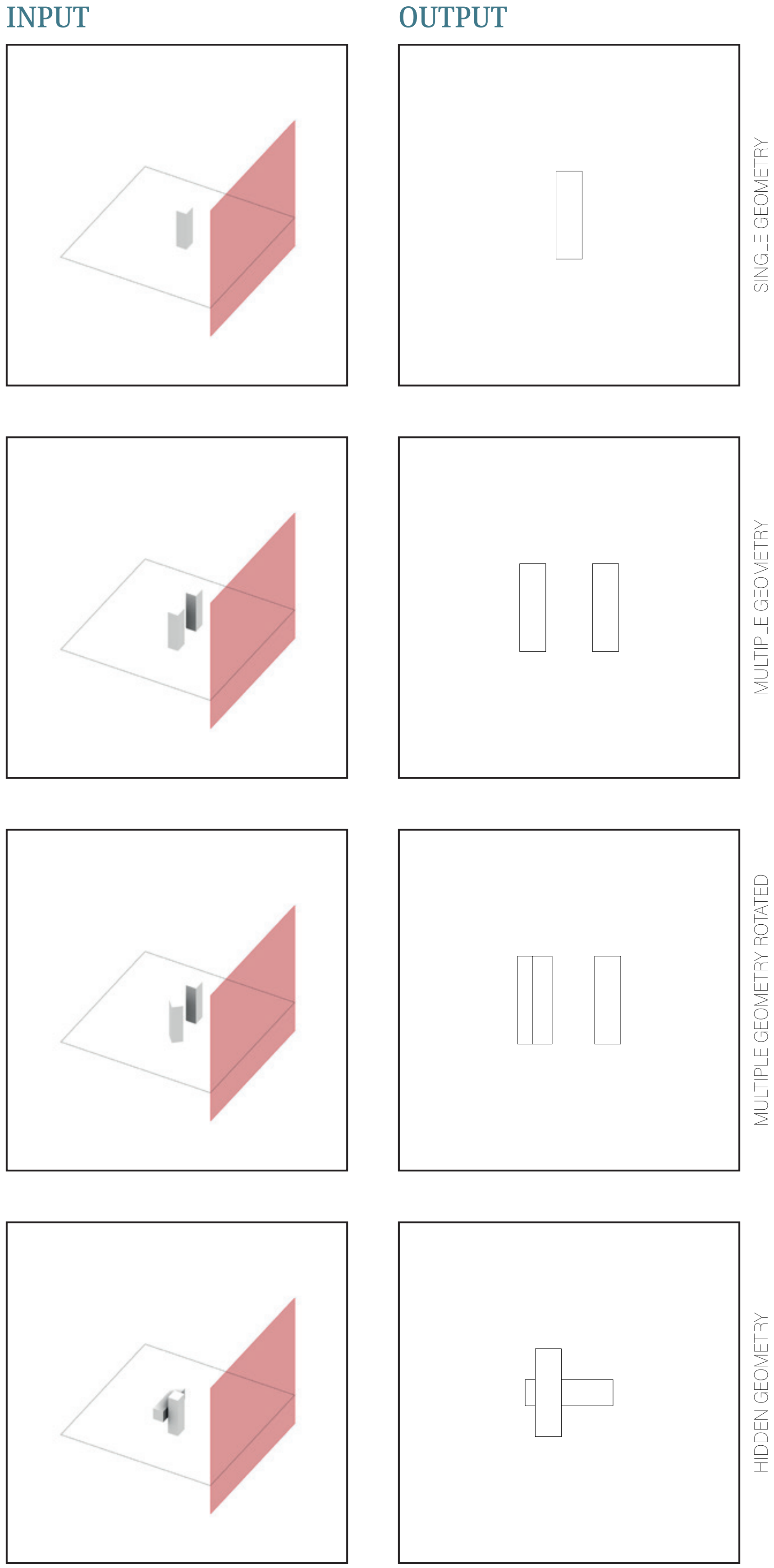
LAYER STRUCTURE & PARAMETERS



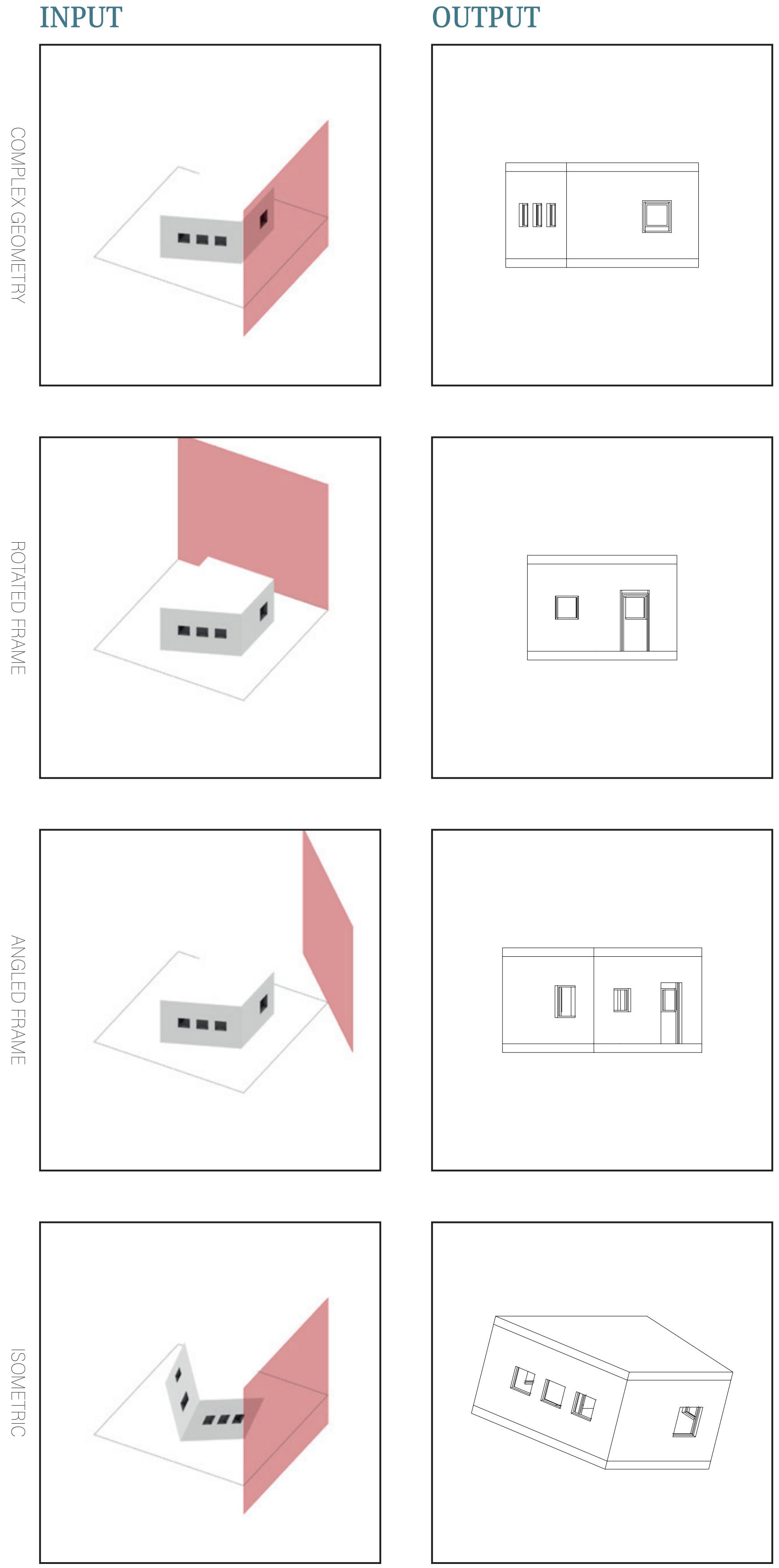
Preset layer-structure



Remote Control Panel



Examples of script functions



Examples of script functions

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2.6. STRUCTURAL MODELLING

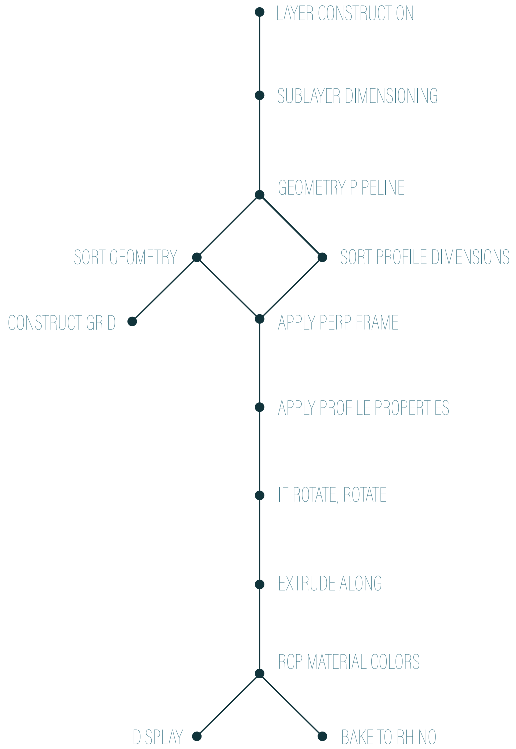
The structural modelling script is perfect for those who like to visualize the structural system of a project. Here, the user is provided with a bunch of example layers to quickly model beam- and column geometry in timber, steel and concrete.

The only inputs are points for columns and curves/lines for beams. A grid can also be instantly generated using a base point.

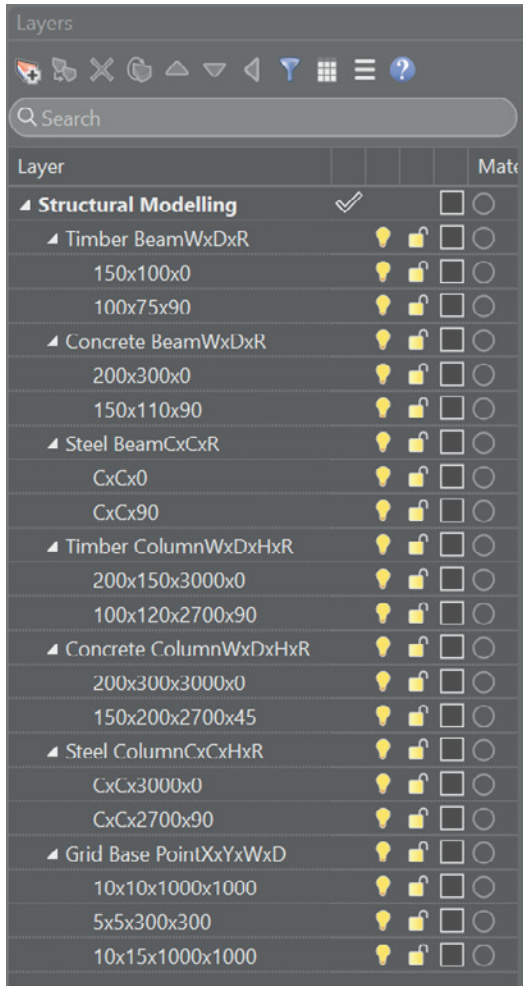
The geometry and specific dimensions are set by the user in the layer structure, by renaming/creating new sublayer to the geometry they want to produce.

A preset layer structure and Remote Control Panel comes when the script is open, which enables the user to make all the necessary changes directly within Rhino. The user can control dimensions, viewing options, color options and bake geometry directly into Rhino.

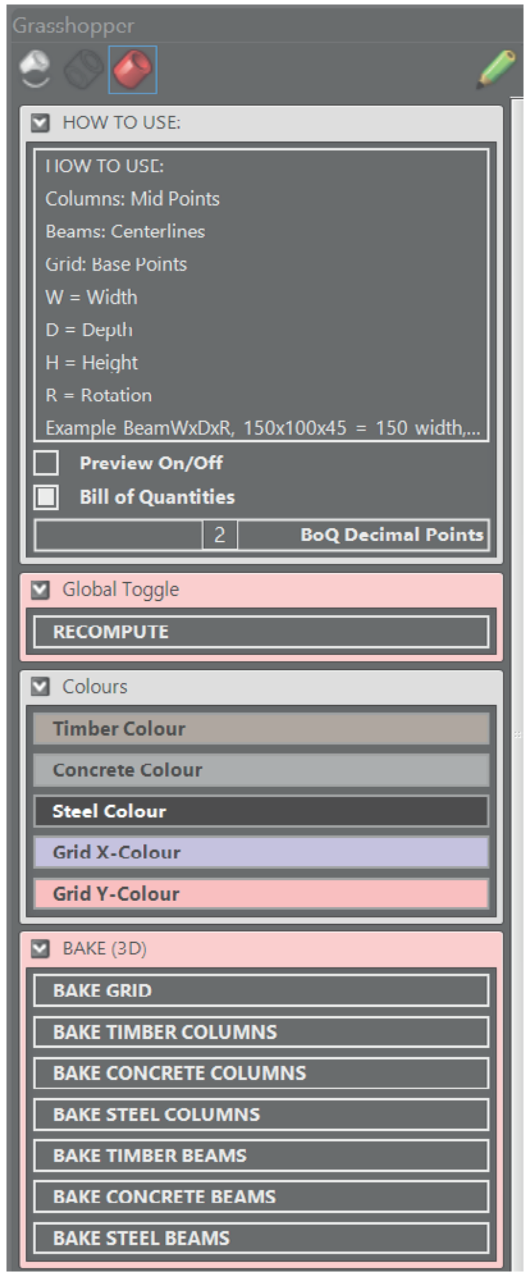
The user can also turn on the function displaying a bill of quantities, allowing them to be aware of how choices they make will affect the sustainable footprint.



LAYER STRUCTURE & PARAMETERS

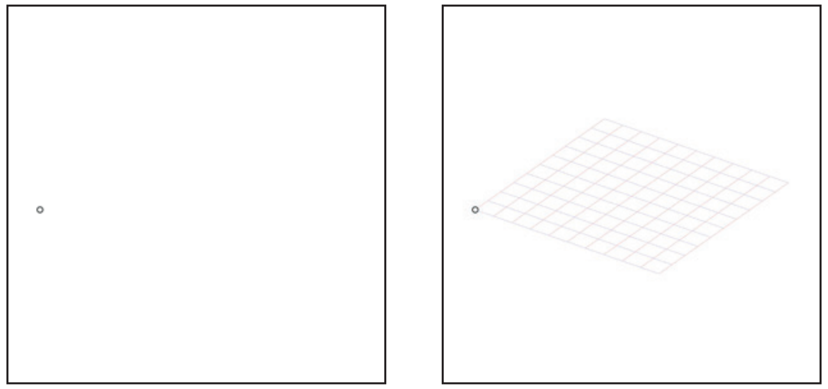


Preset layer-structure

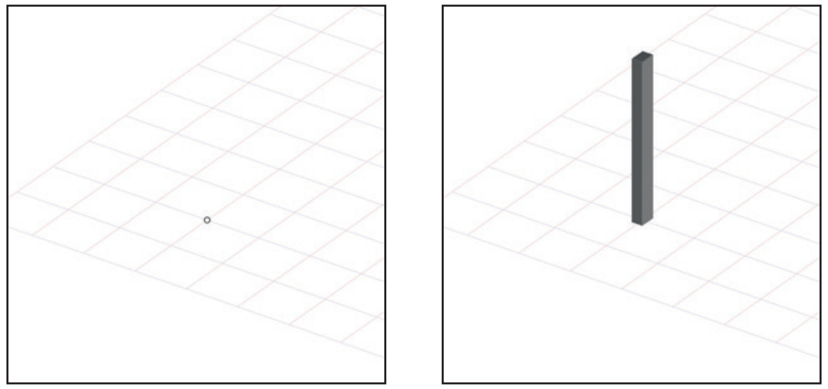


Remote Control Panel

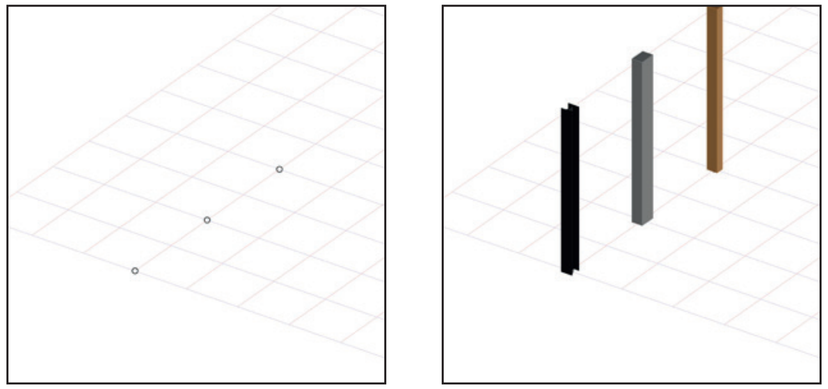
INPUT **OUTPUT**



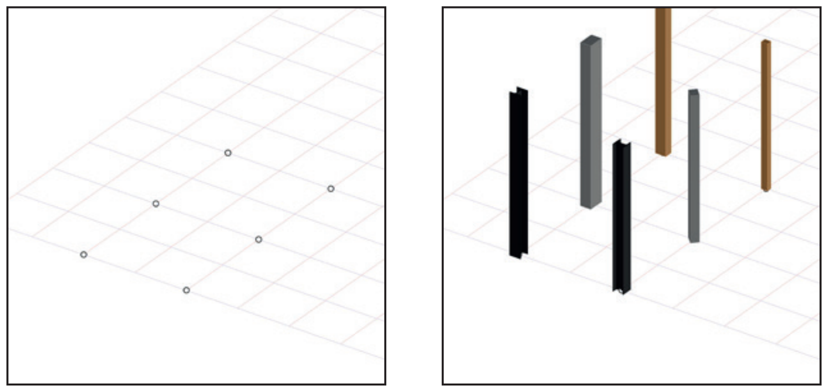
GRID



SINGLE COLUMN



MULTIPLE COLUMNS, MATERIALS

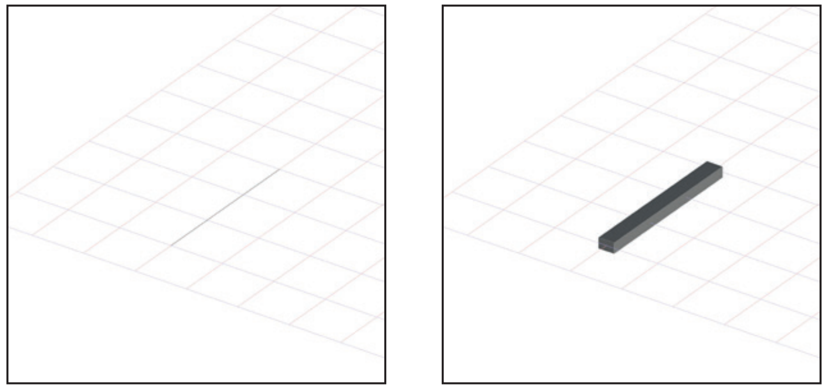


ROTATED COLUMNS

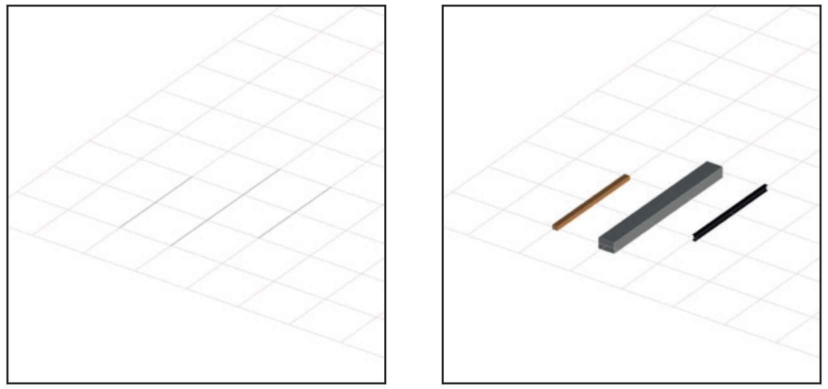
Examples of script functions

INPUT **OUTPUT**

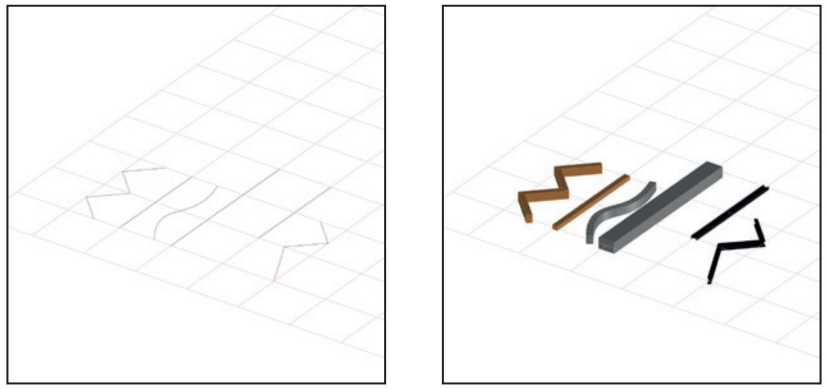
SINGLE BEAM



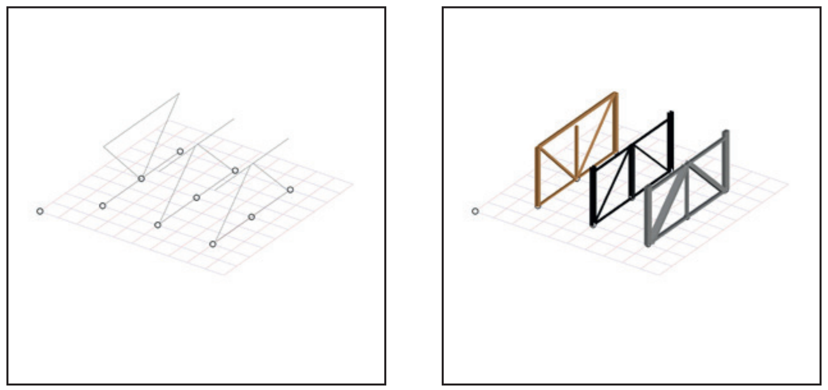
MULTIPLE BEAMS, MATERIALS



COMPLEX BEAMS



COMBINED BEAMS & COLUMNS



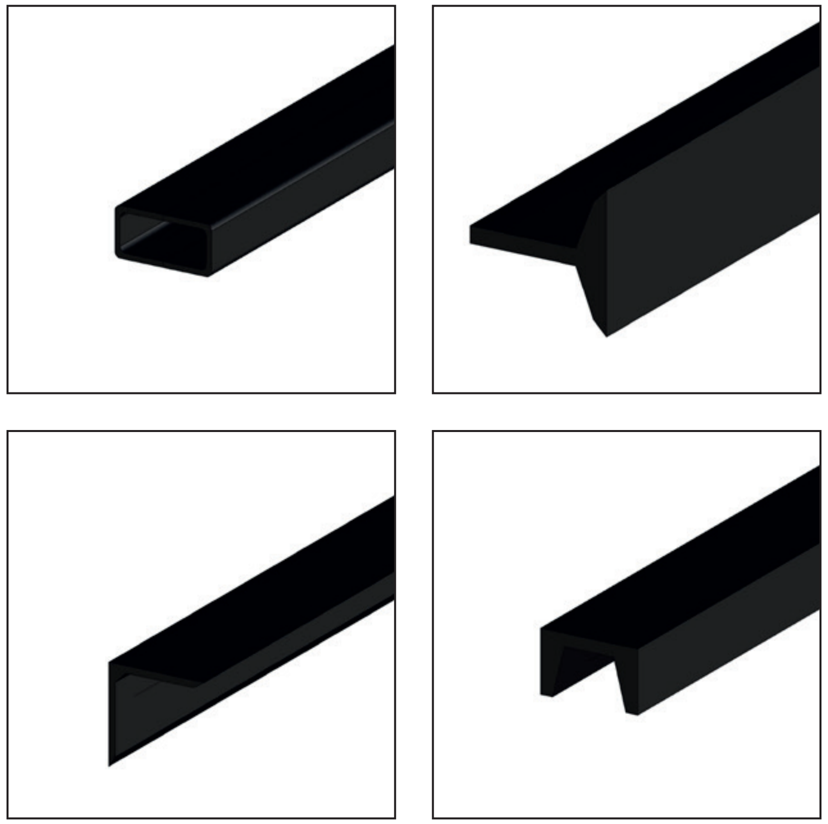
Examples of script functions

REFLECTIONS

This script is quite simple in its logic, the pieces work separately and it has basically no bugs. I'm very happy with the results of this script. The only known flaw it has is it can't have rotated steel beam sections if the input polyline has one or more kinks, instead it displays a non-rotated beam.

STEEL PROFILES

EXAMPLES



Examples of script functions

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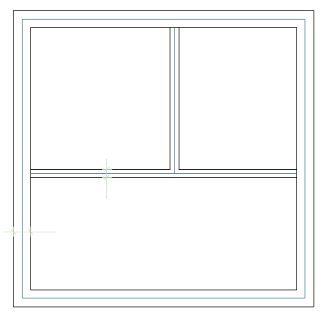
2.7. KEY FUNCTIONS

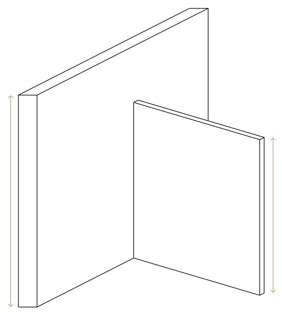
To make sure the tools work appropriately without case specific attributes, it was crucial to define key functions to the logic. The geometry generation scrips, plan drawing, concept modelling and structural modelling, draws information from the layer they're generated from. Numerical values are seperated with x's and assigned to parameters that define the desired properties to the geometry. The numbers are completely customizable to the user.

The visualization key functions are defined by its shapes and distance to the projection plane. The code sorts shapes depending on their distance to the plane, projects the shapes to the plane and then trim away parts that wouldn't be visible in a section or façade. The relative distances to the plane are stored to make sure appropriate line weights and colors can be assigned to each projected shape.

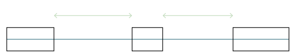
GEOMETRY CREATION LOGIC

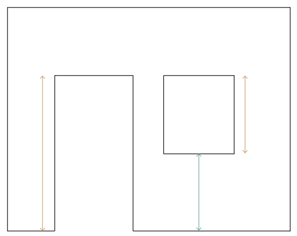
LAYER:
External Walls
0.400x2.7
Internal Walls
0.150x2.4





LAYER:
Doors
0.900x2.1
Windows
0.800x1.2x0.9

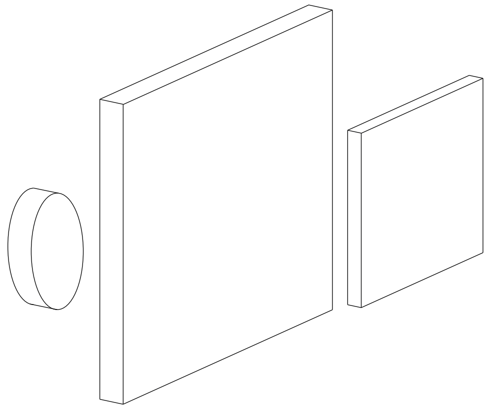




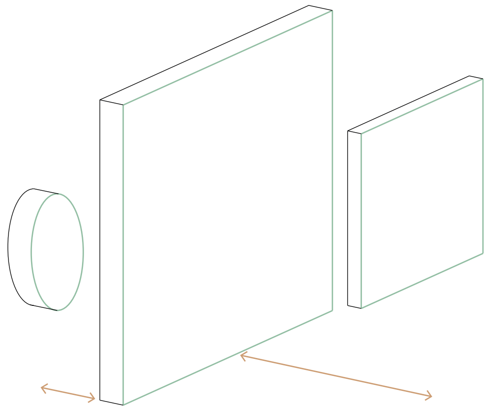
Key functions,
Geometry generation

VISUALIZATION LOGIC

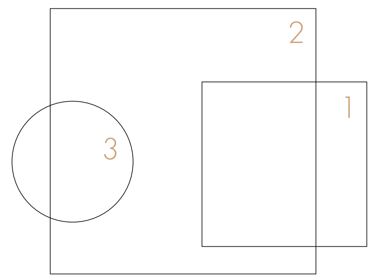
Input shapes



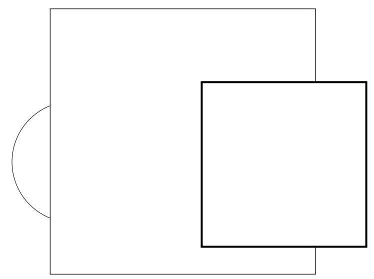
Identify surfaces
Measure distances



Project
Distance hierarchy



Trim
Assign lineweights



Key functions.
Visualization

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3.1. KNIVSTA BOULE PARK

The site proposed for Valloxen Leisure Centre is located in Knivsta, a small municipality with approximately 21 000 inhabitants located about 20 km south of Uppsala. The site has been home to a very popular boule-field, especially for the elder population of Knivsta. It lies in a beautiful forest grove but as the municipality has grown rapidly in the past 5-10 years, the boule-field has lost its popularity and now stands empty and uncared for.

The reason for designing an activity center in this area is to give the elder population of Knivsta a meeting point, something that is currently lacking in Knivsta, in an attractive location, close to the public bathing area and just a short walk from the city center, that has great potential to be popularized and valuable for the community.


Adjacent pathway


Connecting road


Connecting road


View from entrance


View from entrance


View from inside


View from inside


View from inside


View from inside

3.2. SITE ANALYSIS

BUILDING TOPOLOGY
The site is situated in a quiet residential area, with the exception of a couple pre-schools and a small restaurant by the bathing area. The area is dominated by villas and a few row-houses, mostly inhabited by families and the elderly.

ROADS
Connected to the site lays one of the main roads in Knivsta, Apoteksvägen. Apoteksvägen takes you all the way through the city center, to the train station. adjacent to the site, there is a footpath running through the woods connected to the site which leads to the public bathing area "Särstabadet". The footpath is also a good shortcut to other parts of Knivsta, which may be more complicated to go via car.

WATERLINE
The lake "Valloxen" is Knivsta's main lake and spans kilometers alongside the town. There are a few bathing possibilities in Valloxen, but the most popular one is "Särstabadet" which lies just at the end of the footpath running through the woods adjacent to the site. Särstabadet contributes to the area being very popular during warmer periods of the year.

GREEN AREAS
Due to the site being located a bit outside the city center, the area is quite green. The site lays in a forest grove, at the edge of a small but beautiful forest.

ELEVATION
The site itself is almost completely flat, and the surrounding area is also relatively flat, especially on the south and east side.


Recycling station


Entrance pathway to lake area


Entrance pathway to lake area


Pathway to lake area


Pathway to lake area


Pathway to lake area


Pathway back to site


Pathway back to site


Nearby miniature golf

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4.1. ITERATIVE DESIGN SETUP

To thoroughly test and maximize the potential of the tools developed in this thesis, The author will serve as the test subject while iteratively designing the activity center in Knivsta.

To demonstrate the effectiveness of the plan drawing script, a series of design iterations will be conducted. Each iteration will be informed by both positive and negative aspects from the previous version, shaping the next step in the process. The number of iterations will highlight how much progress can be achieved in a short period, thanks to the script's ability to provide instant visual feedback.

A set of criteria will be established to define what constitutes a successful design for this project. Each iteration will be evaluated against these criteria to assess its strengths and weaknesses.

Throughout this iterative process, potential bugs, minor adjustments, and opportunities for new functions will become evident. In this way, the tool will enhance the design process, while the design process will, in turn, refine and improve the tool.

WHAT MAKES A GOOD DESIGN?

* The building mass is appropriately integrated into the site.

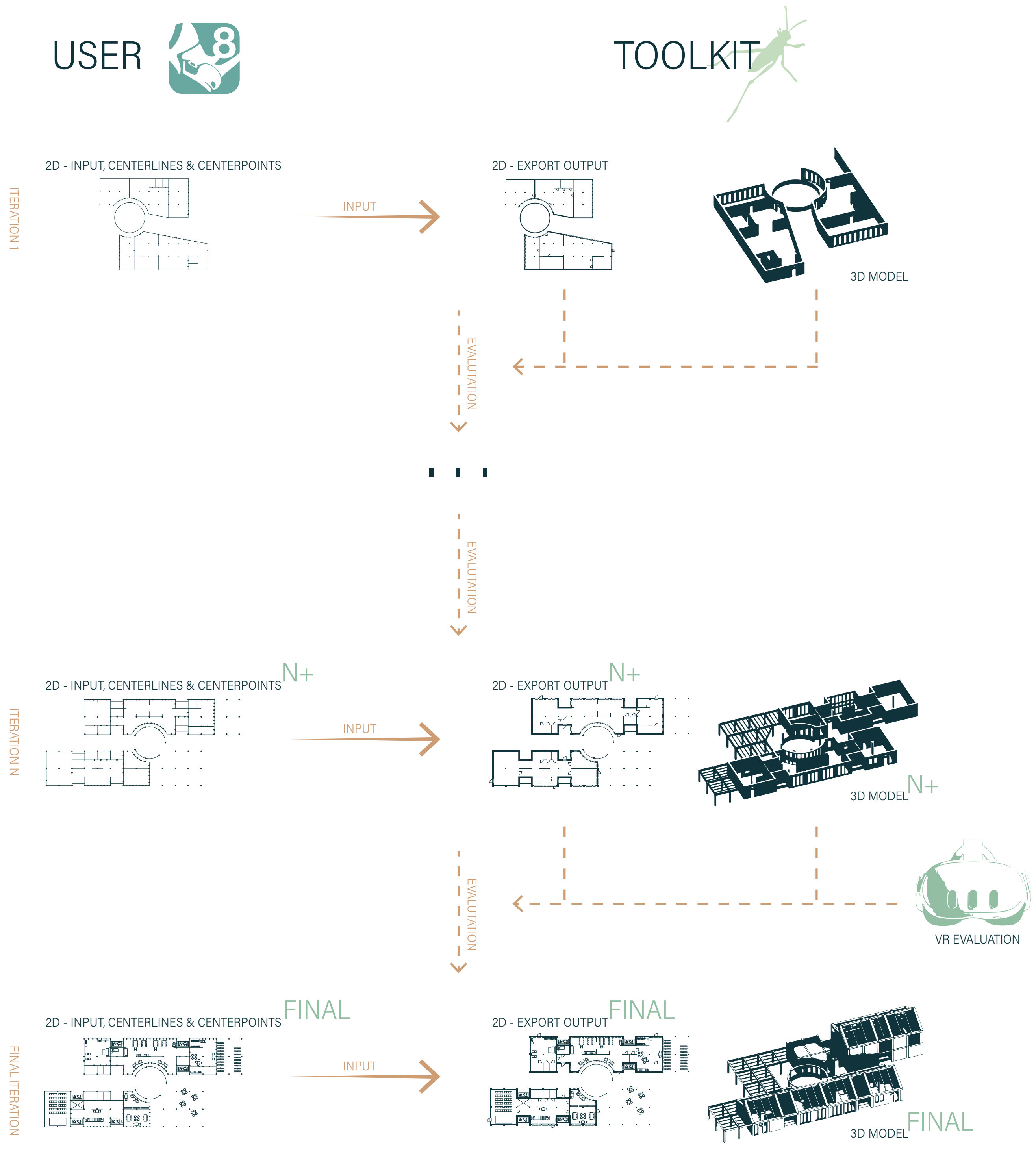
* The building mass and outdoor spaces are proportionally designed to fit the site.

* The functions and circulation are logically organized in relation to the program and building mass.

* The functions and circulation are coherently structured to align with the program and building mass.

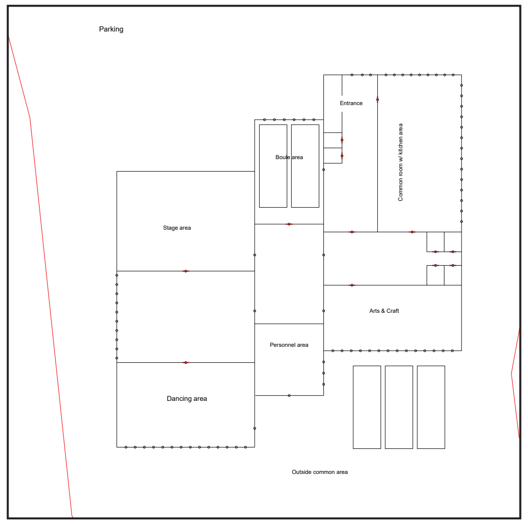
* The indoor room division and layout are designed to optimize space utilization and minimize dead or awkward areas.

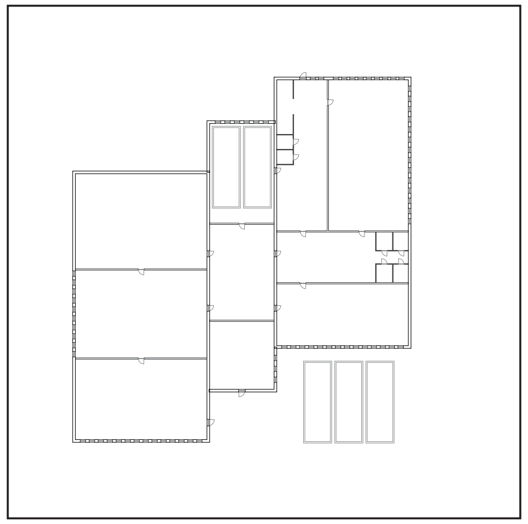
* The building mass, along with the placement of openings such as doors and windows, is arranged to achieve a functional and aesthetically appealing design.

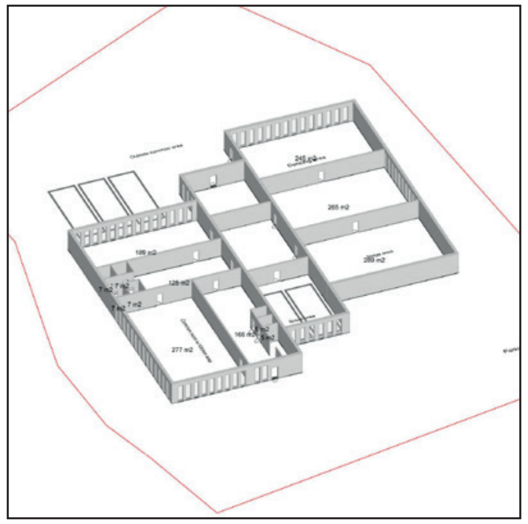


Example workflow

DESIGN ITERATION 1



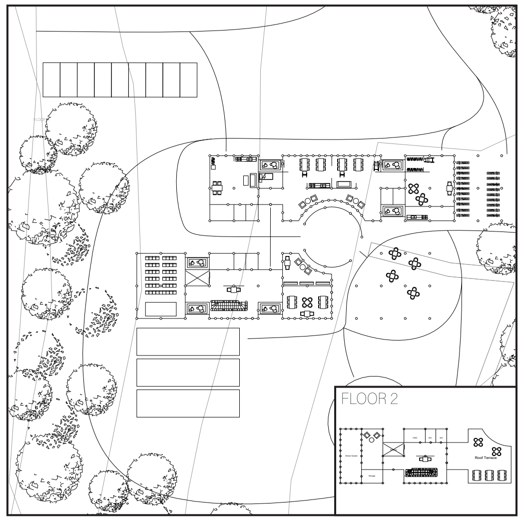




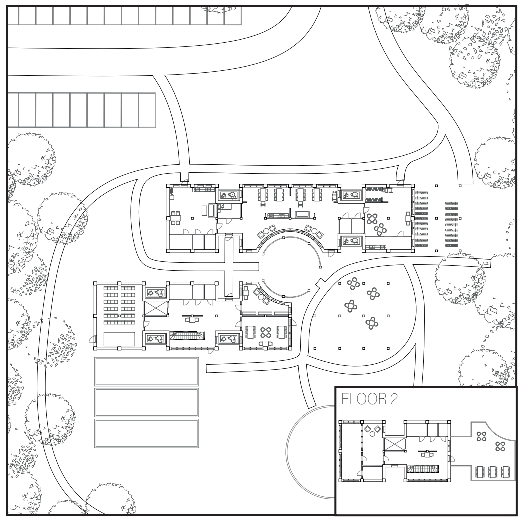
The first iteration primarily focused on defining the required functions and gaining an understanding of the appropriate volume size in relation to the site. Based on the site's characteristics, the north-east corner appears to be the most intuitive location for the main entrance.

DESIGN ITERATION 15

INPUT



2D OUTPUT

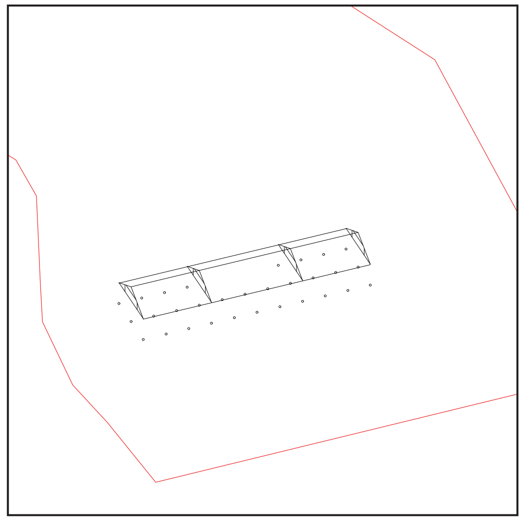


3D OUTPUT

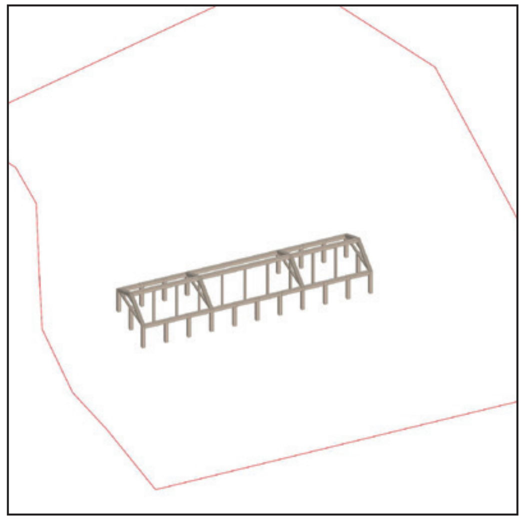
Drawing inspiration from the rapid concept development, a partial second floor was added in the south-west side of the building. By doin this, the winter garden was replaced by a staircase and moved to a more attractive space on the upper floor. The second floor also introduces a spacious roof terrace.

STRUCTURAL ITERATION 1

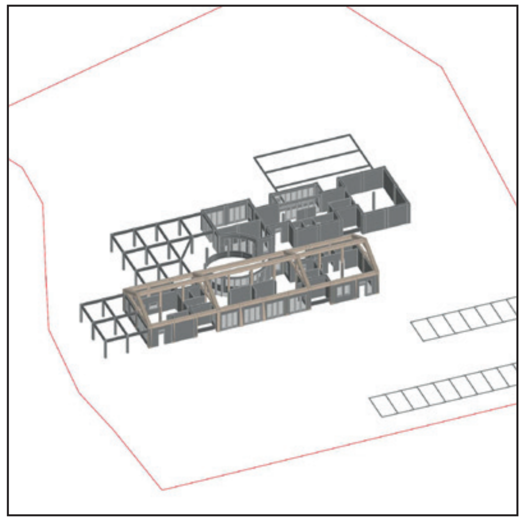
INPUT



3D OUTPUT

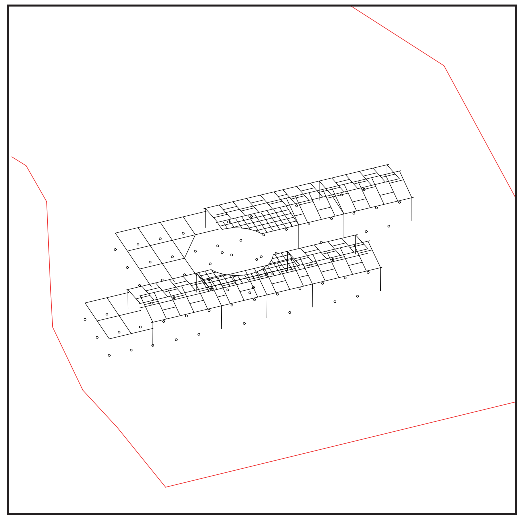


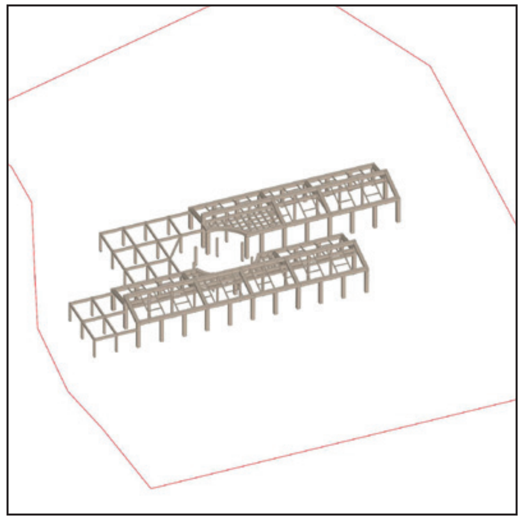
APPLIED TO MODEL

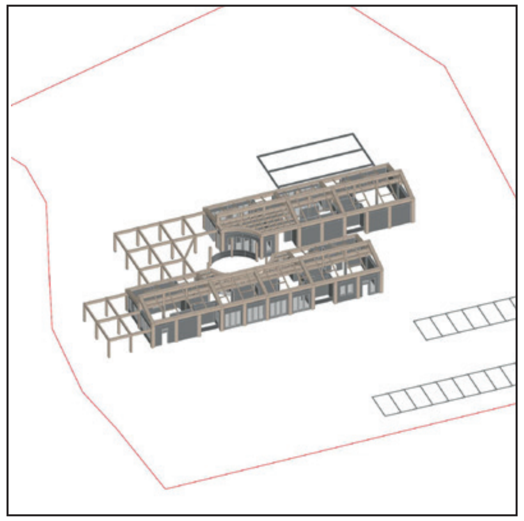


For the initial iteration of the load-bearing structure, I started with a simple approach to test the structural modeling script. The first test used a conventional frame throughout, which integrated well with the overall volume and was easy to apply.

STRUCTURAL ITERATION 9







This iteration focused on refining the structure and adding details to enhance its integrity and credibility. While the dimensions still need further adjustment, the overall system feels solid and functional for now. Next step will be to integrate the main building mass to fit the structure in more detail, while making tweaks to both structure and mass.

READ MORE ABOUT THE ITERATIVE DESIGN PROCESS IN THE APPENDIX

4.2. CONNECTING TO VIRTUAL REALITY

While developing interactive design tools with direct response in the form of generated geometry, the door to exploring design in virtual reality stands wide open. In a scenario where there is a real-time tool connected to a virtual reality environment where the user can explore, create and alter layouts in a three-dimensional, first-person perspective view, a new dimension of design is unlocked.

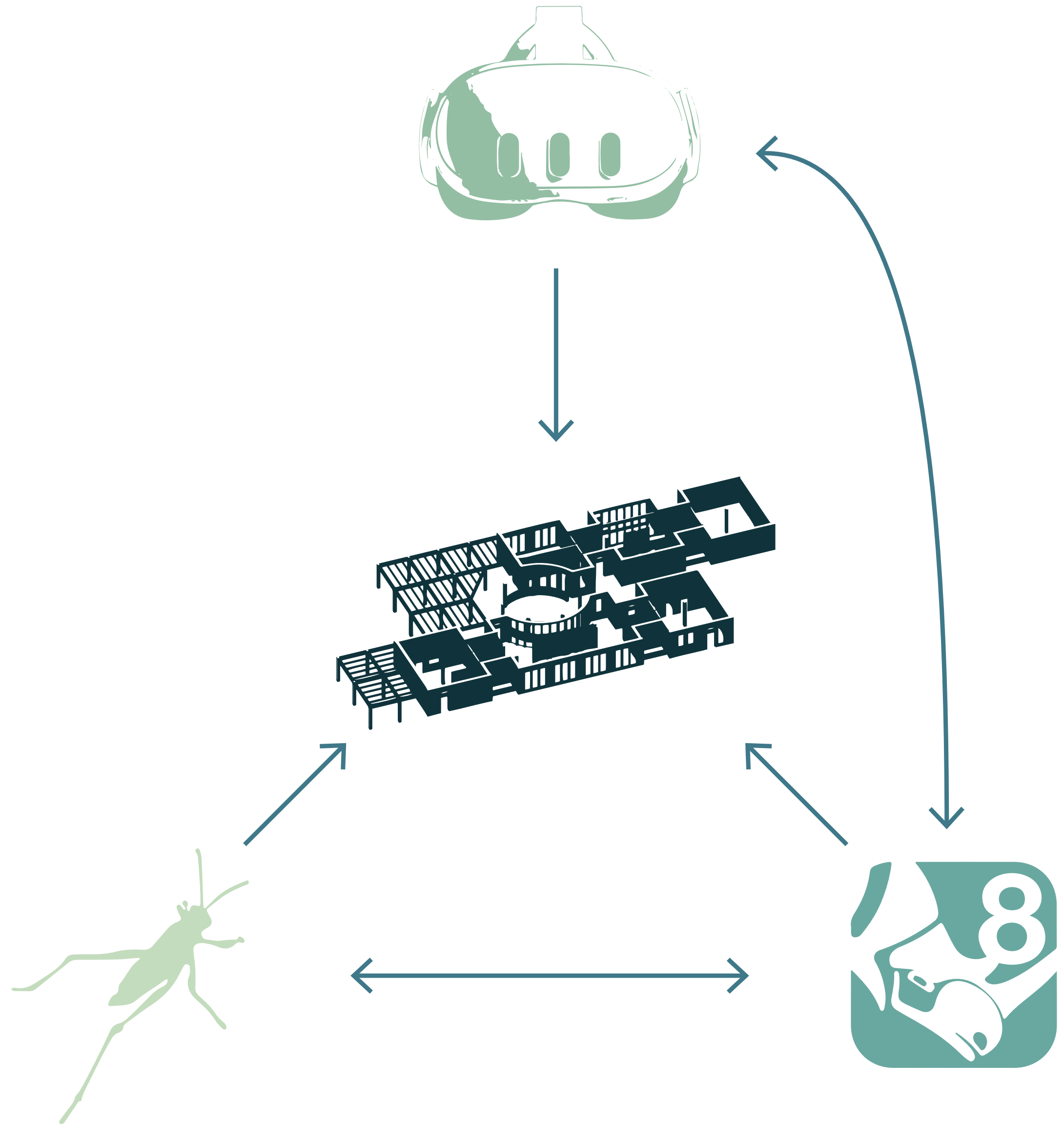
This could all be realized in, for example, the plan drawing script with an addition to generate the geometry from two- to three-dimensional space. Virtual reality is fairly unexplored in the Rhino and Grasshopper environment, but there is an existing VR/AR software called "Mindesk" enabling the user to hop into a Rhino three-dimensional environment via an extension-link to Mindesk.

Upon researching on how to connect this thesis with virtual reality tools, following workflows have been integrated:

INSTANT RESPONSE FEEDBACK WITH USER
- The developed parametric tools for geometry generation have been adapted and optimized for a virtual reality (VR) environment, enabling real-time interaction. By implementing instant push-and-purge functions, any modifications to the design are immediately reflected in the VR space. The workflow involves linking Rhino with TwinMotion, or other appropriate VR-software, which facilitates a walk-mode experience and VR integration. This approach allows users to provide instant feedback within the VR environment while the designer can make real-time adjustments using parametric tools. Additionally, TwinMotion allows the creation of an ambient setting to enhance user immersion and spatial perception.

By streamlining the design process, designers gain the ability to explore a wider range of options and strategies. More importantly, the time saved in development can be redirected toward a more in-depth evaluation of the design. This is where VR-based evaluation becomes particularly valuable, adding an extra dimension to the process by enabling immersive spatial analysis and real-time feedback.

DESIGNING IN A FIRST PERSON PERSPECTIVE
- Since TwinMotion does not support a two-way data exchange with Rhino, an alternative workflow is established using the Mindesk plugin. Mindesk allows designers to generate and manipulate geometry directly within Rhino's VR environment, enabling an immersive first-person perspective for design exploration. While this method does not offer the same environmental visualization capabilities as TwinMotion, it serves as a valuable tool for interactive, real-time design development rather than solely for evaluation purposes. The parametric tools are designed to optimize the user experience by allowing interaction through simple inputs, such as centerlines and center points. This approach allows the designer to investigate spatial proportions while being immersed in the VR-environment.



Virtual Reality workflow

HOW CAN PARAMETRIC TOOLS WITH SUPPORT FOR FIRST PERSON, IMMERSIVE VIRTUAL REALITY HELP EVALUATE A DESIGN PROPOSAL IN THE CONCEPT PHASE?

4.3. RAPID CONCEPT DEVELOPMENT

To demonstrate the potential and effectiveness of the entire streamlined workflow while exploring concepts for the design proposal, a series of concept developments was carried out. Each concept underwent an iterative process, progressing from an initial idea to fully developed conceptual drawings and models within a short timeframe.

As a challenge to the parametric tools, each concept was developed from scratch to a working design concept, complete with drawings and models, within less than a single day. This significantly accelerates a process that would typically require several days or even weeks, depending on the designer's workflow efficiency.

The resulting concepts were then integrated into the virtual reality workflow for evaluation. By assessing their spatial and qualitative aspects in a VR environment, these concepts may generate valuable insights and design ideas for the final project. Thus, rapid concept development becomes an integral part of the iterative design process, enhancing both efficiency and design exploration.

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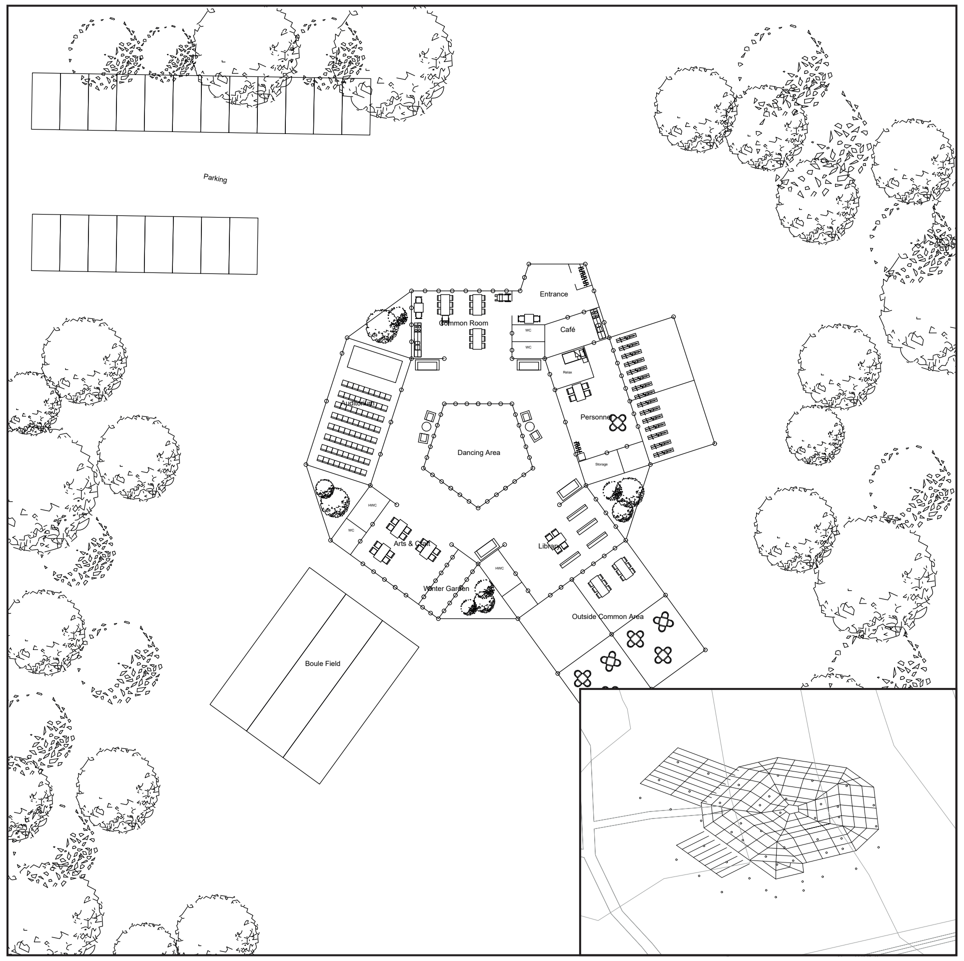

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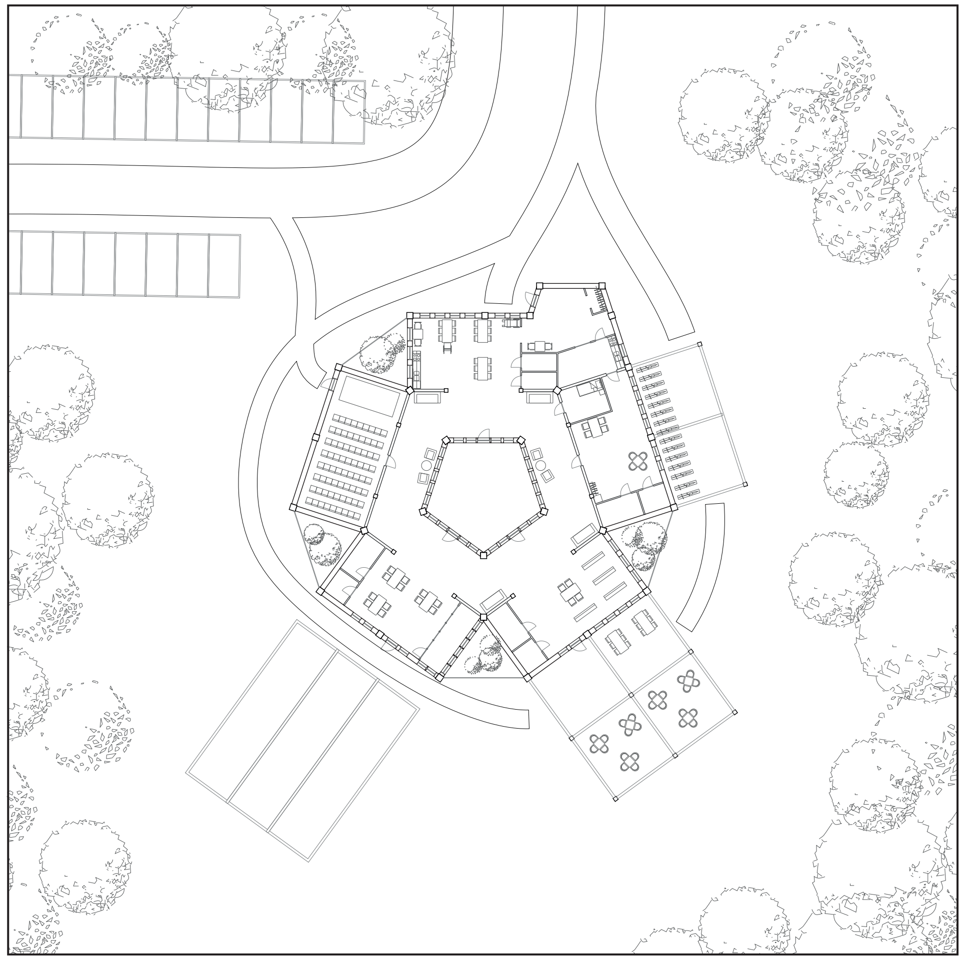

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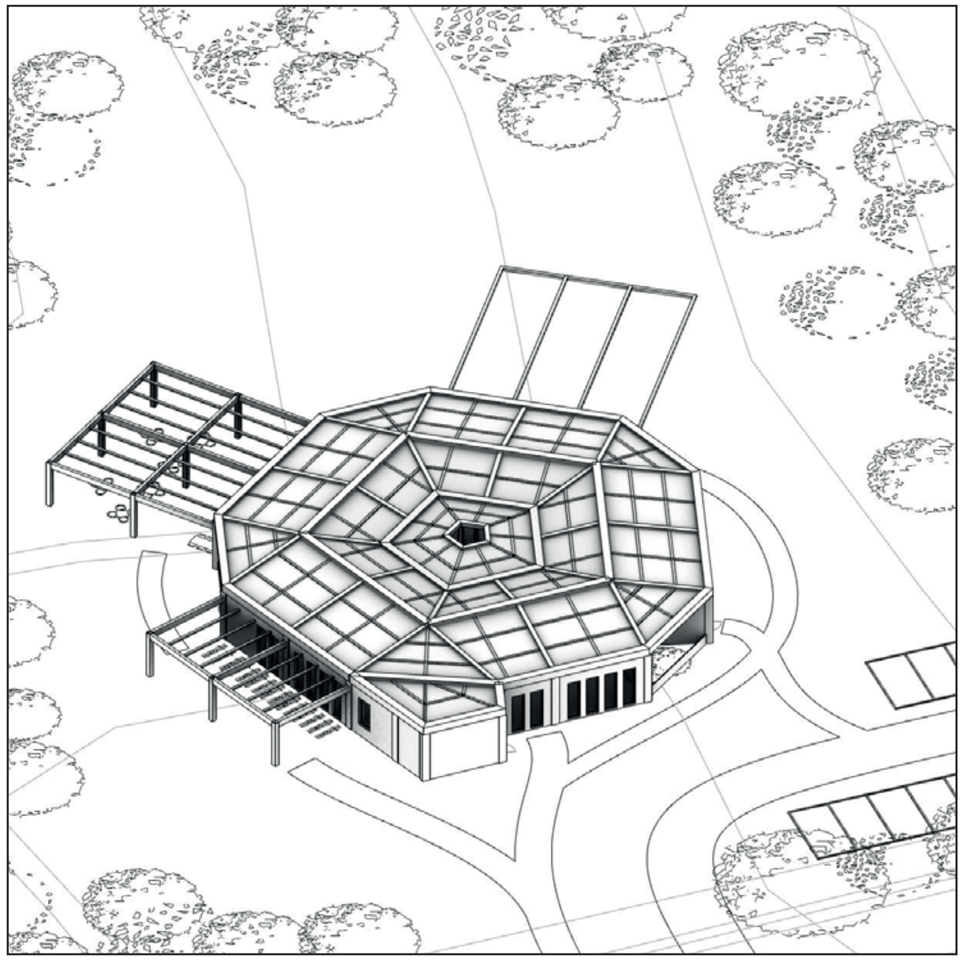

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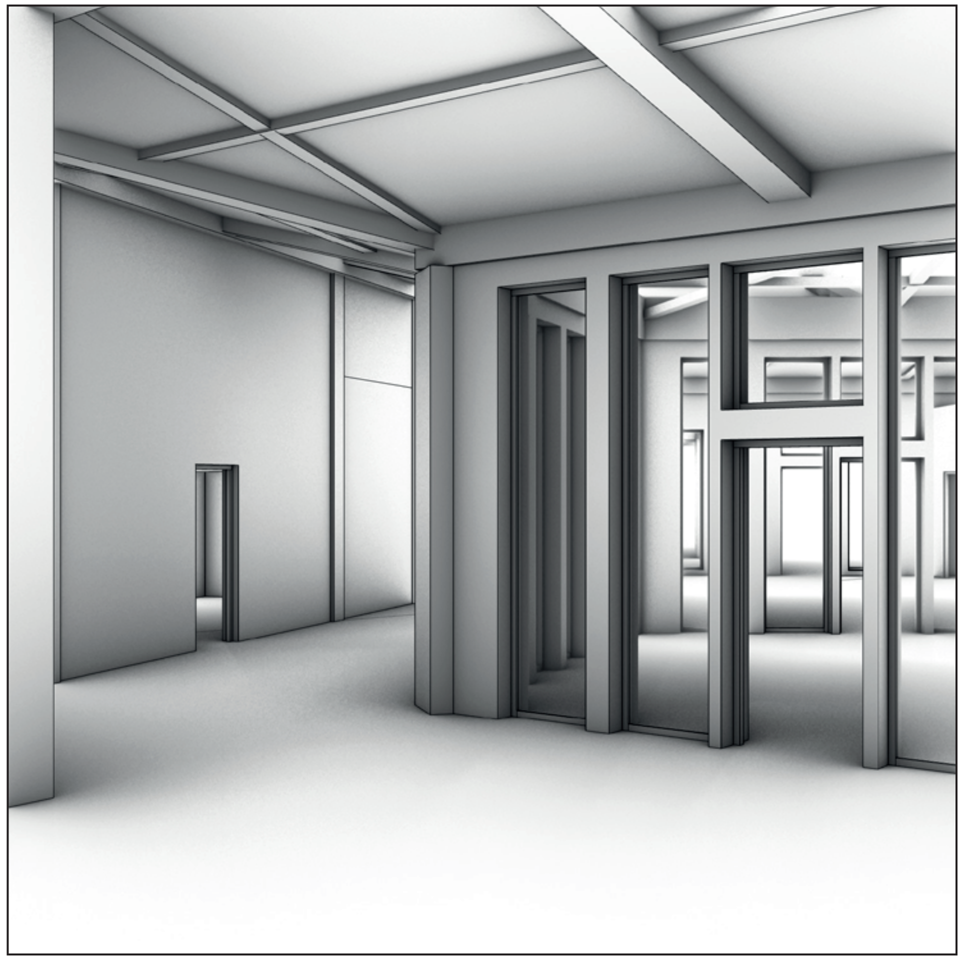

PERSPECTIVE

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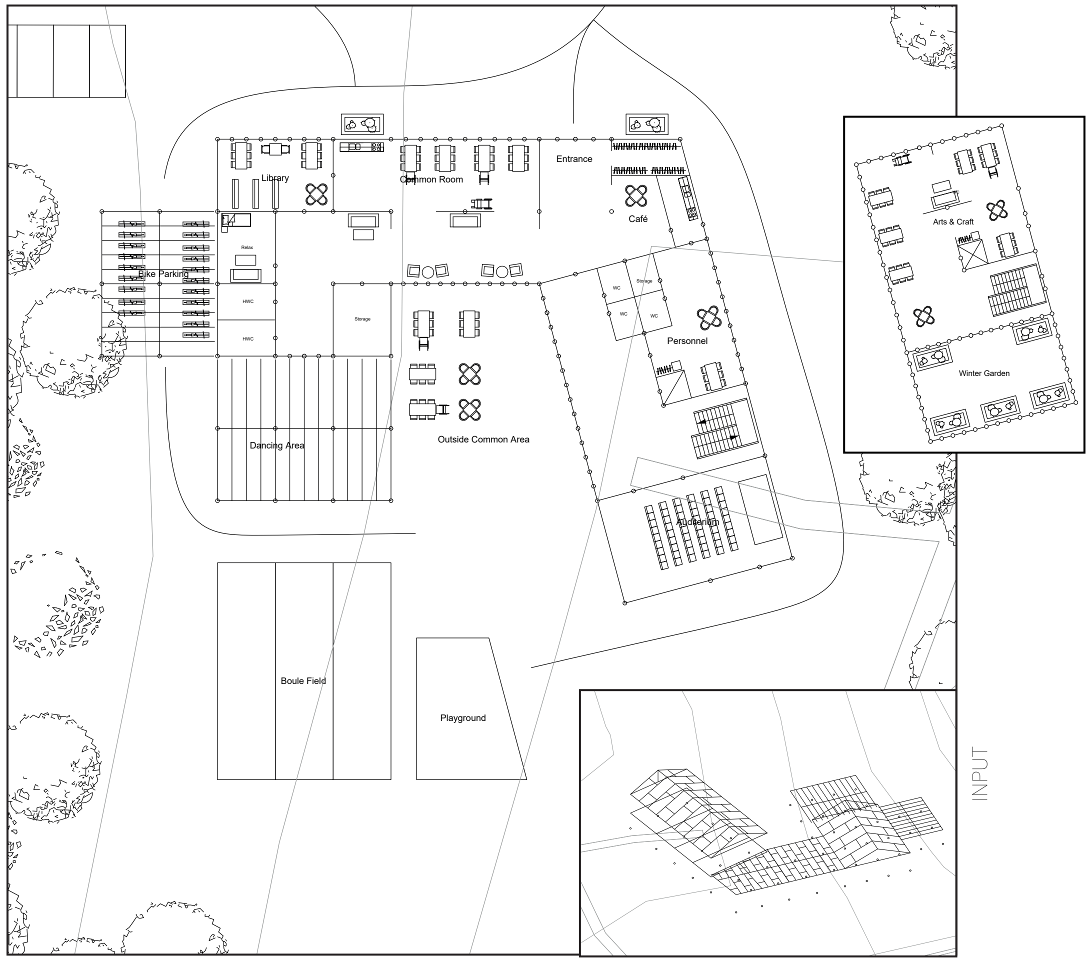

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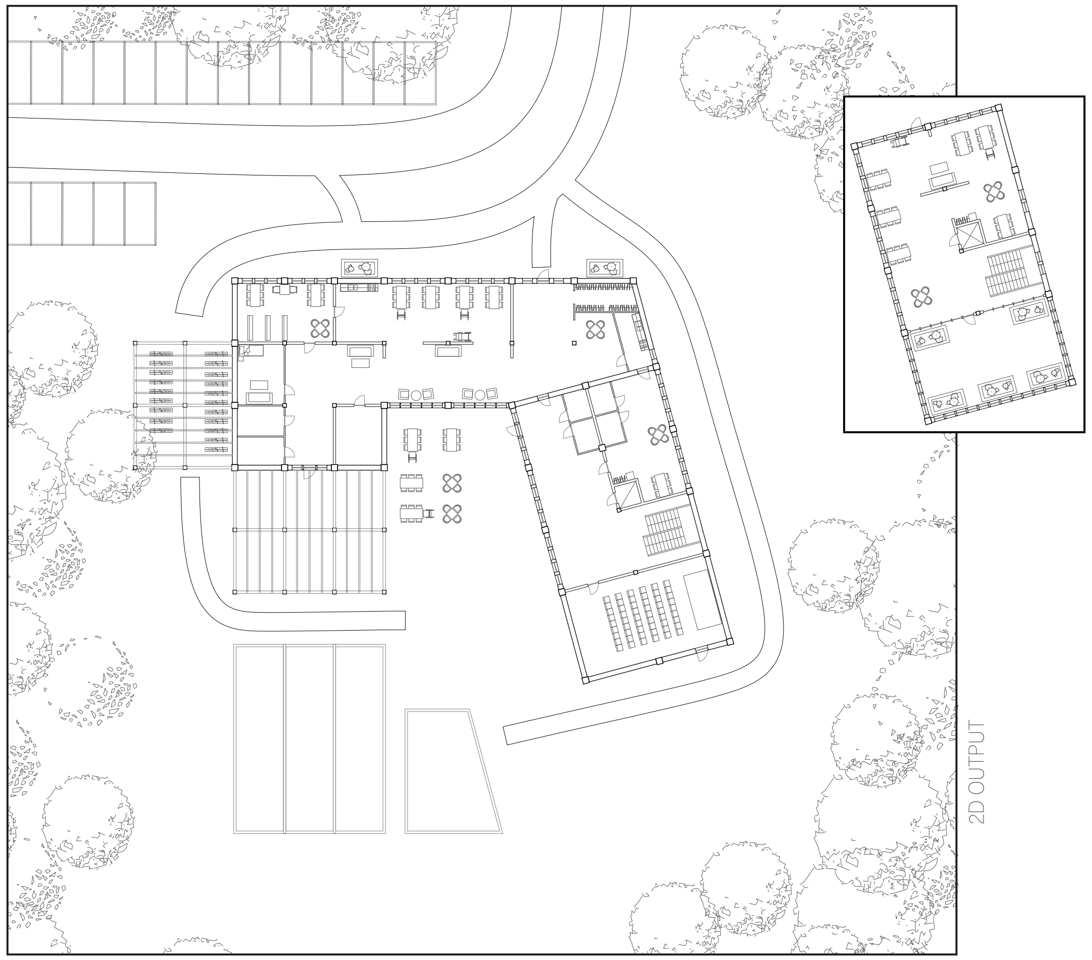

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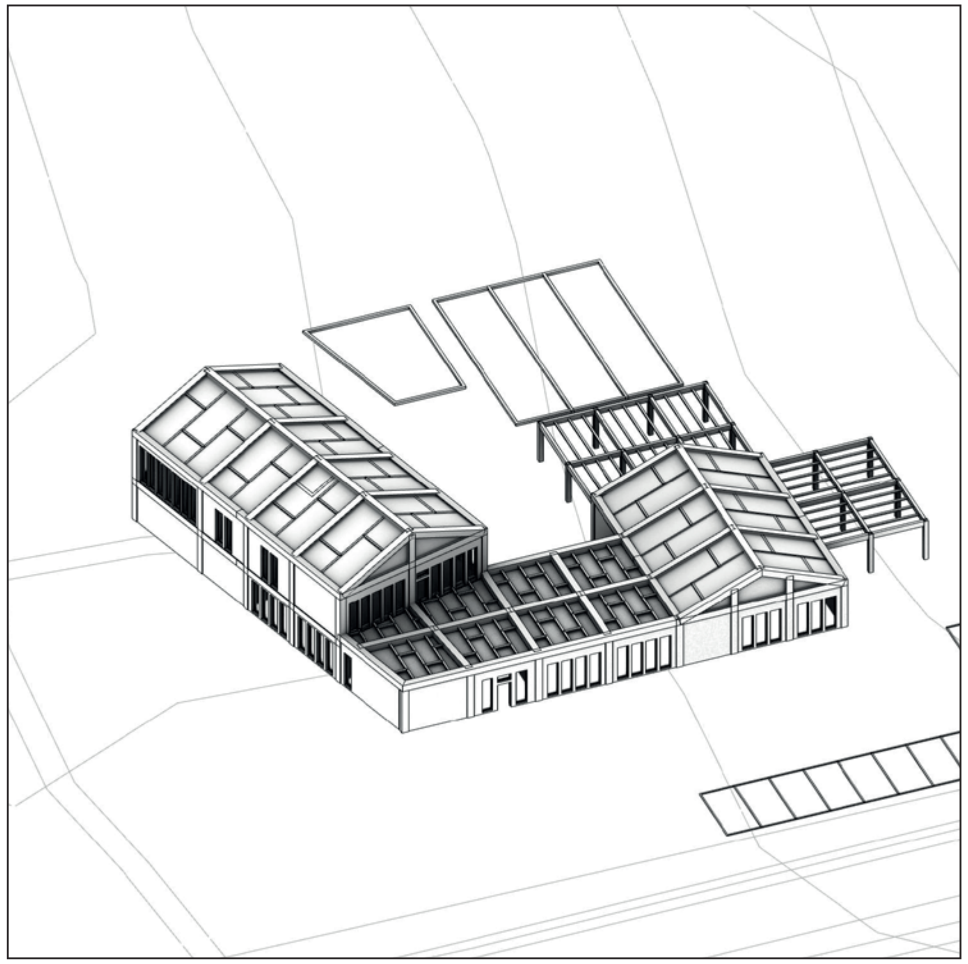

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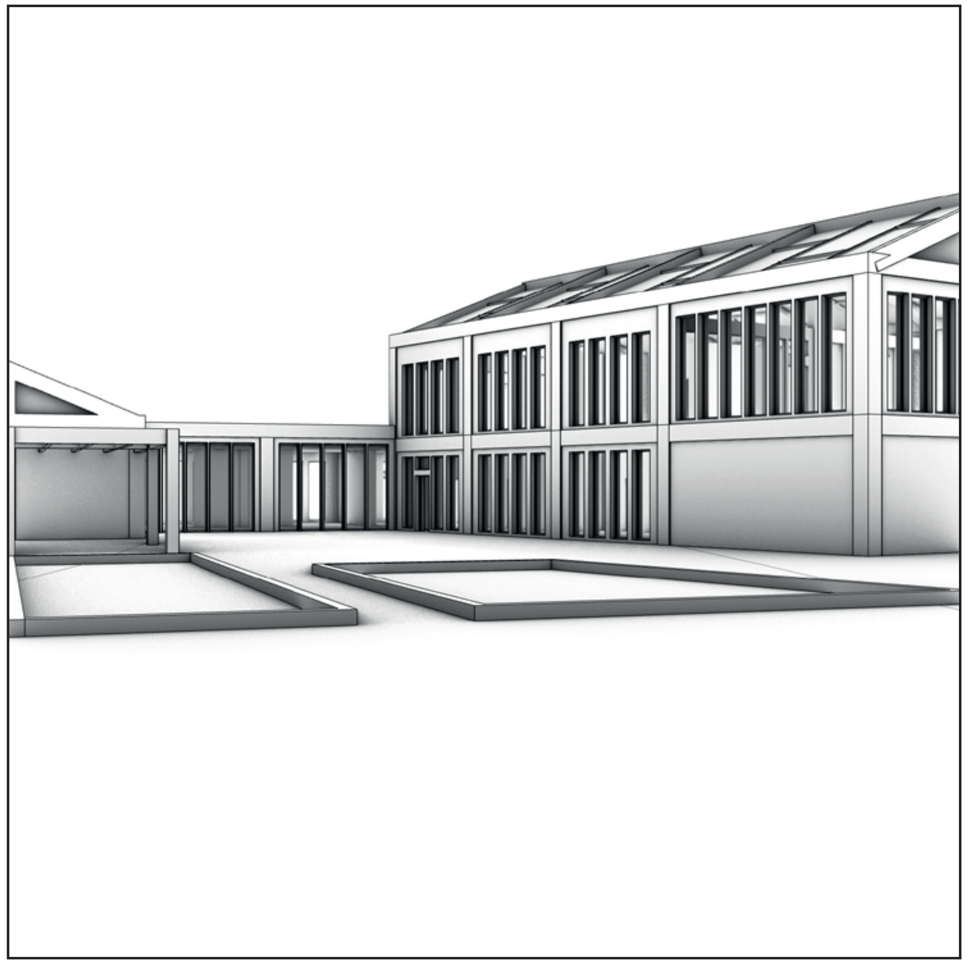

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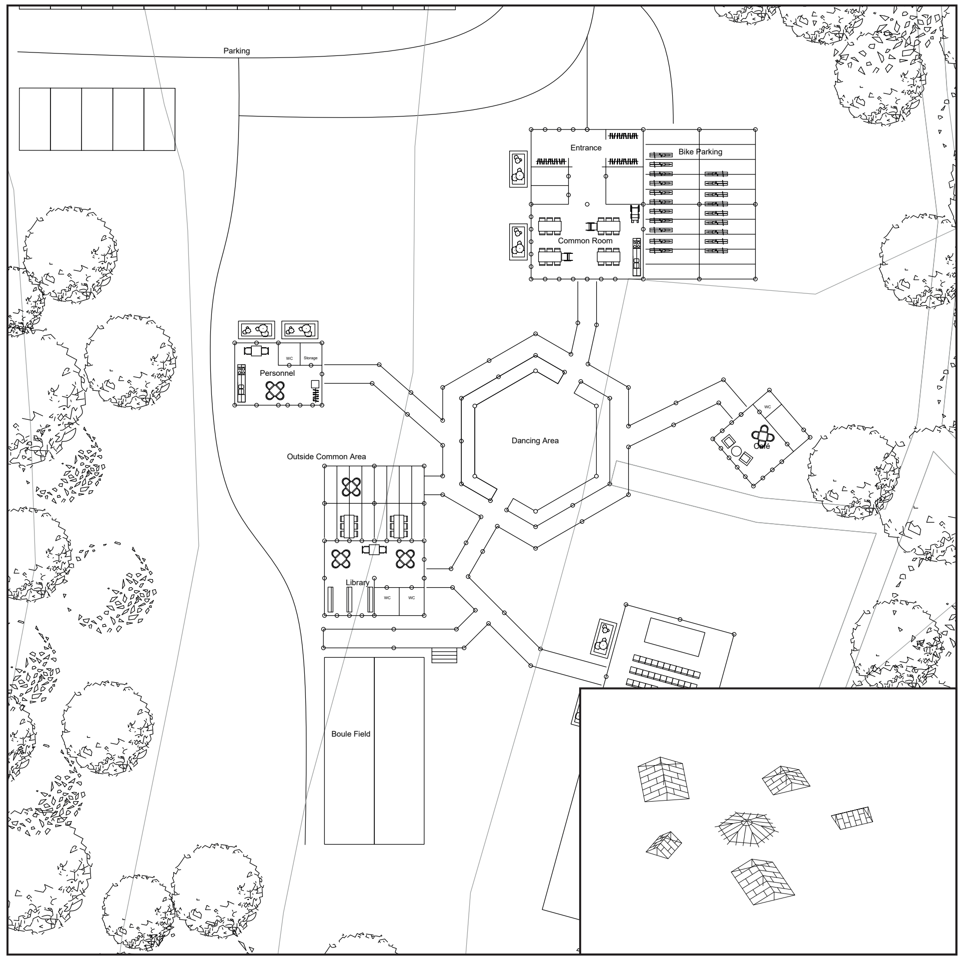

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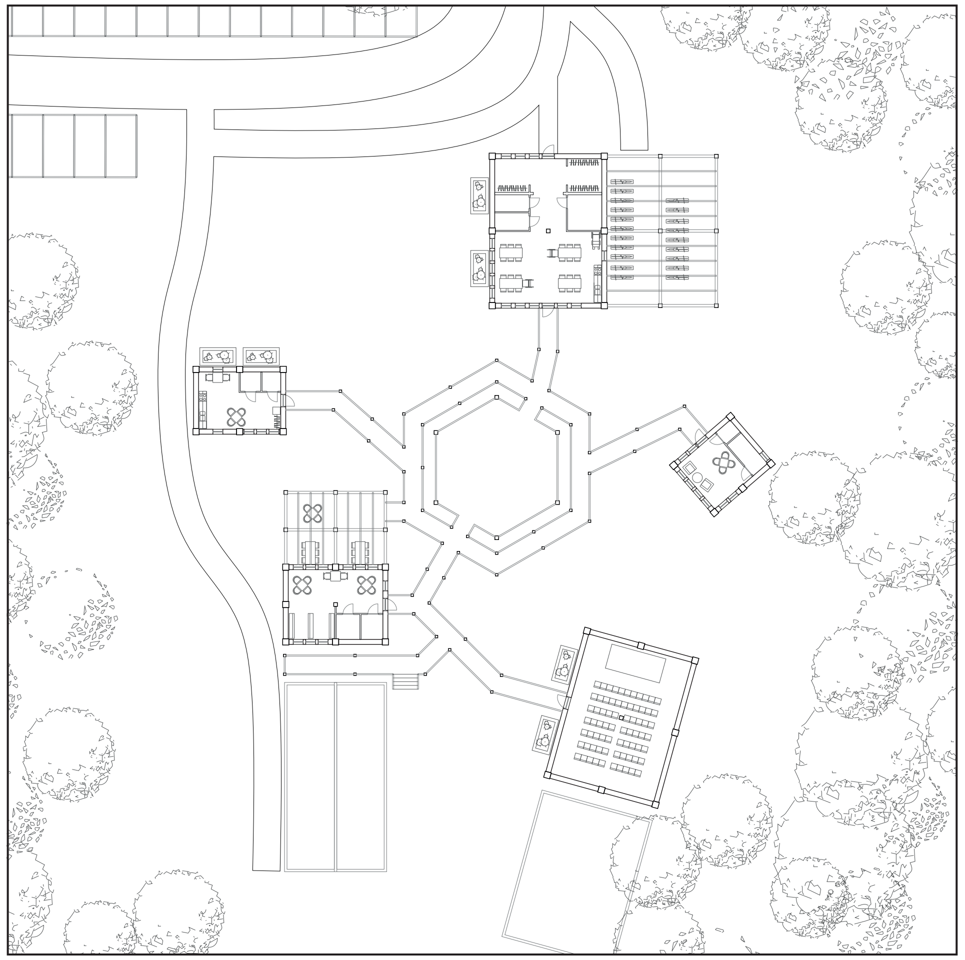

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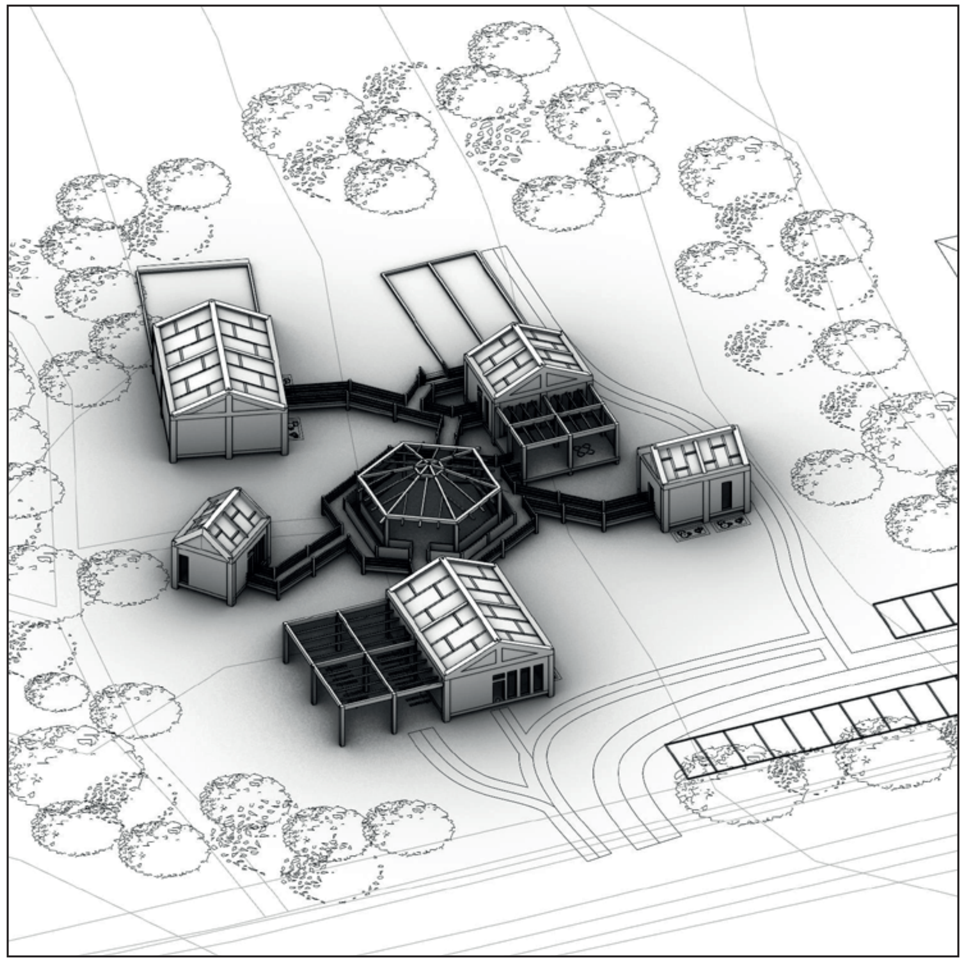

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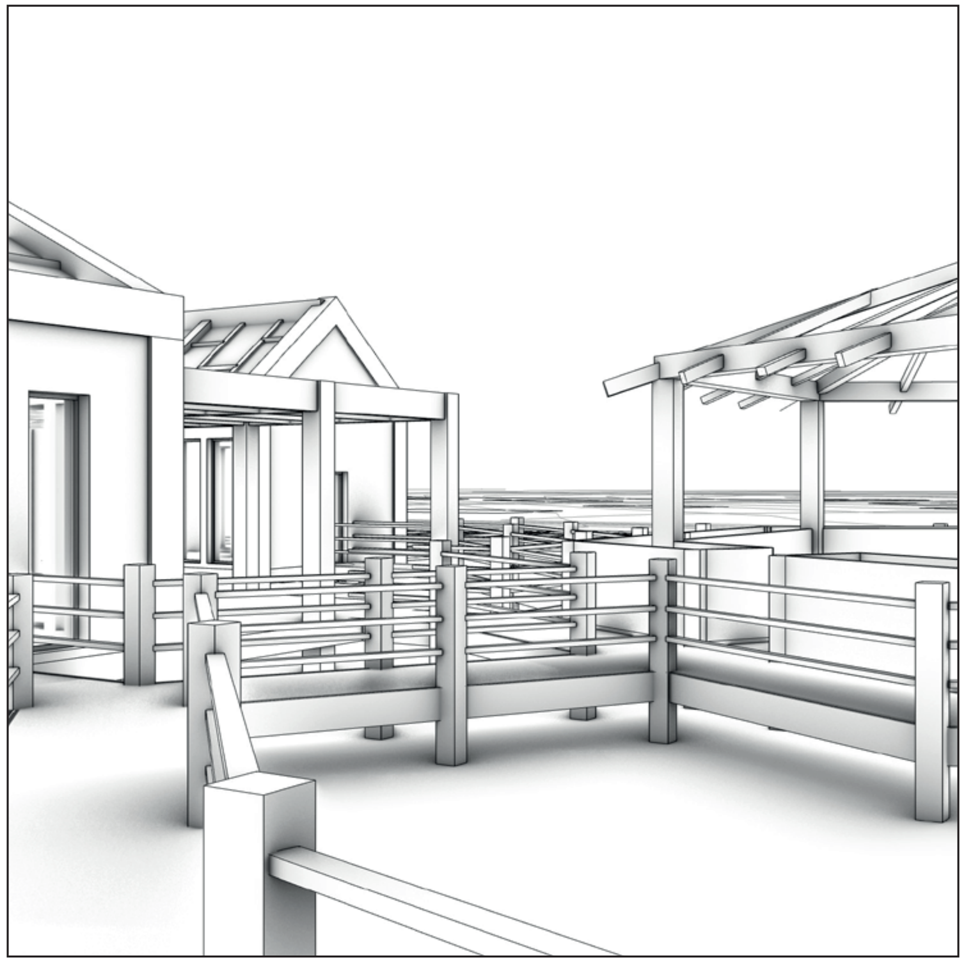

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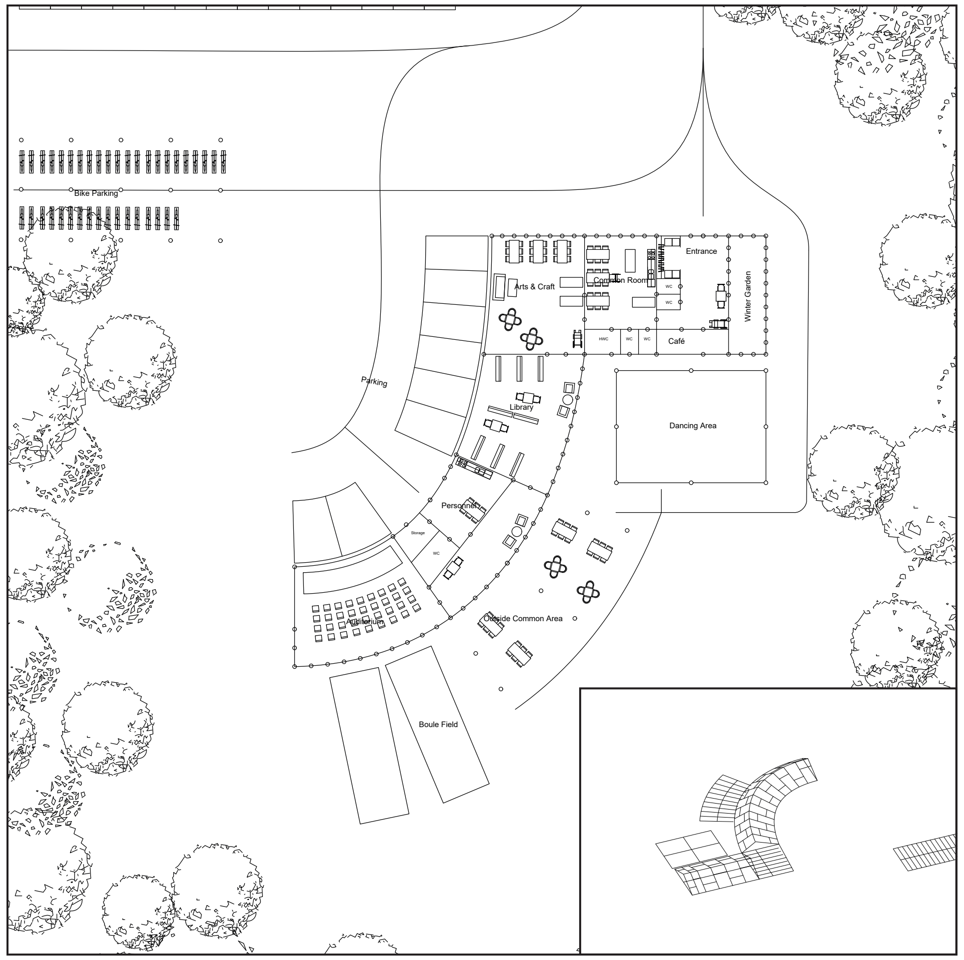

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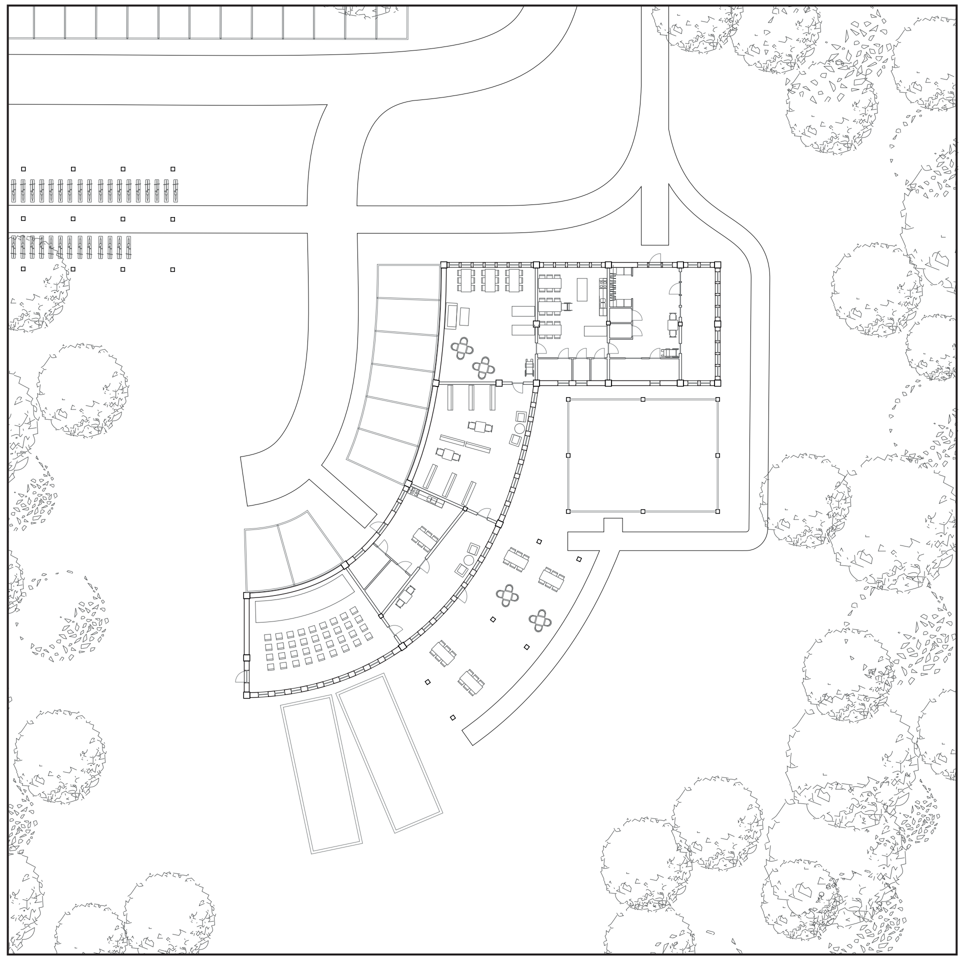

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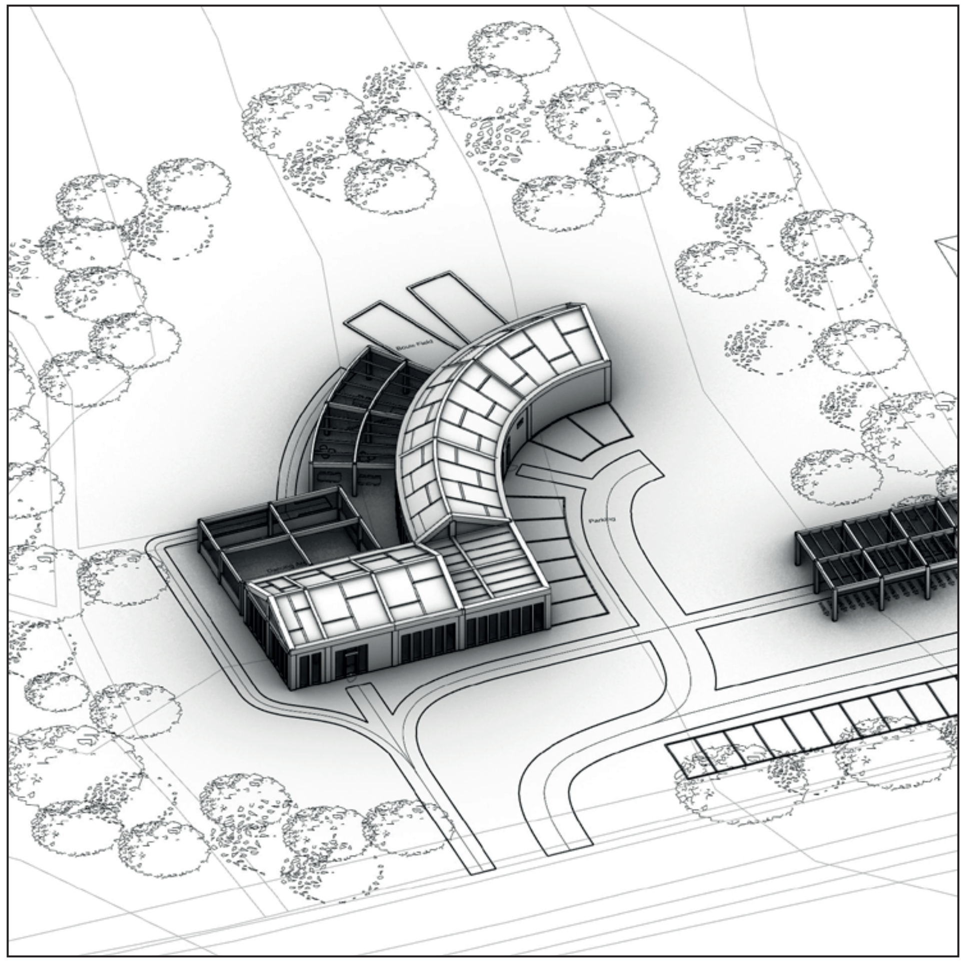

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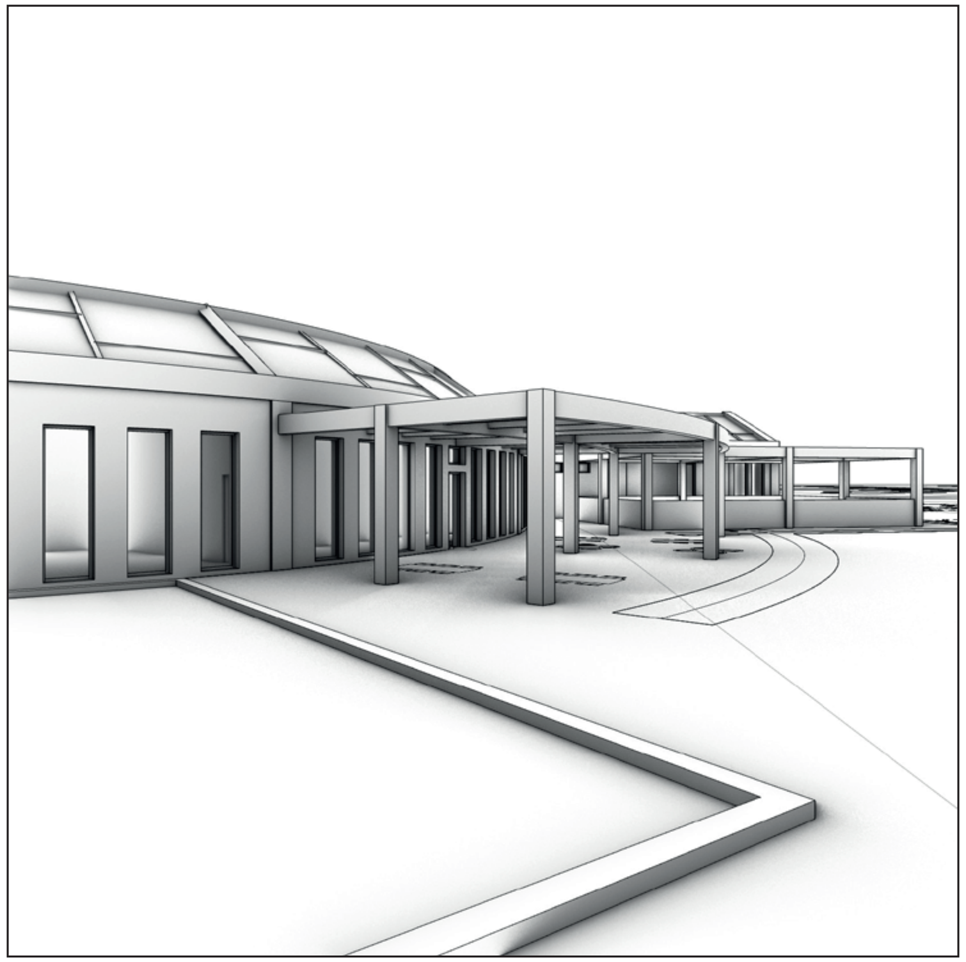

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TAKEAWAYS

After experiencing and evaluating the different concepts in virtual reality, a few things became apparent. The most crucial realization was how different spatial proportions look in a first person perspective compared to what one would expect on a screen. The room proportions appeared way bigger while openings like windows and doors appeared smaller than on the computer. In this context, it can be argued that by using immersive virtual reality to evaluate the concept of choice, designers can more accurately understand how their developed concept can support the watns and needs of the client.

On a technical side, the grasshopper script linked to TwinMotion, through Rhinio, allowed for real time changes and feedback updates to the geometry. This two-way feedback chain proved to be extremely useful while the recipient was experiencing the project in the VR-environment.

VR SETUP

VR EVALUATION

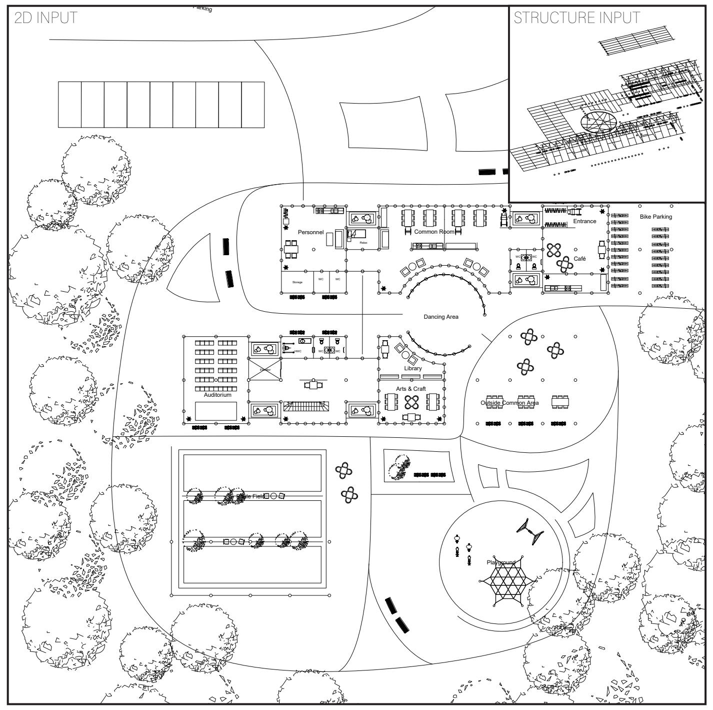
LIVE ADJUSTMENT FROM RHINO TO VR ENVIRONMENT

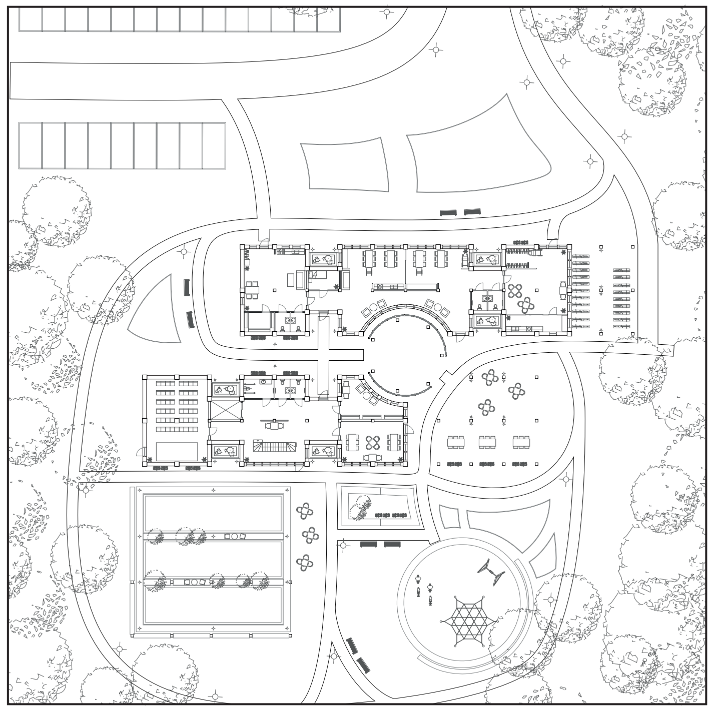
4.4. LANDING POINT

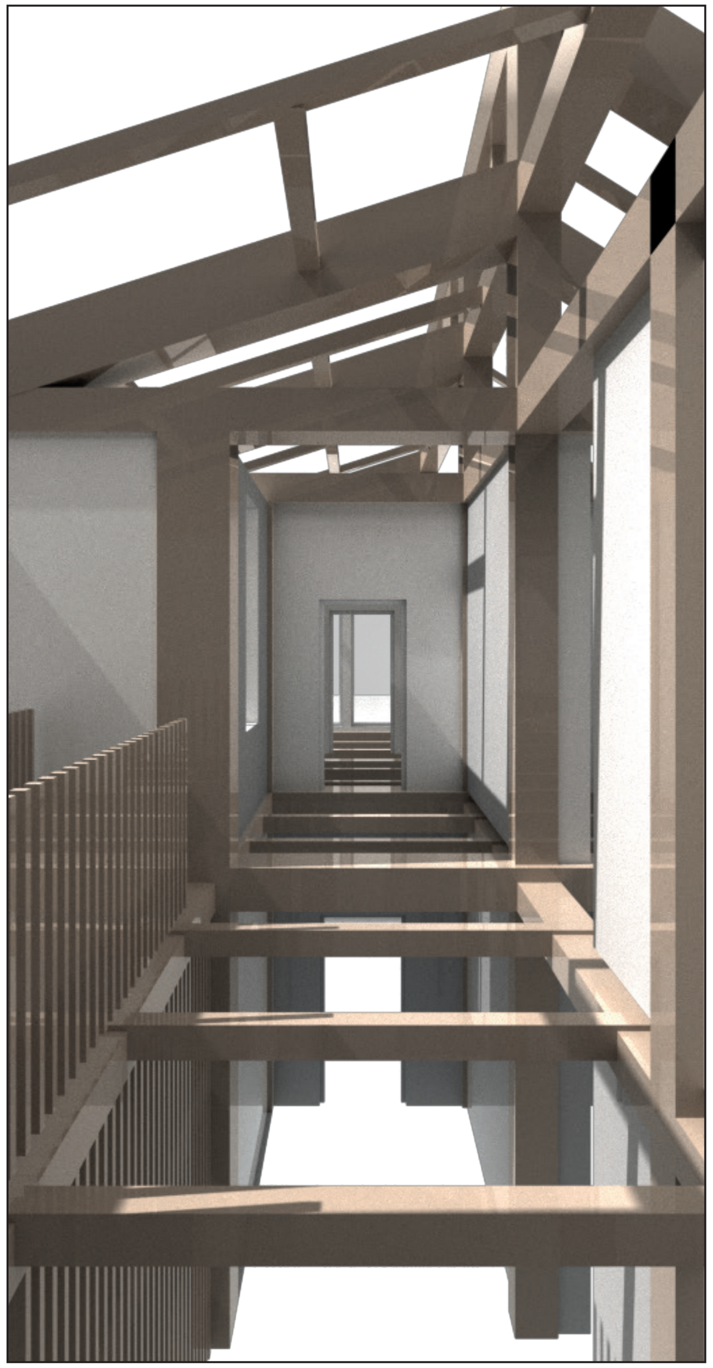
Since the modelling tools, plan drawing, concept modelling and structural modelling are intended and designed to be used as conceptual tools, there's a limit to the level of detail they can achieve before it gets too case-specific. Hence, the material displayed here serves as an example of the level of resolution to the concept development using these tools. 100% of the geometry displayed to the right, and below, were generated entirely by the algorithms responding dynamically to the user input.

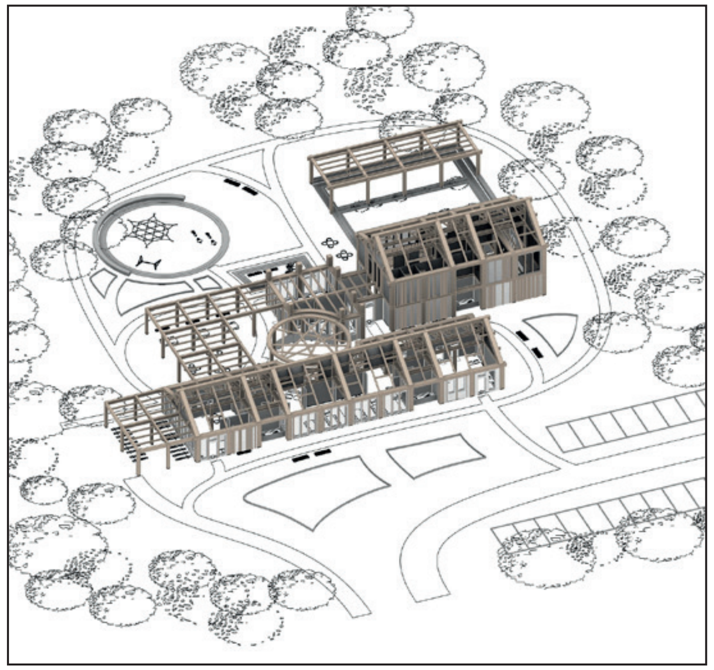
As the design proposal progresses, detailing will be done both manually and parametrically. However, this phase will not be integrated in any developed tool, as it requires a case-specific approach. Instead, the project is further developed to showcase how rapid concept development allocates a significant amount of time for enhanced level of detailing in the aftermath.

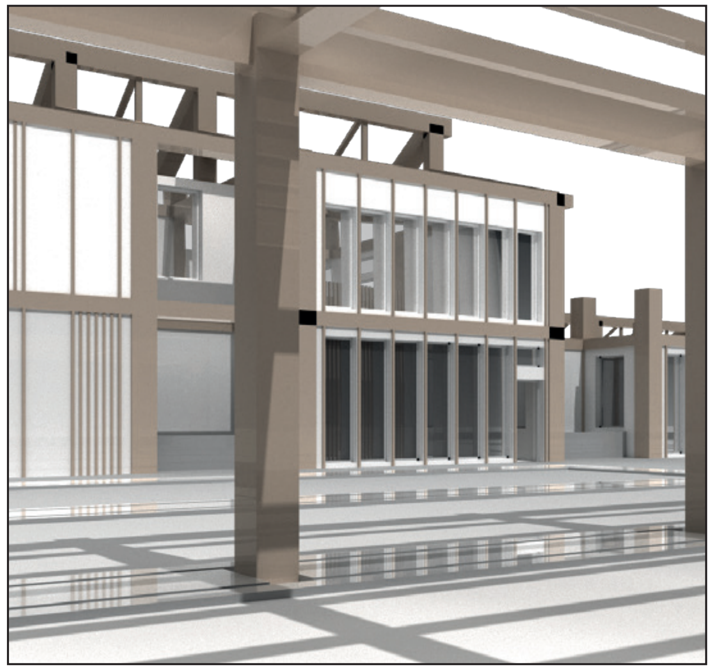
The visualization tools, namely the 2D-output of the plan drawing tool and the section- and façade generation tools, will continue to lay the linework foundation of the visual representations throughout the project.



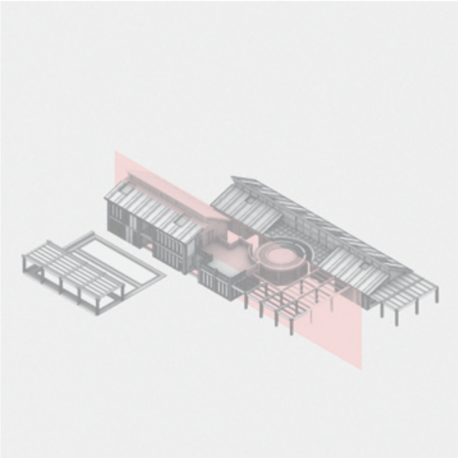




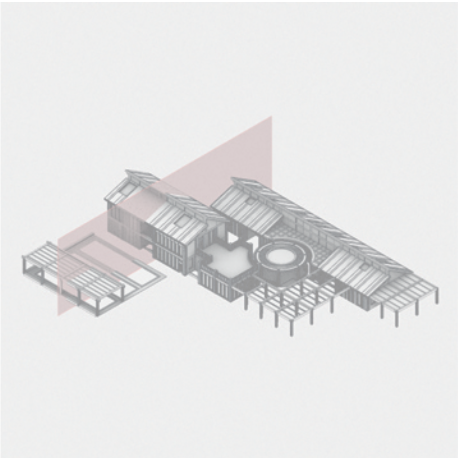




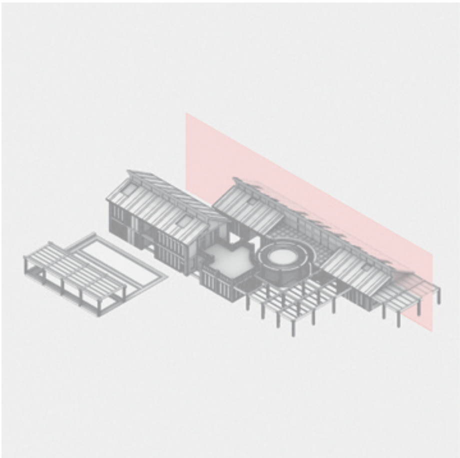
Algorithmic output

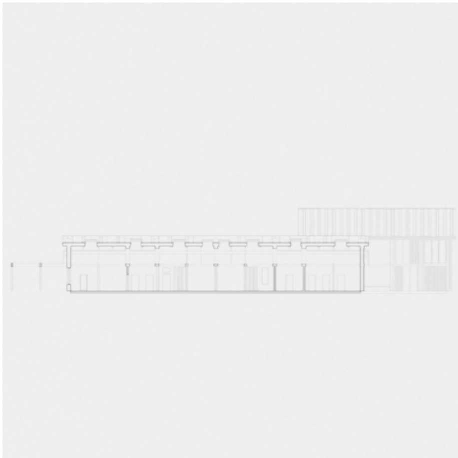

Section A Generation Input

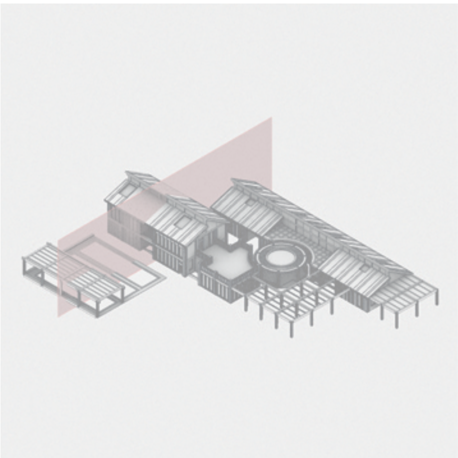

Section A Generation Output


Section B Generation Input


Section B Generation Output

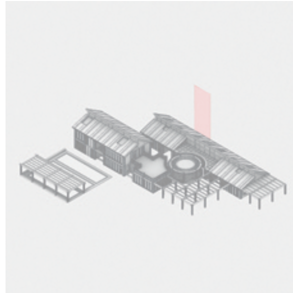

Section C Generation Input


Section C Generation Output

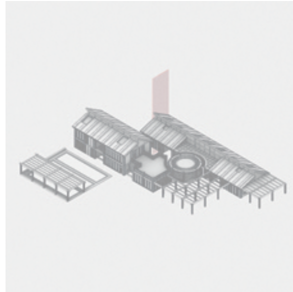

Section D Generation Input


Section D Generation Output

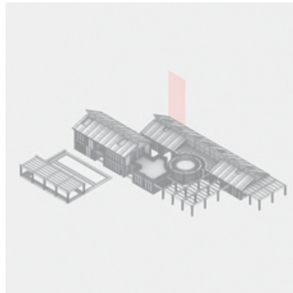
Algorithmic generated section drawings


North Facade Generation Input

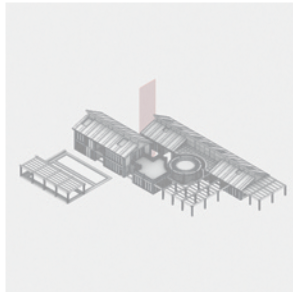

North Facade Generation Output


West Facade Generation Input

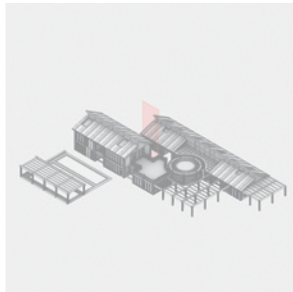

West Facade Generation Output


North Facade Generation Input

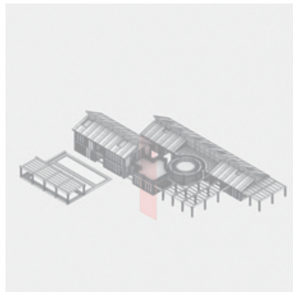

North Facade Generation Output


West Facade Generation Input


West Facade Generation Output


South Facade Generation Input


South Facade Generation Output


South Facade Generation Input


South Facade Generation Output

Algorithmic generated facade drawings

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4.5. DETAILING PHASE - BENEFITING FROM EFFECTIVE WORKFLOWS

Moving forward with the design proposal, a higher level of detailing will be in the center of the focus. By working with effective strategies and tools in the concept workflow, we can allocate a significant amount of more time into detailing. The aim of providing a high level of detailing into a project proposition is to give the viewer that "wow-effect", leaving them to wonder how the designer had time to put their focus into the details.

This might be appropriately related to Baroque architecture in the late 16th and 17th century, and its effect of awing the spectator with its grand architectural statement. Baroque architecture is known for its spectacular rich detailing, size, focus on lighting and dynamic forms (National Gallery of Art, n.d.). This made contemporary buildings look and feel minimal compared to the new style of architecture, in the forms of magnificent churches, palaces, fountains etc. often commissioned by the Catholic Church's counter-reformation to the Protestant Reformation (Triumph of the Baroque, n.d.).

The style and level of detail and richness from the Baroque era might not be plausible in today's architecture. Baroque architects and artists had completely different conditions for achieving this level of richness, mostly in the time-space and economic support from the Catholic Church opposed to today's stride for functionality, economic and sustainable building. However, other types of details in the form of realistic representations in a design proposal can achieve the same awe-effect in the eye of the observer, especially in the time frame normally provided for students and/or competition briefs. With a workflow supported by computational tools and automated repetitive tasks, the concept models can serve as a foundation for further detailing where the designer can provide a rich representation and achieve this said effect.

There are many ways to design and propose a building design. The proposal in this thesis serves as an example of how computational tools can aid a design built with conventional, vernacular building elements. Three-dimensional geometry generating tools developed in this thesis might not serve the same purpose in more organic shaped architecture, flowy shapes that people might associate with the word "parametric design".

Figure 4: Landmark building with water reflection.
Note. From D. Geib, Konst, landmärke, vatten, byggnad [Photograph], 2019. Pexels.

Figure 5: White and brown concrete building.
Note. From D. Gregušová, Vit och brun betongbyggnad [Photograph], 2020. Pexels.

Figure 6: City landmark and building.
Note. From T. Robertson, Stad, konst, landmärke, byggnad [Photograph], 2021. Pexels.

Figure 7: Chicago architecture with historical dome.
Note. From M. Suat Gunerli, Chicago arkitektur med historisk kupol [Photograph], 2022. Pexels.

Figure 8: Baroque interior with intricate ceiling details.
Note. From E. Astakhova, Konstnärlig design av interiören av en byggnad [Photograph], 2019. Pexels.

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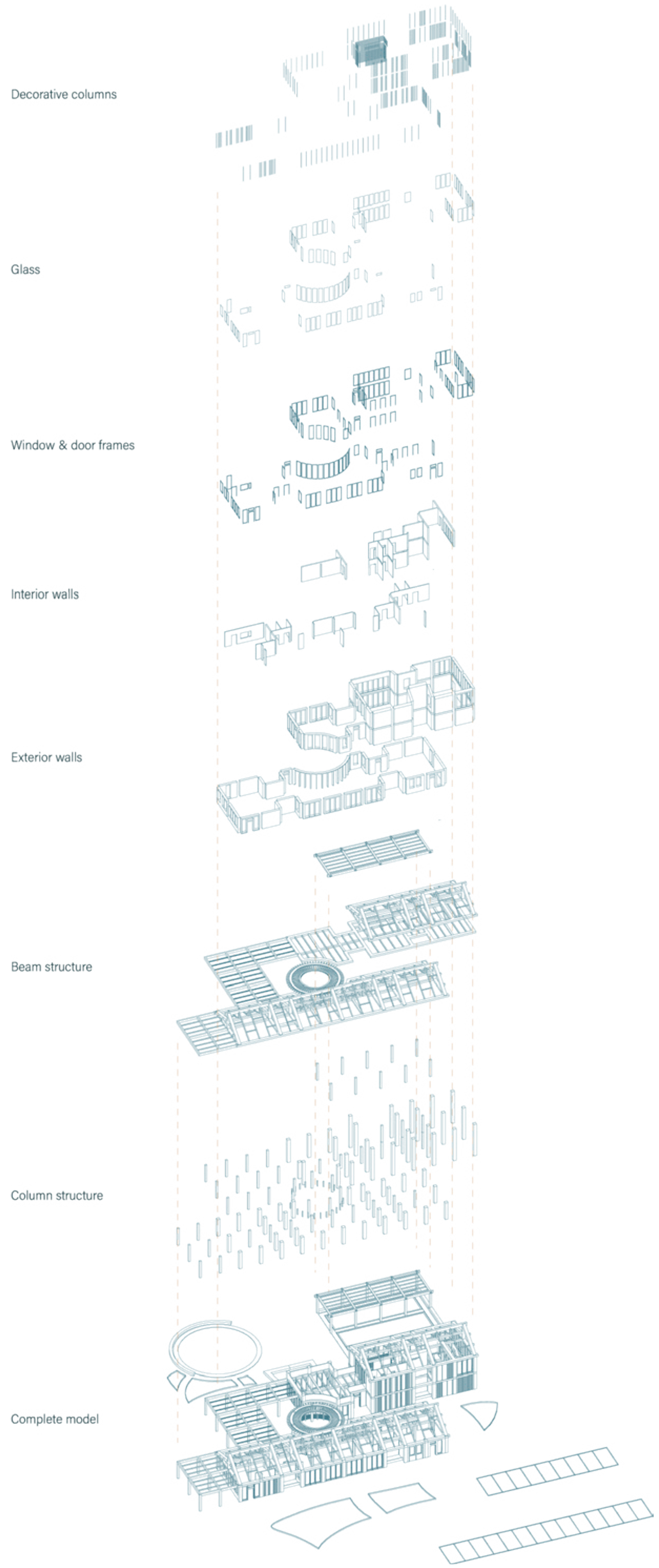
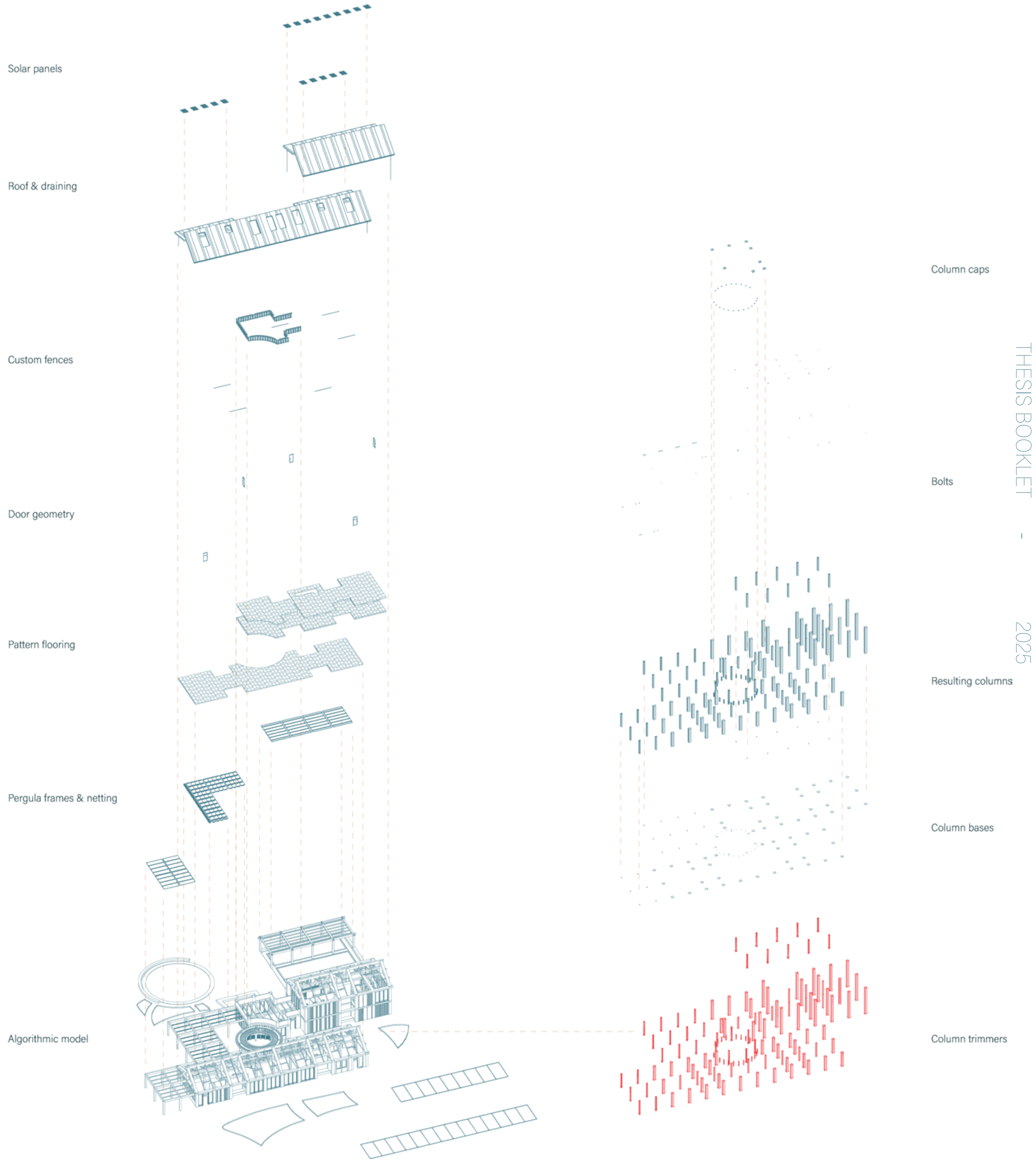


Algorithmic output



Detailed additions

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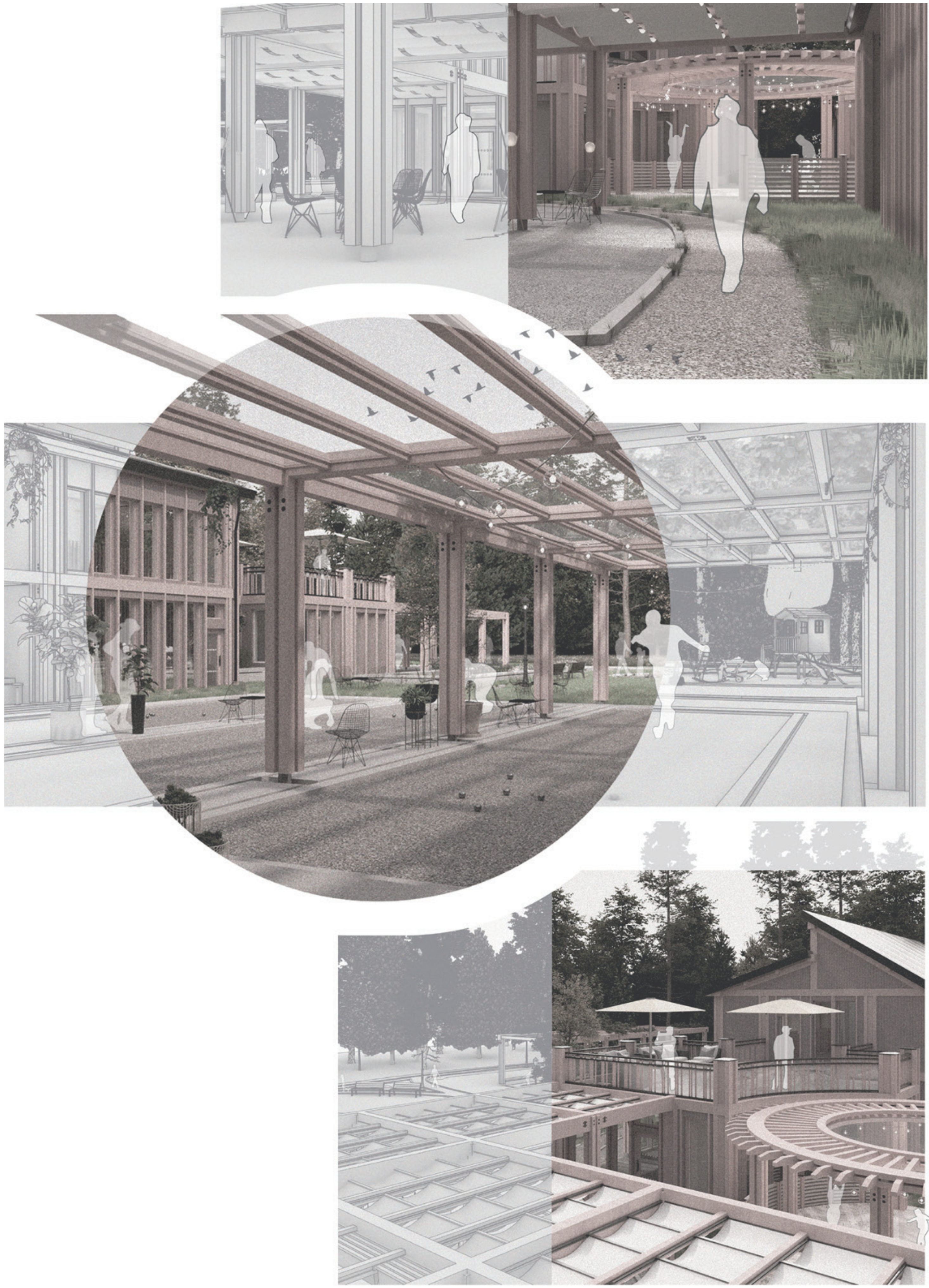
4.6. FINISHED PRODUCT

Valloxen Leisure Centre is named after the nearby lake Valloxen, a key local attraction in the area known for its popular bathing area on the other side of the small forest. The facility aims to reactivate the forest grove, previously home to a boule field which was popular amongst the elder generation of Knivsta before the rapid growth of the village. Here, the seniors can meet, socialize and engage in physical activities such as boule and dancing. Valloxen Leisure Centre, envisioned to be a centralized area with spaces for activity and connection, becomes a meaningful and familiar place for seniors, especially those at risk of isolation.

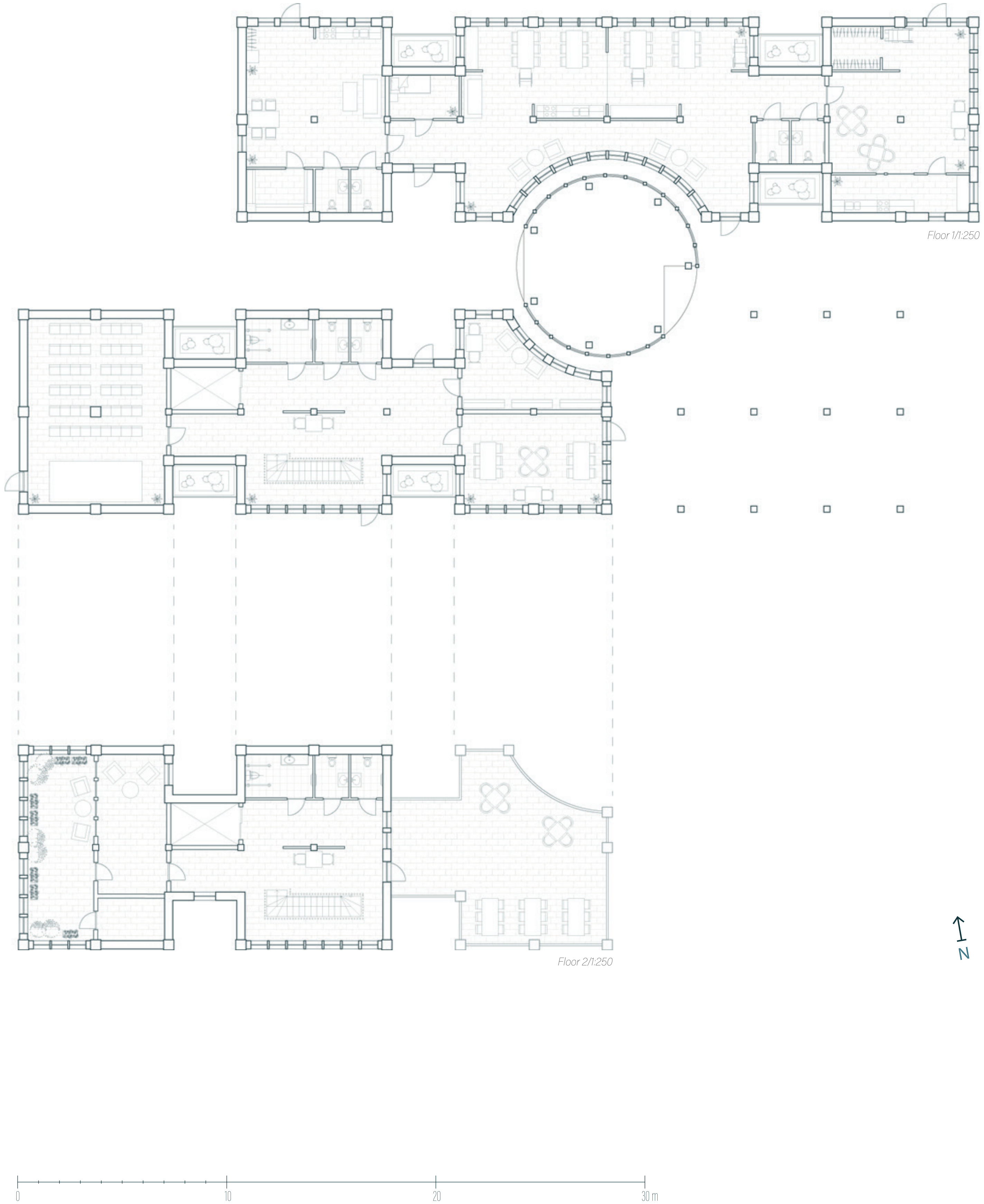
The proposal is constructed almost entirely in a red tinted timber externaly with a green tinted interior to convey a sustainable and vibrant expression, while giving a visual contrasting impression to the green forest surrounding the site. Based on a grid layout with a structural column-beam system, it ensures spaces to be flexible, enabling future reconstruction if necessary. The facades are enriched with high, narrow windows to let in as much natural light as possible. The gable-roof profile is designed to enhance light intake from the south side through elevated windows, creating a bright interior atmosphere.

The program includes boule courts, a dance hall, a café, and an auditorium, along with spaces for rest and reflection such as a winter garden, library, arts and crafts, and relaxation rooms. Flexible common rooms for gatherings both inside and outside can adapt to different social activities and needs. Additionally, a small playground is situated on the south side of the site, offering a space for children who may accompany their grandparents while parents are at work.



Exterior perspectives

Site plan/1:500



Floor 1/1:250

Floor 2/1:250

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South Facade/1:100


South Facade/1:100


South Facade/1:100


North Facade/1:100


North Facade/1:100

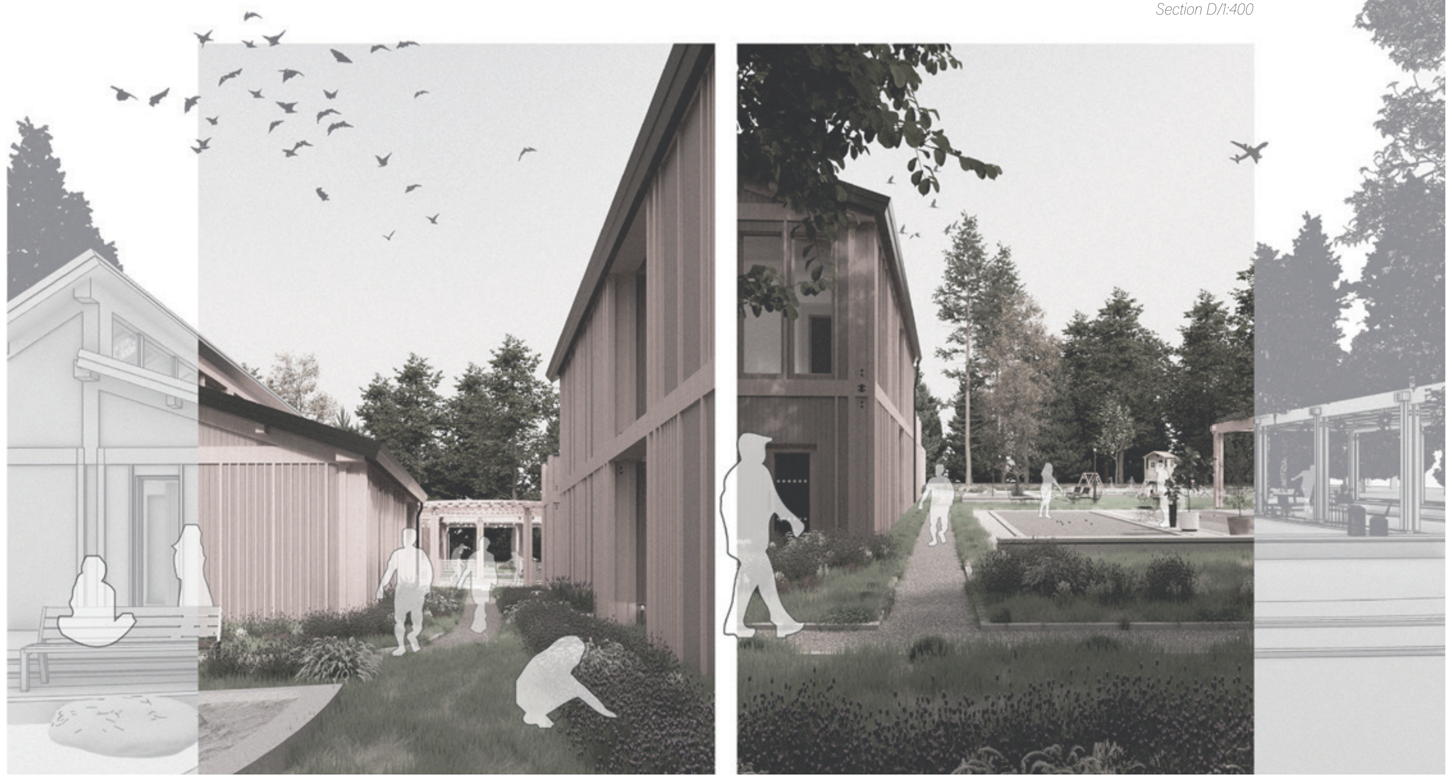

North Facade/1:100

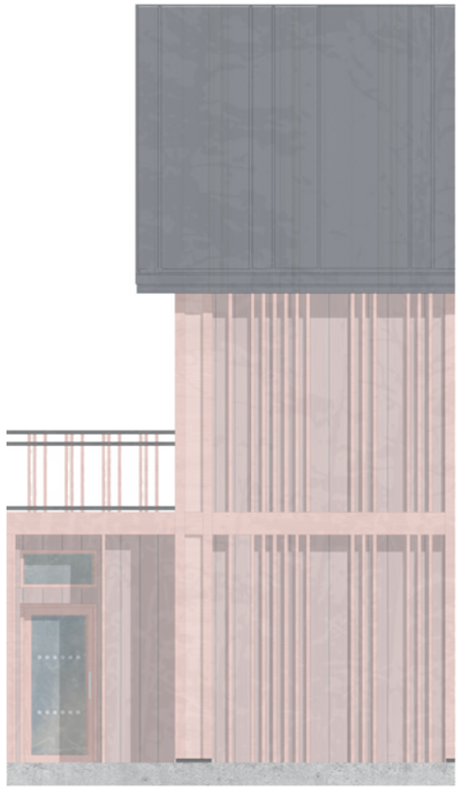

Section A/1:400

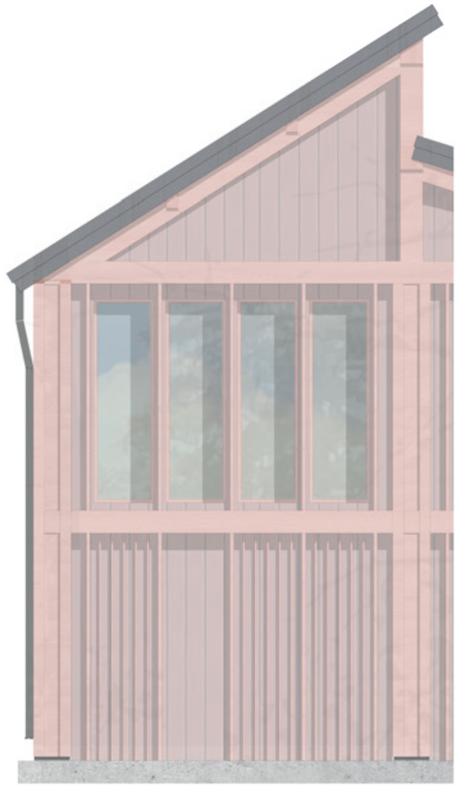

Section B/1:400

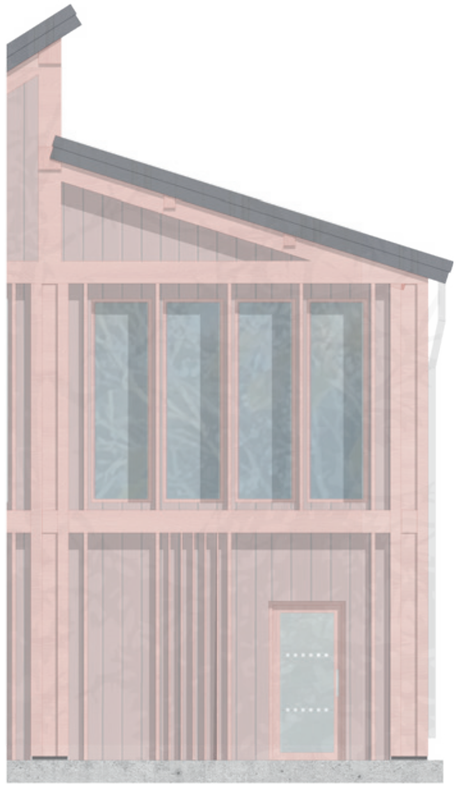

Section C/1:400


Section D/1:400

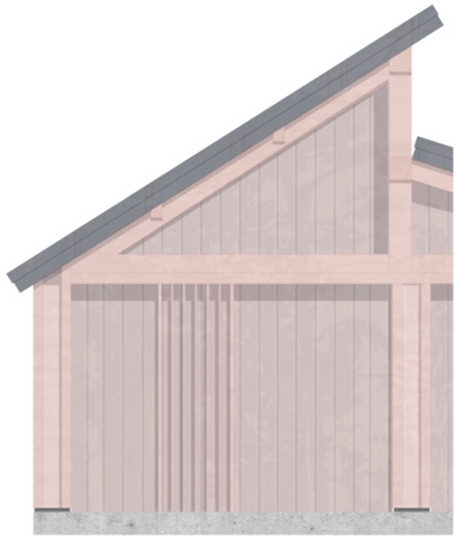

Exteriror perspectives

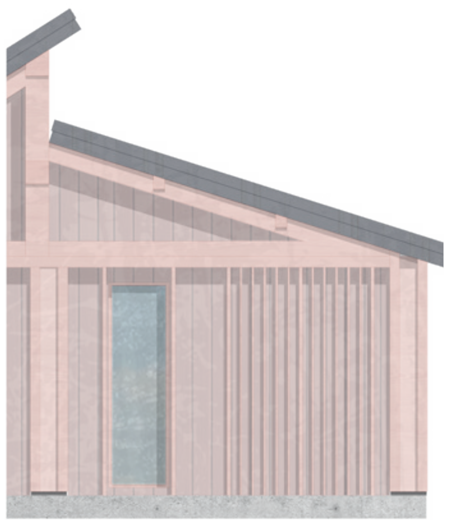

North Facade/1:100


West Facade/1:100


West Facade/1:100


South Facade/1:100


West Facade/1:100


West Facade/1:100


Interior perspectives

5. DISCUSSION

This thesis focused on how computational design tools could improve workflows, especially in early-stage architectural projects. The tools were specifically designed to be used by architects no matter how much computational expertise they might have. Evaluation and testing of the proposed workflow, during the development of Valloxen Leisure Centre, suggest that it significantly improved design efficiency. Similar to the tools developed by Parametric Solutions for generating and evaluating early-stage urban design proposals (Parametric Solutions AB, 2024), the parametric implementations in this thesis reduced time spent on repetitive tasks by automating them. Geometry generation tasks—such as plan drawings, high-resolution concept models, and structural modelling—became instant feedback, responding visually to the designer's decisions. Similarly, visualization processes like façade- and section drawings were automated and computed within seconds or minutes. These tasks could normally, without automation or computational support, take hours or even days depending on the designer's personal efficiency. Together, these examples support the idea that computational tools can streamline early design decisions. As a result of significant improvements to the effective workflow, by saving time on repetitive tasks and achieving instant feedback on design decisions, the designer unlocks possibilities to allocate more time to other aspects that can improve the overall finished product. For instance, increased time for iterations enables designers to explore different solutions to design challenges, potentially improving the outcome. Parametric Solutions use this strategy by allowing designers to compare multiple solutions side-by-side and depart from something more than a blank paper (Parametric Solutions AB, 2024).

By allocating more time for evaluation, the designer and/or clients are rewarded with the opportunity to give feedback in different phases of the process. Evaluating the design in different media, for example in immersive virtual reality, can be crucial to increase spatial understanding related to room size, identifying hidden sightlines as well as logistical flow of a space. Consequently, a shared understanding of the building design between client and architect is more likely to be facilitated via use of immersive VR, compared to traditional design review medias such as 2D drawings or 3D perspectives. Another important direct consequence of efficient workflow is the possibility to enrich the design in more detail in a later phase. This aspect could be important in, for example, competition briefs where detailed drawings can improve the reader's understanding of the design concept.

It should be noted that the workflow tools were developed by the author, potentially introducing bias aligned with the author's design preferences. Nevertheless, the author deliberately developed the tools to be generic, user-friendly, and accessible to designers with varying levels of computational experience. The code (Grasshopper-script) is also given to the user, allowing users to extend or modify the tool in real time.

As highlighted in the thesis introduction, a paradigm is emerging that contrasts the efficiency, readability, and interpretability of simple hand sketches with high-resolution concept illustrations. Since this paradigm remains subjective, discussing this topic with claims of facts is irrelevant in this context. However, after developing multiple high-resolution concept models that would serve as communication to a client, the author can see both advantages and disadvantages compared with traditional concept sketches and believes that they can serve different purposes while they could be combined to work symbiotically in an early design process. The traditional concept sketches capture the simple context behind the idea and leave room for flexibility and interpretation, encouraging discussion and collaboration between client and architect. High-resolution concept illustrations are more informative and give the reader more context and a better understanding of the design decisions behind them. At the same time, simple hand sketches may communicate the broader idea behind a design proposal, where the high-resolution models can serve as informative arguments supporting the sketch. As such, the designer has consideration for the level of detail shown to the client via high-resolution images, while using hand-sketches to more readily available explore ideas.

The motivation behind the Architect's Design Code is to showcase the significance of better tools for architects. As discussed by Fabian Sellberg in his master's thesis from 2020 *Deep Architecture*, architects struggle with existing software that from a technical point of view lags behind other industries, for example the medical industry and agriculture with automated processes thanks to the data available (Sellberg, 2020). Scott C. Chase (2005) points out in his article *Generative design tools for novice designers: Issues for selection* that architects still spend an excessive amount of time manually manipulating geometry—time that could be saved through computational support and automation. Although the toolkit remains a prototype with clear areas for improvement—such as code optimization to reduce lag and support for more dynamic volumes—it nevertheless showcases the power of computational workflows and how they can lay the foundation for more advanced tools in the future. A notable limitation of this study is the lack of external user testing, excluding informative feedback to if, and how the toolkit can be further developed to improve usability as a non-developer. Future research could include testing computational design tools in real studio environments to ensure and evaluate usability and broader applicability.

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6.2. IMAGES

Figure 1: Coughi, E. (2020). Guggenheim Museum, Frank Gehry [Photograph]. Unsplash. https://unsplash.com/photos/brown-concrete-building-during-daytime-fql-IJc3Jhc

Figure 2: Ancill, R. (2020). Analogue Design [Photograph]. Unsplash. https://unsplash.com/photos/person-writing-on-white-paper-nGsVMkRatgM

Figure 3: ThisisEngineering. (2020). Computer-Aided Design [Photograph]. Unsplash. https://unsplash.com/photos/black-flat-screen-computer-monitor-hoivM01c-vg

Figure 4: Geib, D. (2019). Konst, landmärke, vatten, byggnad [Photograph]. Pexels. https://www.pexels.com/sv-se/foto/konst-landmarke-vatten-byggnad-3220859/

Figure 5: Gregušová, D. (2020). Vit och brun betongbyggnad [Photograph]. Pexels. https://www.pexels.com/sv-se/foto/vit-och-brun-betongbyggnad-3722890/

Figure 6: Robertson, T. (2021). Stad, konst, landmärke, byggnad [Photograph]. Pexels. https://www.pexels.com/sv-se/foto/stad-konst-landmarke-byggnad-3512681/

Figure 7: Suat Gunerli, M. (2022). Chicago arkitektur med historisk kupol [Photograph]. Pexels. https://www.pexels.com/sv-se/foto/chicago-arkitektur-med-historisk-kupol-31502910/

Figure 8: Astakhova, E. (2019). Konstnärlig design av interiören av en byggnad [Photograph]. Pexels. https://www.pexels.com/sv-se/foto/konstnarlig-design-av-interioren-av-en-byggnad-3450330/

All other graphical content are created and owned by the author.

6.3. AI APPENDIX

During the research and exploration phase of this thesis, the use of Artificial Intelligence (AI) has been used slightly to aid the author in different aspects. To complement Grasshopper tools with custom Python and C# code-built components, AI has been used as help to construct and discuss the logic behind these implements. AI also aided in finding some of the visual references used in this thesis. Note that no text published in this thesis has been generated with the use of AI.

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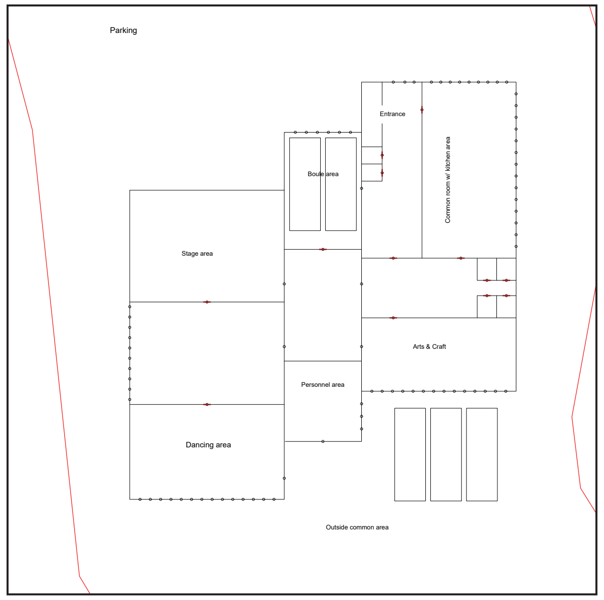
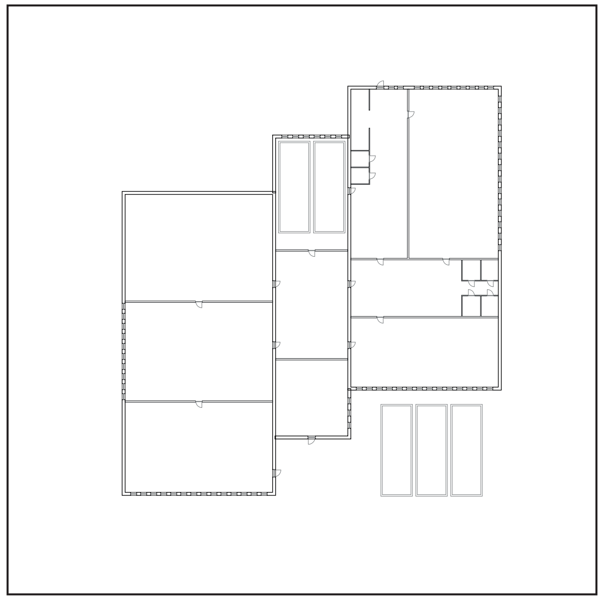
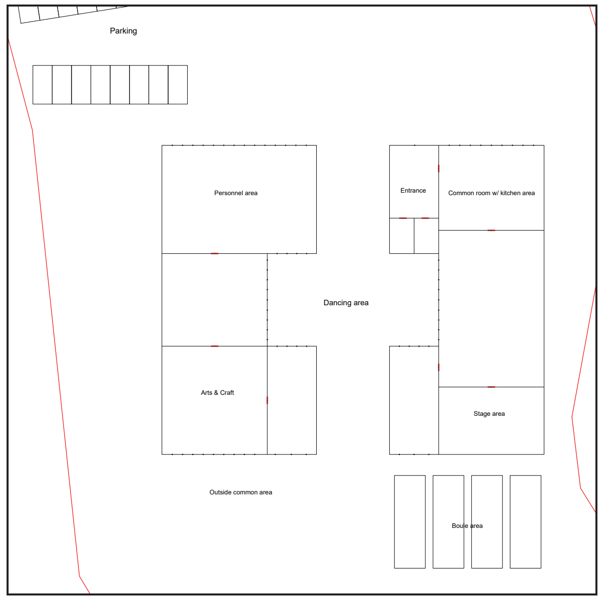
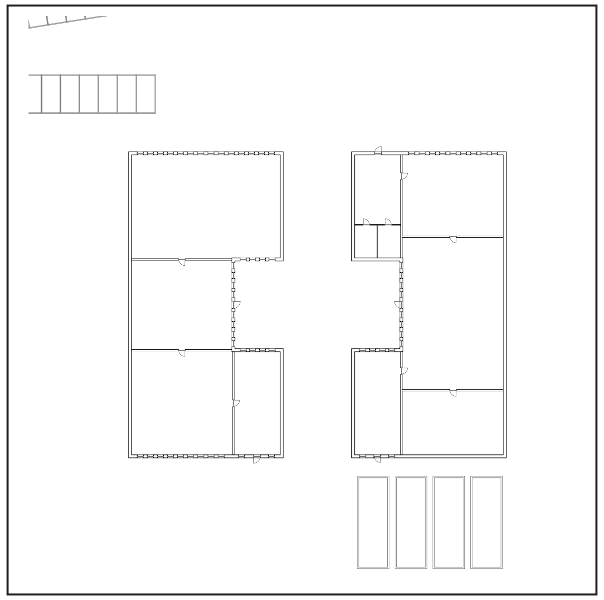
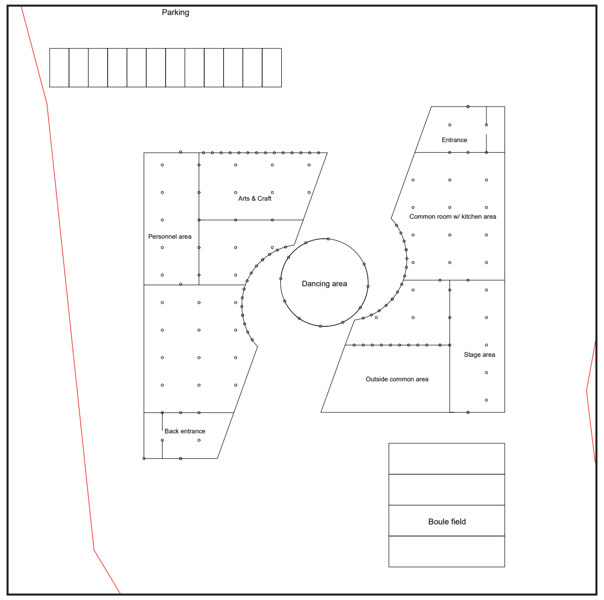
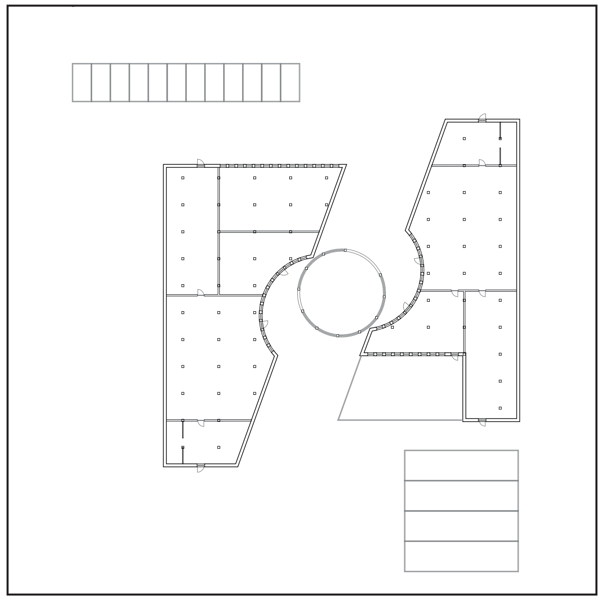












3D OUTPUT

Design Iteration 1

The first iteration primarily focused on defining the required functions and gaining an understanding of the appropriate volume size in relation to the site. Based on the site's characteristics, the north-east corner appears to be the most intuitive location for the main entrance situation and the south side for outside common functions such as a boule field and common area.

+ Shifted volumes
- A bit too big for the site
- Flow of the functions

* The building mass is appropriately integrated into the site.

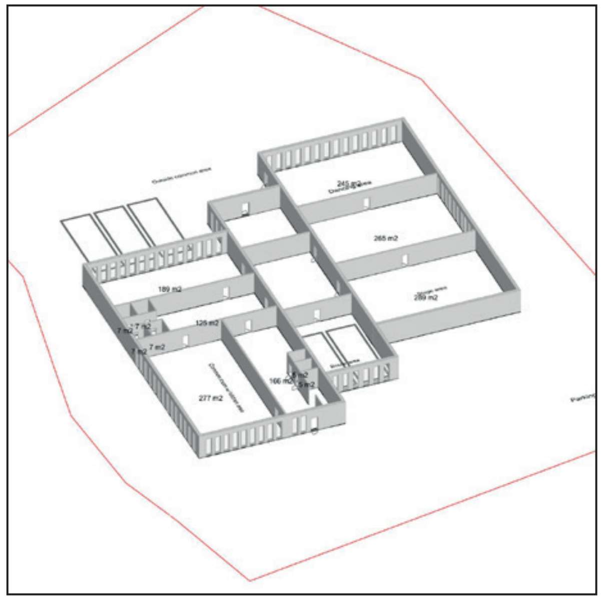
* The building mass and outdoor spaces are proportionally designed to fit the site.

* The functions and circulation are logically organized in relation to the program and building mass.

* The functions and circulation are coherently structured to align with the program and building mass.

* The indoor room division and layout are designed to optimize space utilization and minimize dead or awkward areas.

* The building mass, along with the placement of openings such as doors and windows, is arranged to achieve a functional and aesthetically appealing design.



Design Iteration 2

The second iteration explored the potential of separating the building volumes. A centralized space, called the "dancing area," was introduced to position one of the most popular activities at the heart of the building, allowing other functions to be arranged around it. Additionally, parking and expanded outdoor areas were incorporated to enhance accessibility and usability.

+ Size of building
+ Centralized activity
- A bit too rigid and boring in volume

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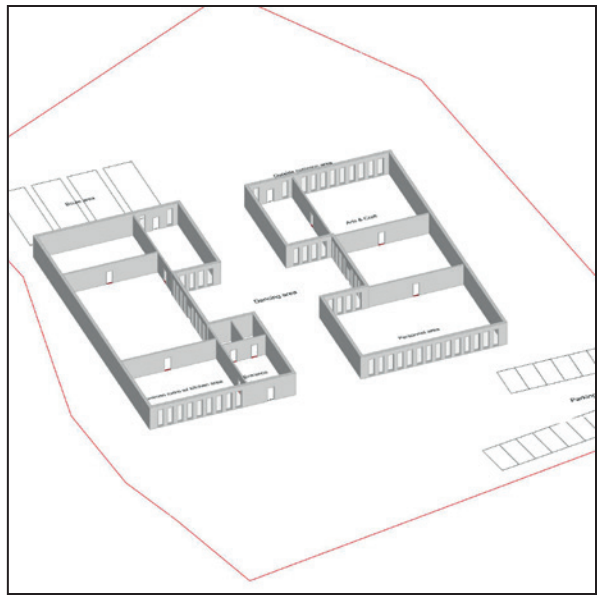

Design Iteration 3

The third iteration maintained the centralized functions while experimenting with shifting the building volumes. The shapes of the volumes were refined to create a more distinctive architectural identity. Additionally, a section of one of the volumes was subtracted to form an outdoor common area, enhancing spatial variation and connectivity. A column-grid structure was also introduced to support the design. While the overall shape and centralized function are promising, further iterations are needed to refine the concept.

+ Overall shape
+ Centralized activity
+ Outside common area
+ Column grid
- Shifted cutout for the center

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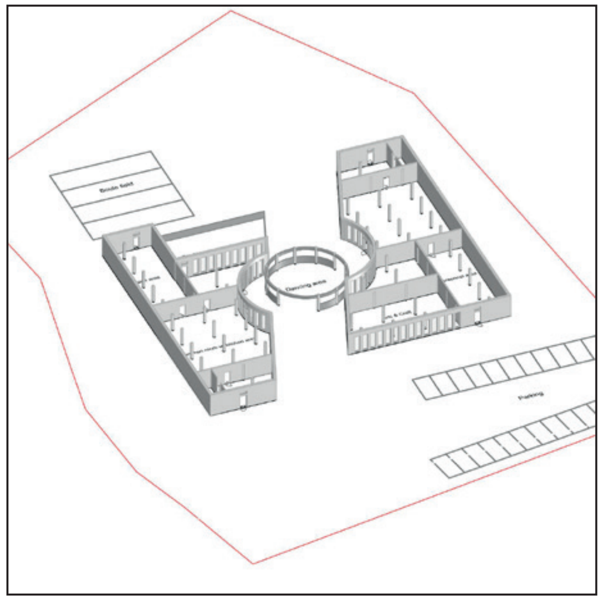

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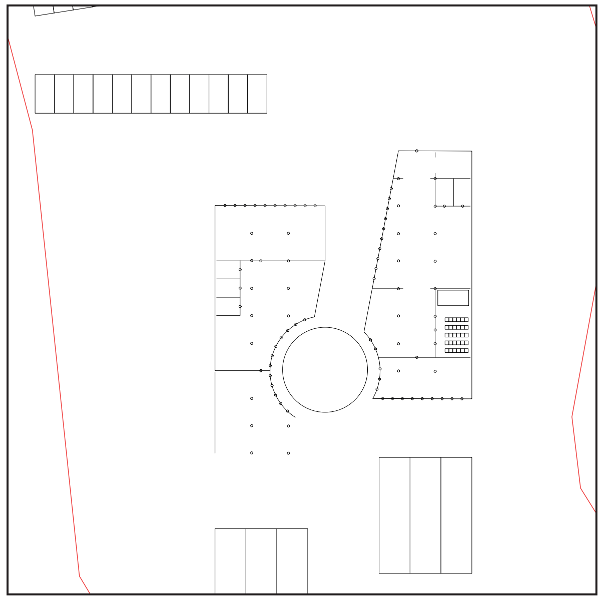

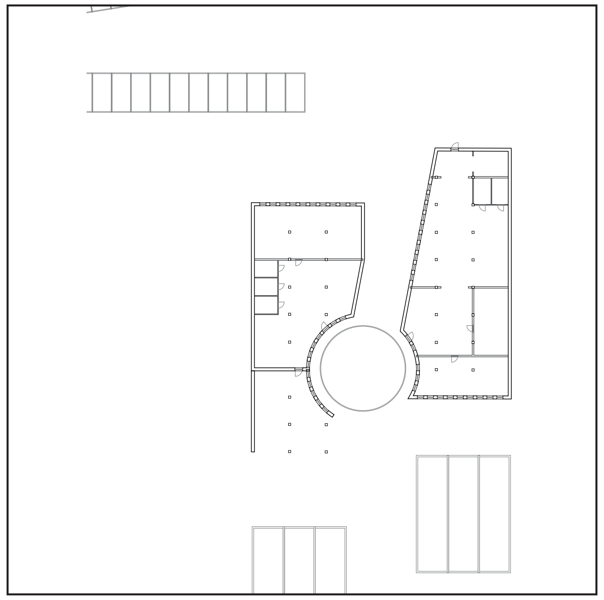

Design Iteration 4

Iteration 4 focused on refining the overall shape and enhancing the qualities developed in previous iterations. The size and form of the volumes, as well as their shifting arrangement, feel well-balanced. Keeping the centralized activity area in a fixed position, rather than shifting it, proved to be a better choice. Additionally, the auditorium/stage area was slightly reduced in size, which seems like a beneficial adjustment. The centralized area kept a more dynamic shape to contrast with the rigidity of the overall structure.

+ Shape
+ Shift
+ Size
- Symbiosis with site

* The building mass is appropriately integrated into the site.

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* The functions and circulation are coherently structured to align with the program and building mass.

* The indoor room division and layout are designed to optimize space utilization and minimize dead or awkward areas.

* The building mass, along with the placement of openings such as doors and windows, is arranged to achieve a functional and aesthetically appealing design.

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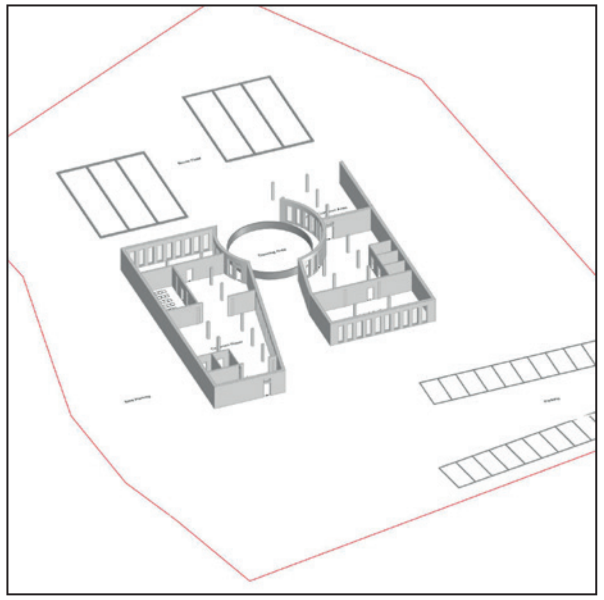

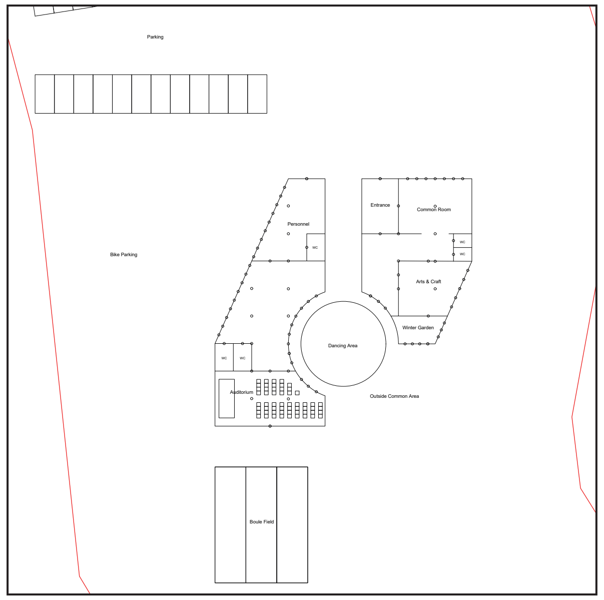

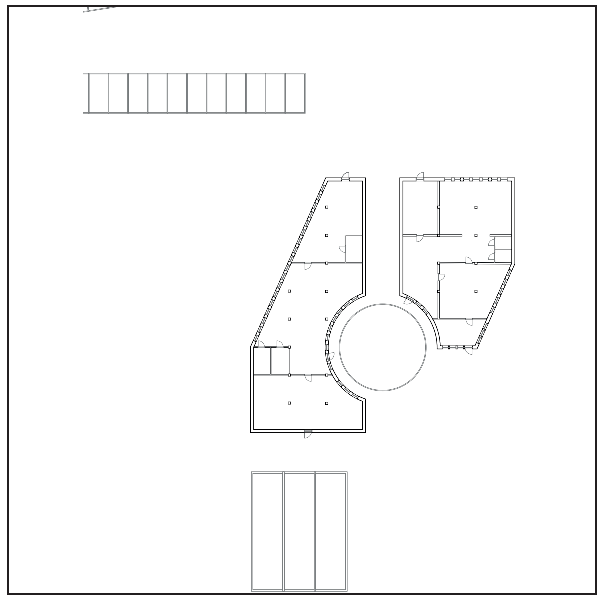

Design Iteration 5

Iteration 5 retained key elements from the previous iteration, such as the circular dancing area serving as the central hub for other functions. The shapes of the two main volumes were slightly adjusted to improve spatial relationships. I particularly like how the dancing area opens up toward the outdoor common area, enhancing relation between indoor and outdoor spaces. Overall, the room sizes feel appropriate, and a small winter garden was introduced to add a new attractive function to the design.

+ Better overall shape
+ Dancing area location
+ Winter garden
- Winter garden size
- Some dead space

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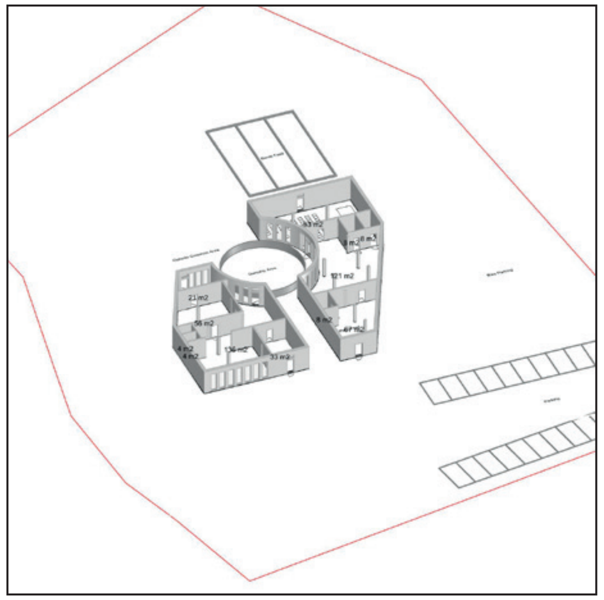

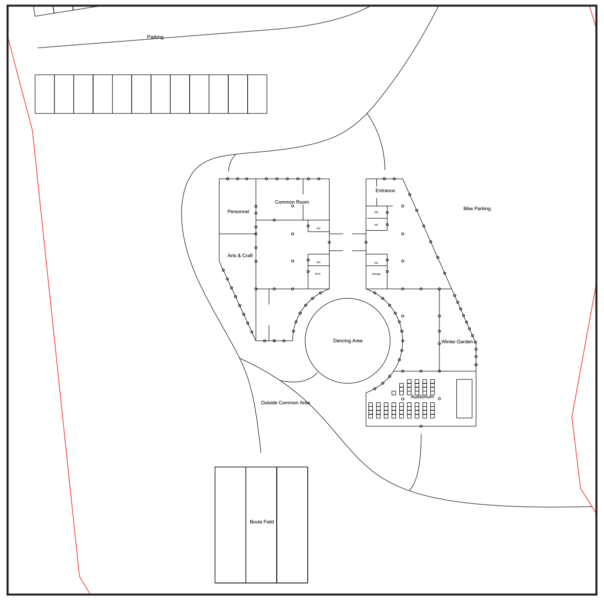

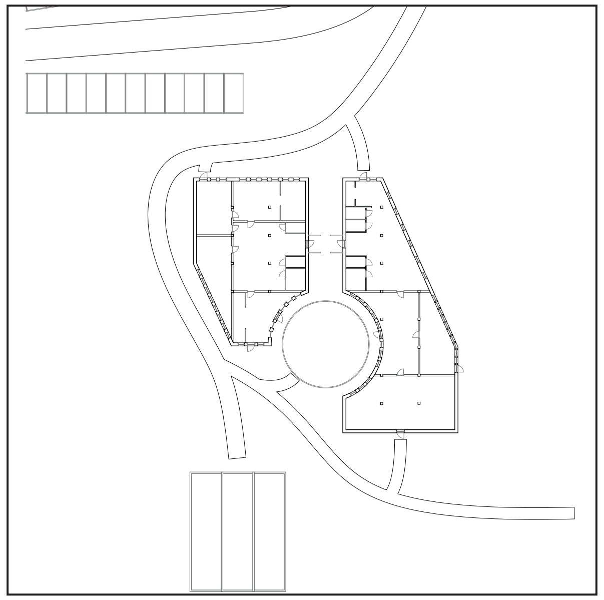

Design Iteration 6

In this iteration, I retained the overall volume shape from the previous version but mirrored it to better align with the site conditions. The main focus was on improving the interior flow, refining room divisions, adjusting room sizes, and enhancing circulation throughout the building. While the current layout is functional, further iterations will help optimize it further. Additionally, I introduced a trail function to the script, adding another layer to the design process.

+ Fits better at site now
+ Better flow between functions
- Still some dead space, but better
+ Better size for winter garden and auditorium

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* The building mass and outdoor spaces are proportionally designed to fit the site.

* The functions and circulation are logically organized in relation to the program and building mass.

* The functions and circulation are coherently structured to align with the program and building mass.

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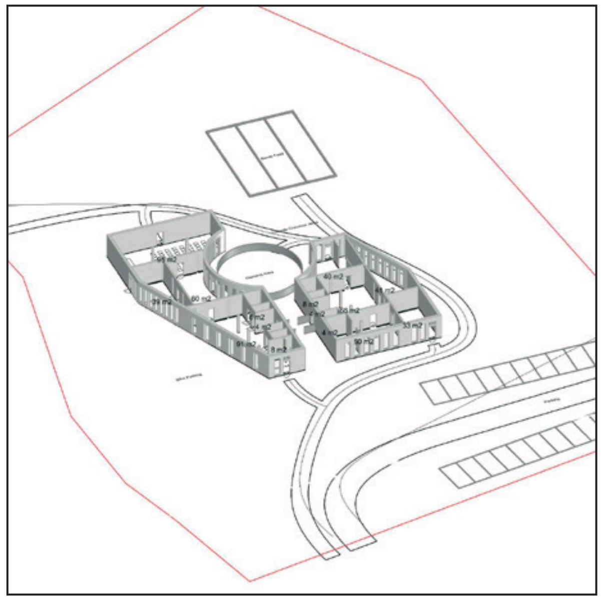

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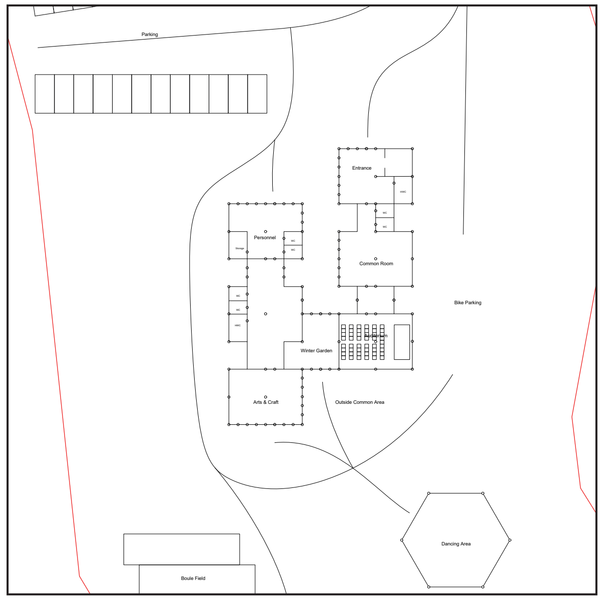

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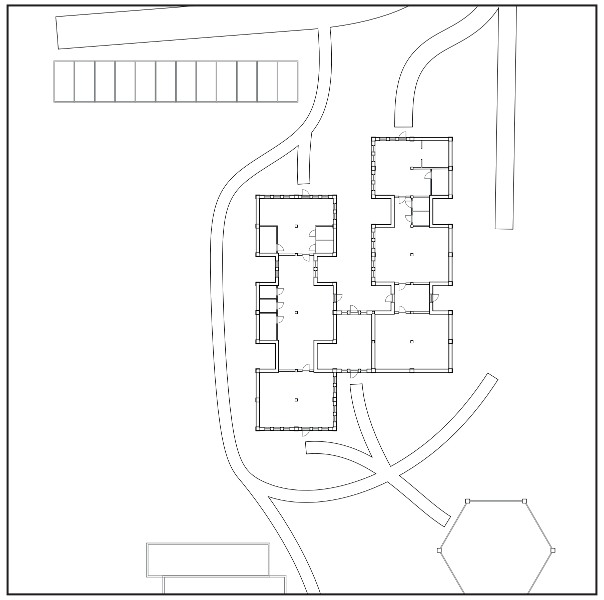
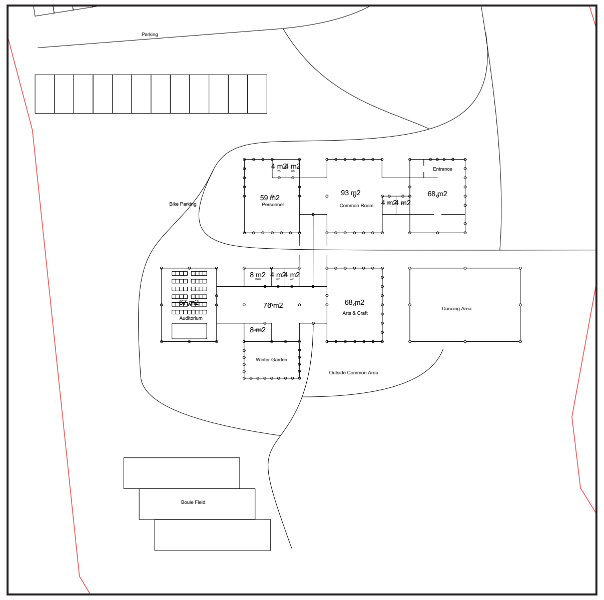
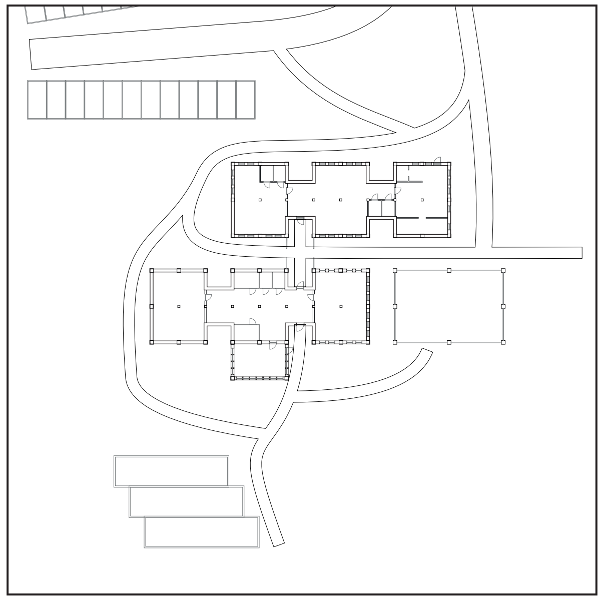
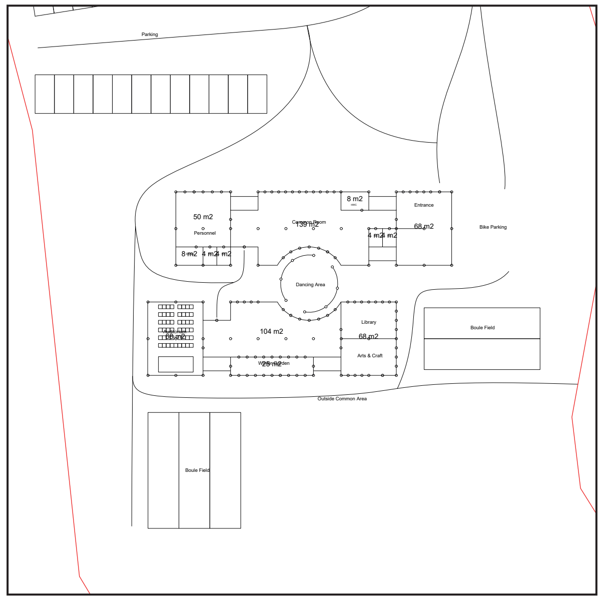
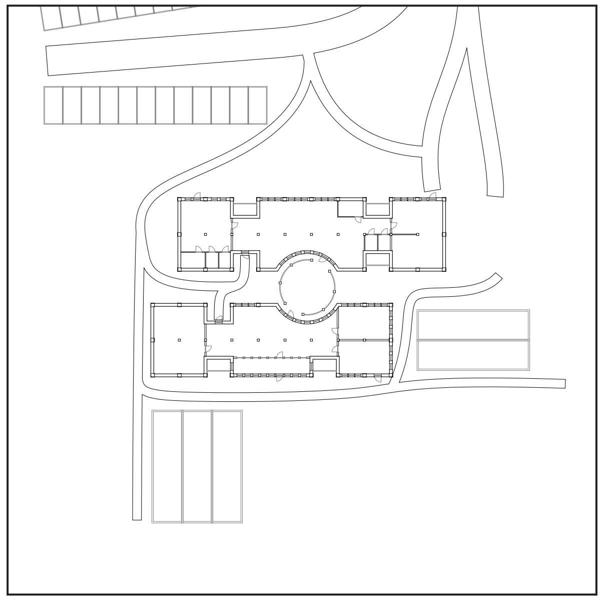










Design Iteration 7

Iteration 7 introduced a more rigid and "logical" volume shape, offering a new perspective on the project. This resulted in a clearer and more functional room layout, with straight angles enhancing spatial organization. However, the dancing area, previously the central activity, had to be relocated outside the main building. This change presents both advantages and challenges, balancing spatial efficiency with the hierarchy of functions.

+ Clearer room divisions
+ Easier to work with
+ Less awkward areas
+ Separate dancing area
- Separate dancing area
- Winter garden a bit cold

* The building mass is appropriately integrated into the site.

* The building mass and outdoor spaces are proportionally designed to fit the site.

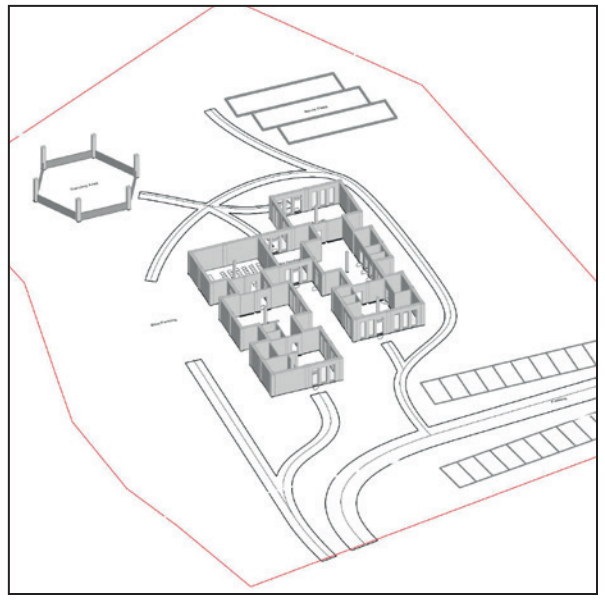
* The functions and circulation are logically organized in relation to the program and building mass.

* The functions and circulation are coherently structured to align with the program and building mass.

* The indoor room division and layout are designed to optimize space utilization and minimize dead or awkward areas.

* The building mass, along with the placement of openings such as doors and windows, is arranged to achieve a functional and aesthetically appealing design.

3D OUTPUT



Design Iteration 8

The next iteration took inspiration from the volume in the previous iteration but rotated it 90 degrees. This new orientation better presents the building to the site, offering a more welcoming appearance from the road. The winter garden was reintroduced as an extension of the volume, maximizing sunlight intake compared to iteration 7. Additionally, the dancing area is now more integrated with the main building, ensuring that activity and movement remain centralized on the site.

+ Better face to the road
+ Dancing area better integrated
+ Trails better integrated
+ Room division more logic to site and volume

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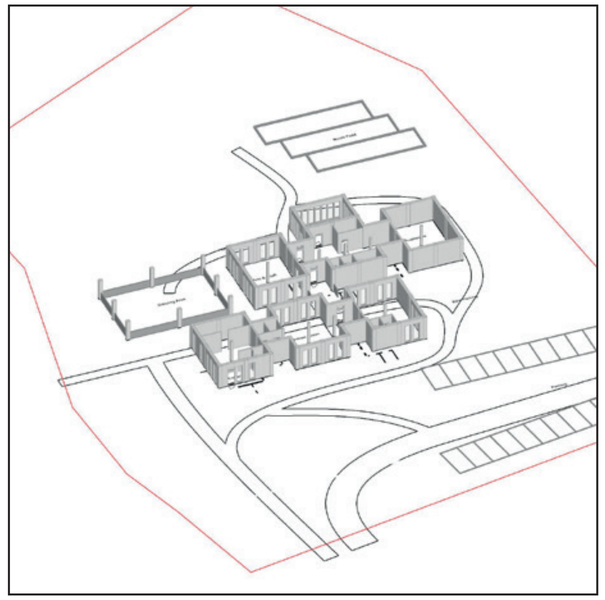

Design Iteration 9

Iteration 9 combined elements from iterations 7 and 8, as well as earlier iterations, to create a more balanced design. The rigid volumes from 7 and 8 were paired with the circular central dancing area, helping to soften the overall rigidness of the form. While this experiment proved to be a positive step forward, some interior spaces ended up feeling a bit awkward. Additionally, I experimented with varying window sizes and integrated the winter garden into the building again, maintaining its autonomy while still ensuring cohesion with the main structure.

+ Aspects from several iterations
+ Makes sense volumetrically and functional
+ Autonomous but integrated winter garden
- some small awkward spaces

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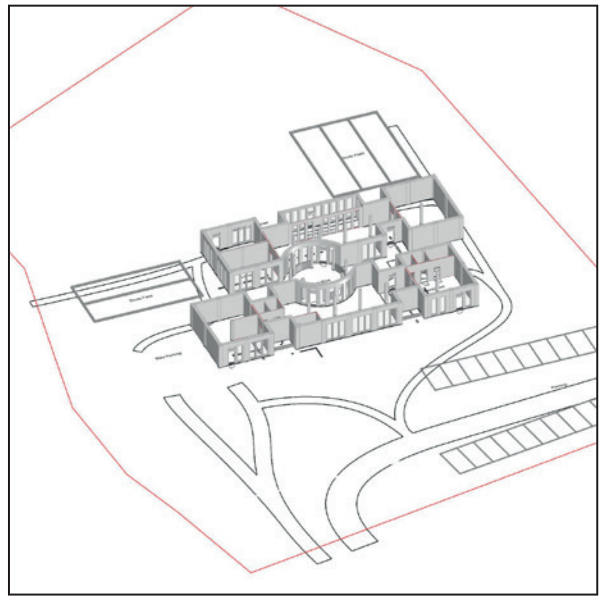

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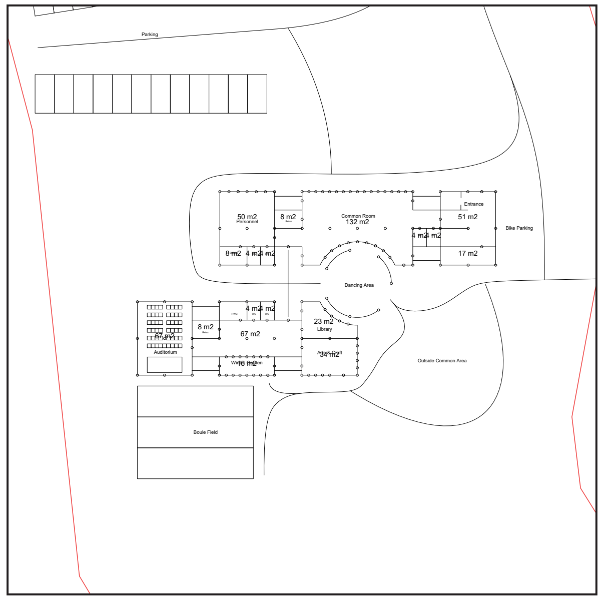

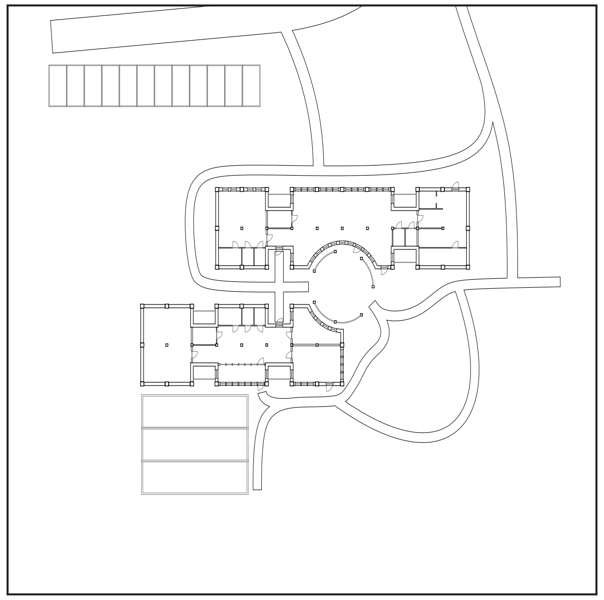

Design Iteration 10

Iteration 10 focused on refining the shape from iteration 9, further enhancing the relationship between the two volumes. The interplay between the volumes has significantly improved, and the previously awkward interior spaces have been resolved. The centralized dancing hall was successfully integrated, with its connection to the outside common area being preserved in a way I liked from iterations 5 and 6. The design feels

+ Shape feels somewhat complete
+ Dancing area works with volume and outside common area
- Room division needs work

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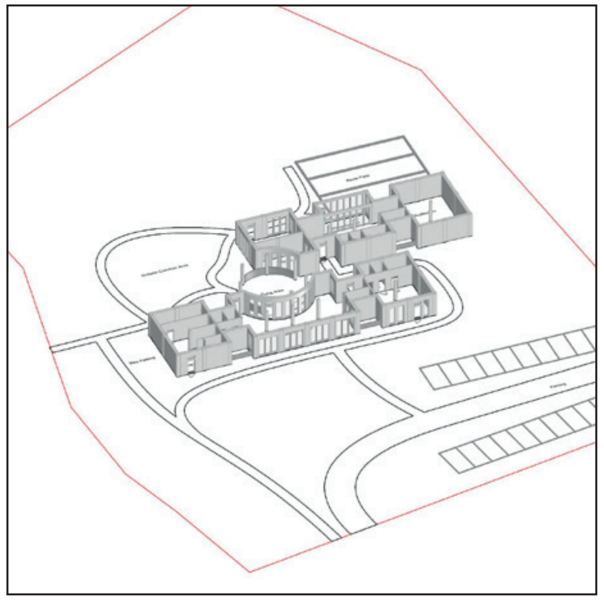

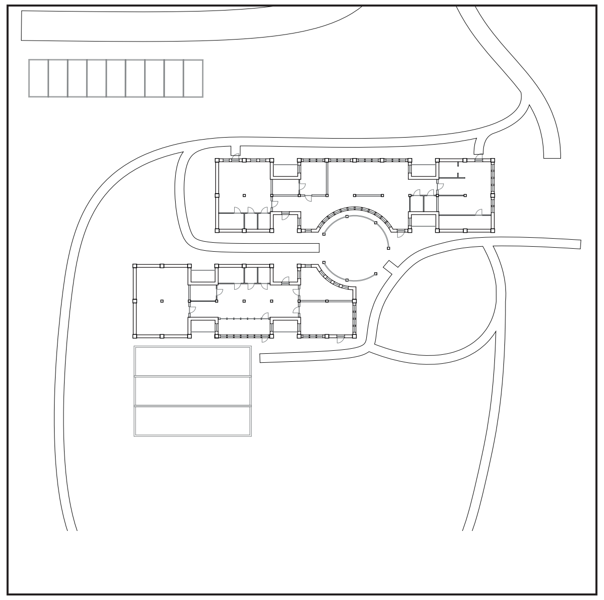

Design Iteration 11

While the overall shape and flow are now satisfactory, the focus in this iteration was on refining the room divisions. The room sizes and their locations feel appropriate, but the interaction between the interior spaces and the exterior volume could benefit from further iterations to optimize their relationship and spatial dynamics.

+ Better flow and sizes interior
- Could be better intreplay between rooms and exterior

* The building mass is appropriately integrated into the site.

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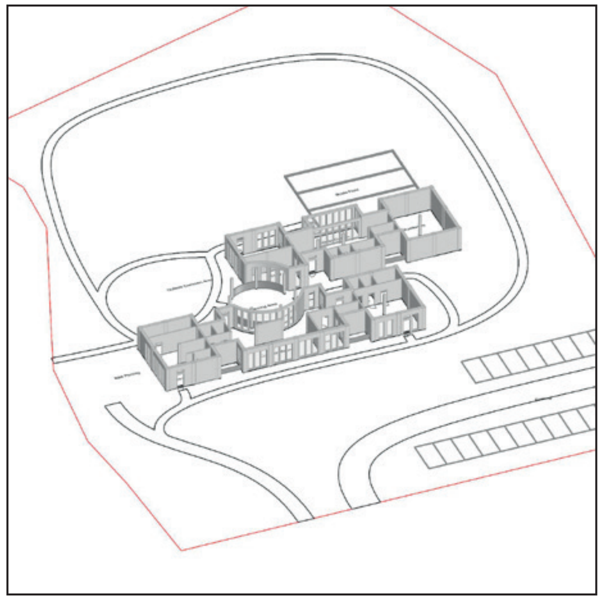

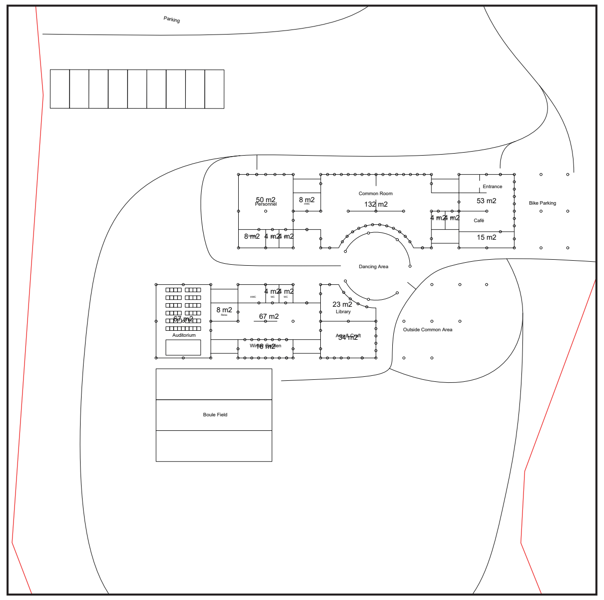

Design Iteration 12

Building on iteration 11, I focused more on the room divisions. They are functional as they are, with only one small area feeling a bit narrow, though still usable. To further optimize the room layout, I plan to consider furniture and other elements to inform decisions and make necessary adjustments. Additionally, columns were introduced to frame the outdoor common space and bike parking, adding structure and definition to those areas.

+ Room division and interplay works better
+ Overall volume and size
+ More defined outdoor spaces

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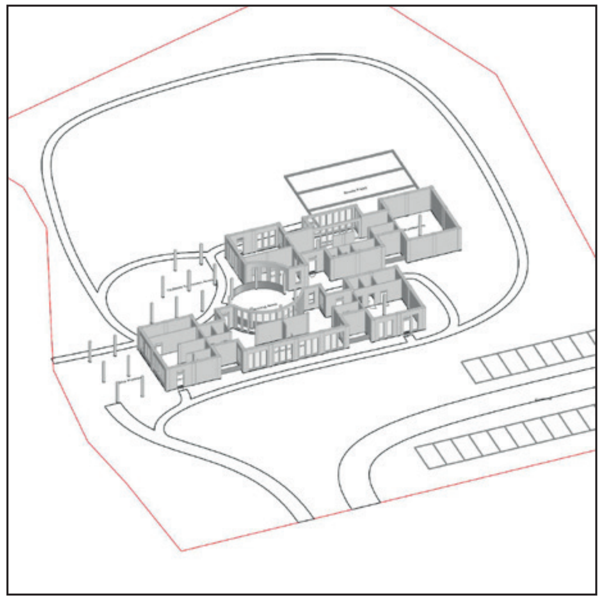

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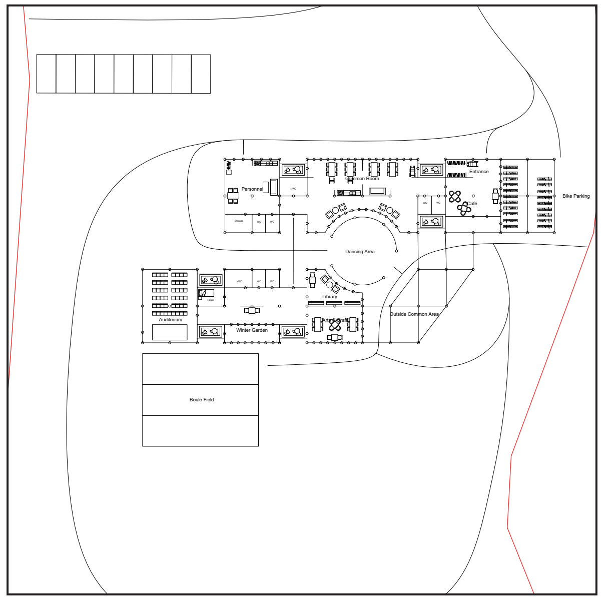
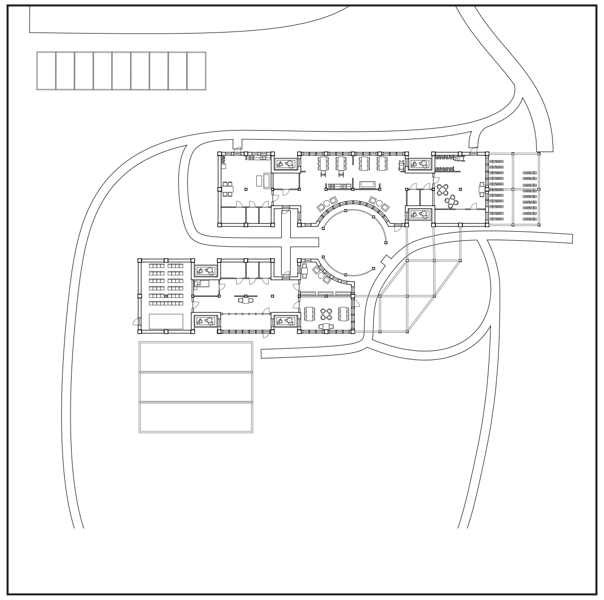
3D OUTPUT





Design Iteration 13

After finalizing the exterior shape and room layout, I began adding basic furniture to the design. This helped refine the previous iteration, leading to the removal of a wall and the addition of railings to the outside column grids to better frame the outdoor areas. I also adjusted the script to differentiate the line weights of the above ground railings from ground-level elements. Additionally, furniture was incorporated into the export feature automatically if placed in the correct layer.

+ Furniture is logic and adds a sense of life
+ Framed outdoor areas
+ New features

* The building mass is appropriately integrated into the site.

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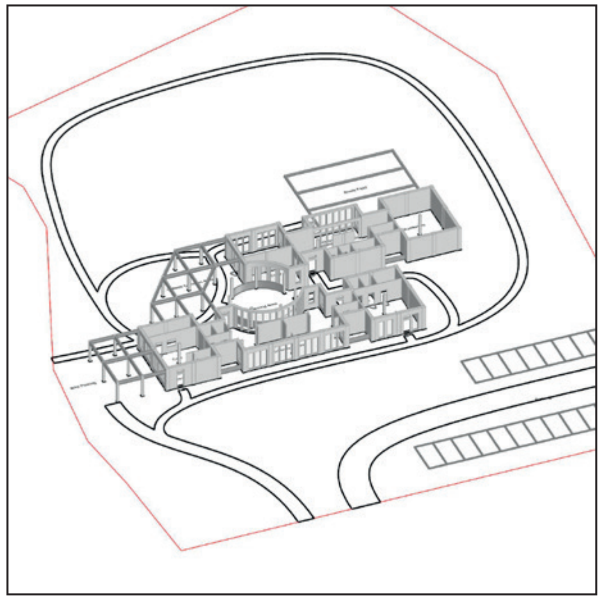
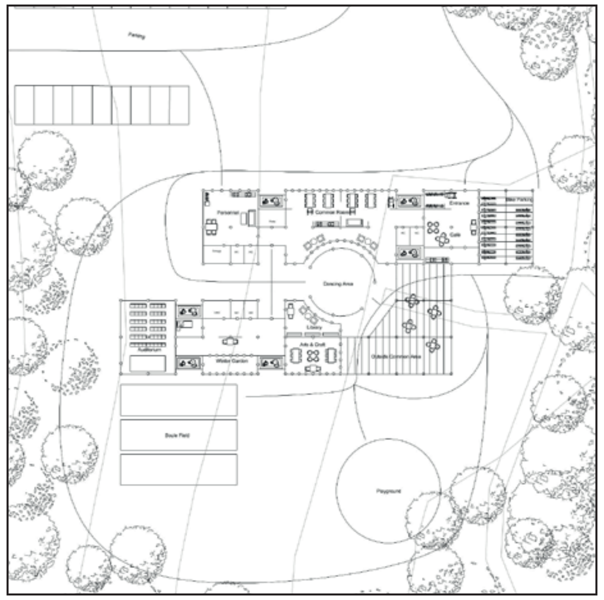
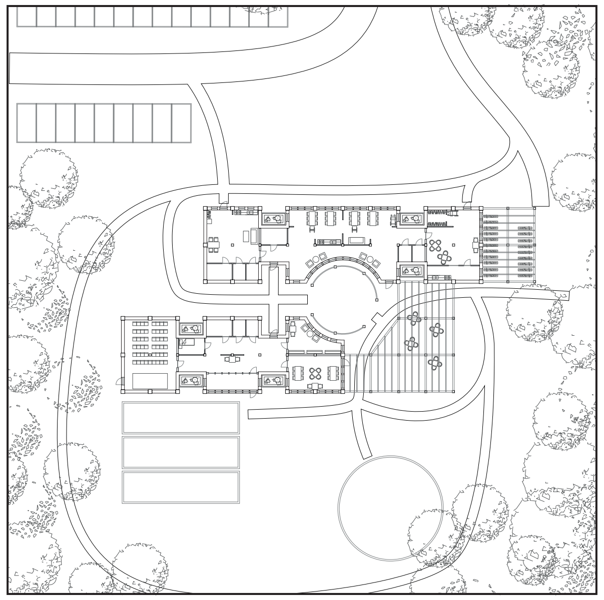
* The building mass, along with the placement of openings such as doors and windows, is arranged to achieve a functional and aesthetically appealing design.







Design Iteration 14

Beyond adding and adjusting a few elements in the main mass, more of the actual site context was incorporated, providing a clearer sense of the site's limited size. A new playground was introduced, considering that some seniors might bring their grandchildren to the activity center while parents might be busy at work or similar.

+ New playground
+ Better sense of the site
+ More details

* The building mass is appropriately integrated into the site.

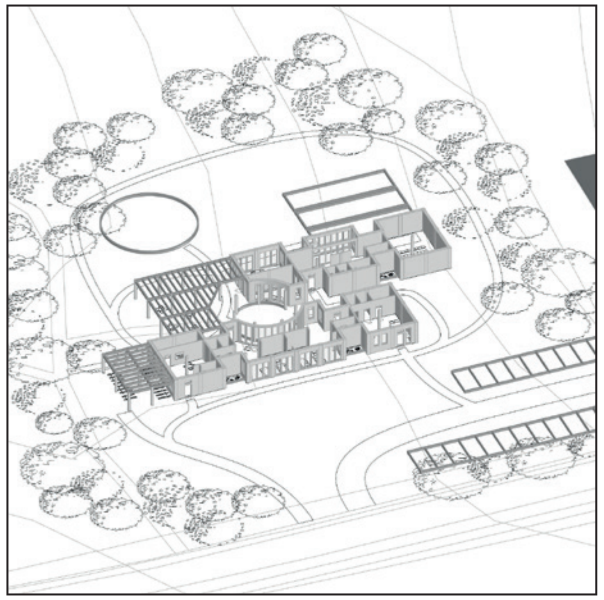
* The building mass and outdoor spaces are proportionally designed to fit the site.

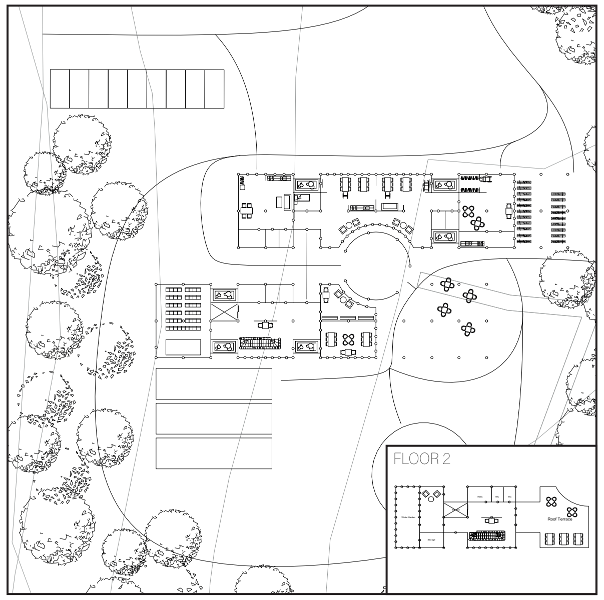
* The functions and circulation are logically organized in relation to the program and building mass.

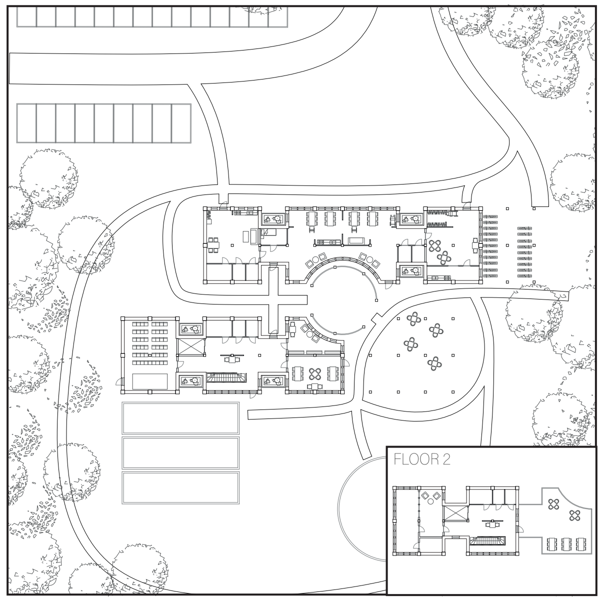
* The functions and circulation are coherently structured to align with the program and building mass.

* The indoor room division and layout are designed to optimize space utilization and minimize dead or awkward areas.

* The building mass, along with the placement of openings such as doors and windows, is arranged to achieve a functional and aesthetically appealing design.







Design Iteration 15

Drawing inspiration from the rapid concept development, a partial second floor was added in the south-west side of the building. By doing this, the winter garden was replaced by a staircase and moved to a more attractive space on the upper floor, allowing light intake from three directions. The second floor also introduces a spacious roof terrace.

+ Optional vertical movement
+ Better winter garden
+ Roof terrace

* The building mass is appropriately integrated into the site.

* The building mass and outdoor spaces are proportionally designed to fit the site.

* The functions and circulation are logically organized in relation to the program and building mass.

* The functions and circulation are coherently structured to align with the program and building mass.

* The indoor room division and layout are designed to optimize space utilization and minimize dead or awkward areas.

* The building mass, along with the placement of openings such as doors and windows, is arranged to achieve a functional and aesthetically appealing design.

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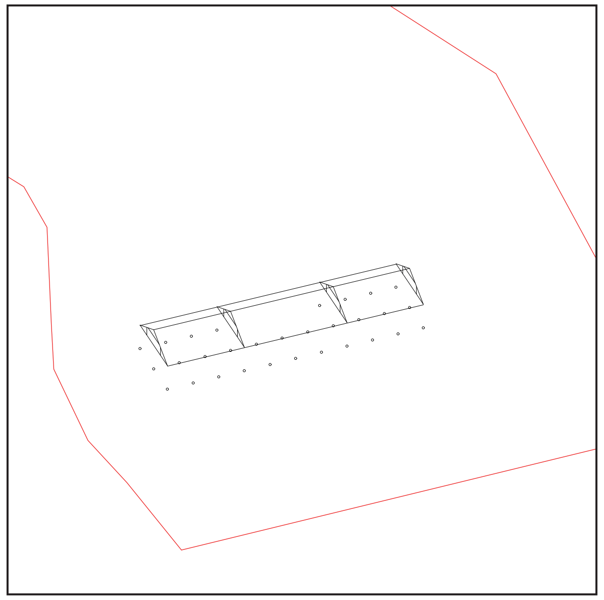
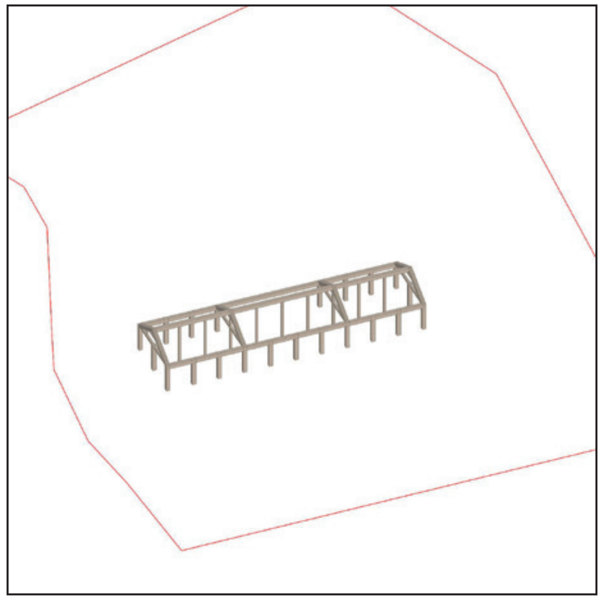
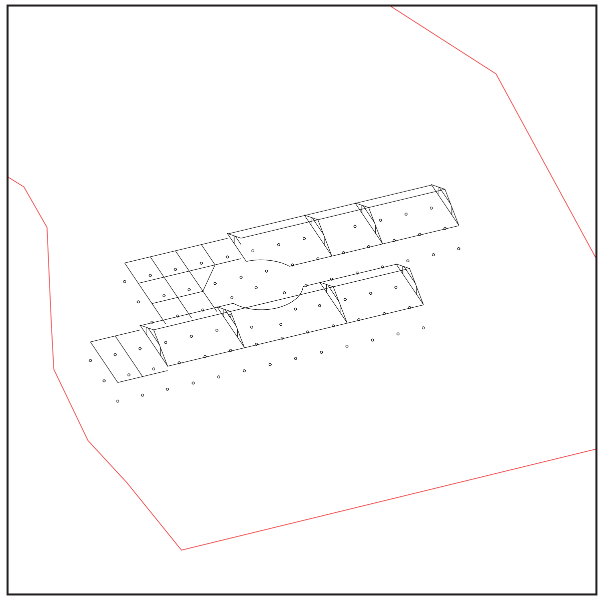
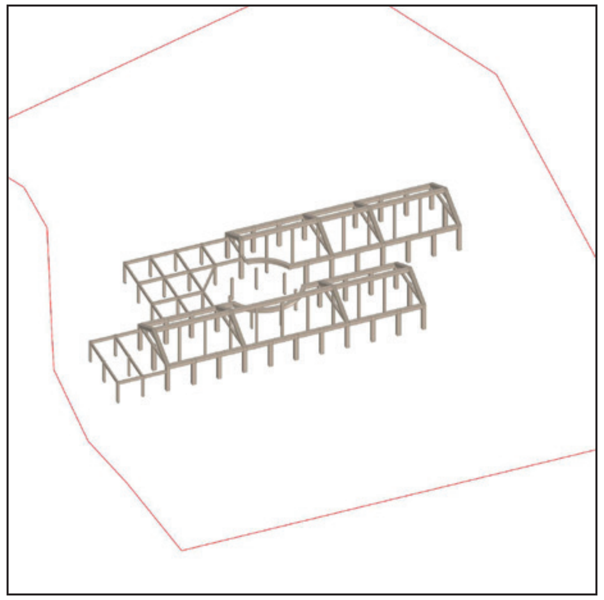
INPUT

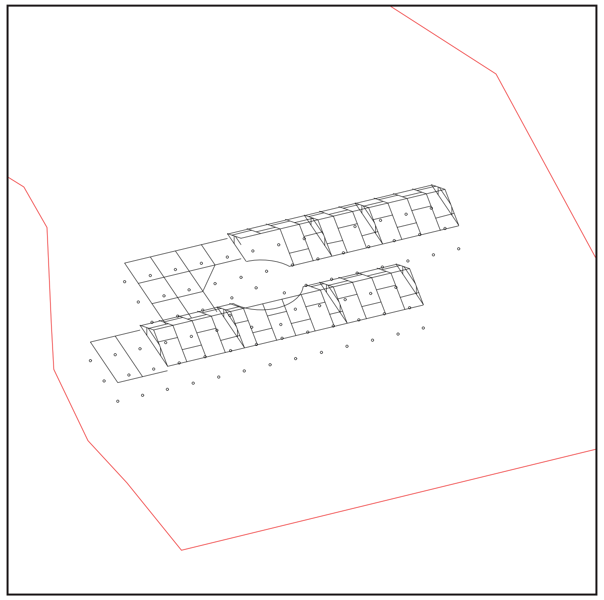
3D OUTPUT

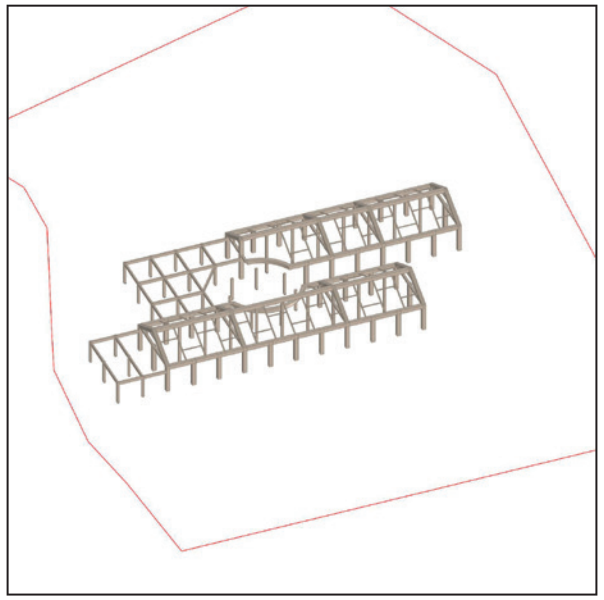








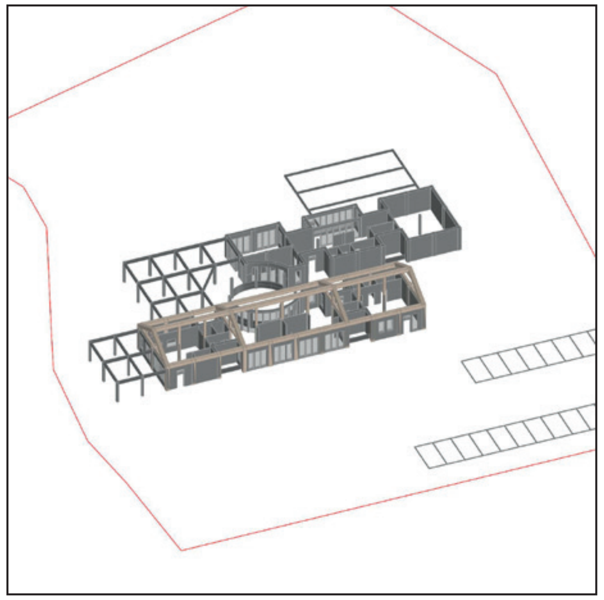




Structural Iteration 1

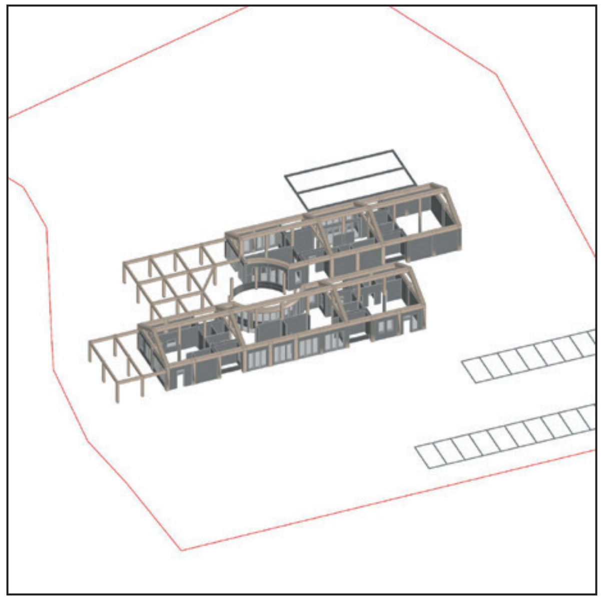
For the initial iteration of the load-bearing structure, I started with a simple approach to test the structural modeling script. The first test used a conventional frame throughout, which integrated well with the overall volume and was easy to apply.

APPLIED TO MODEL



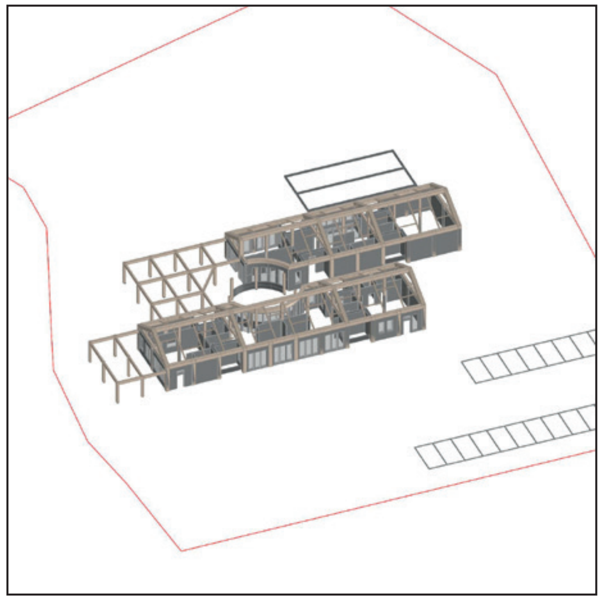
Structural Iteration 2

The concept was successfully applied to the rest of the building without issues. A few areas require customization due to the more dynamic shape and cut-offs in the volume, but overall, the structure remains functional and visually logic and easy to understand.



Structural Iteration 3

The final iteration of this concept added more construction details to enhance its applicability and structural integrity. While the design is logical and easy to understand, it feels somewhat simplistic , unconventional and uninspiring. Further iterations exploring alternative structural concepts could bring more depth and innovation to the overall design.



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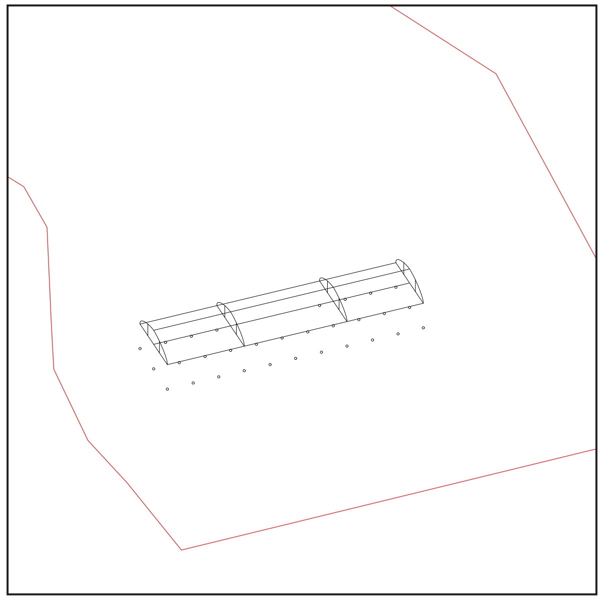
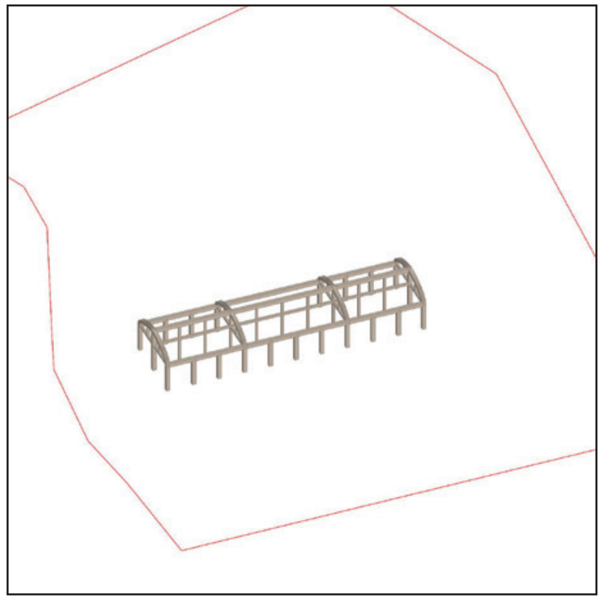
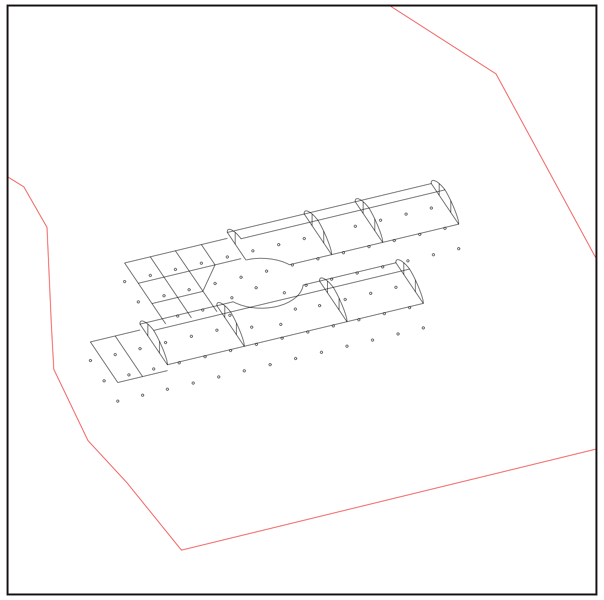
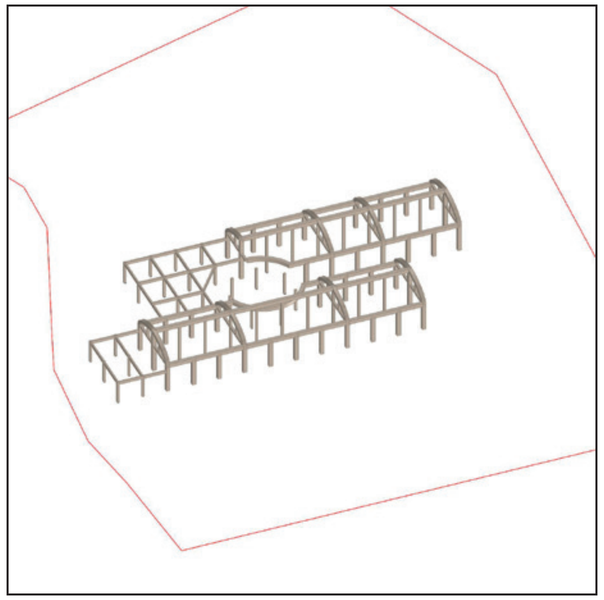
INPUT

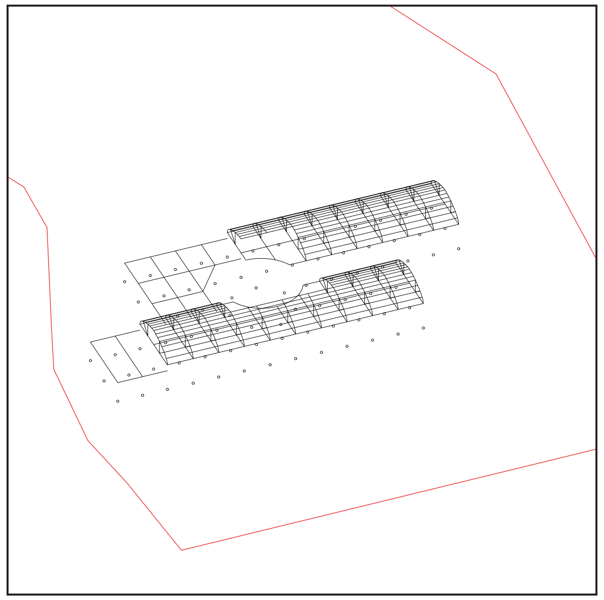
3D OUTPUT

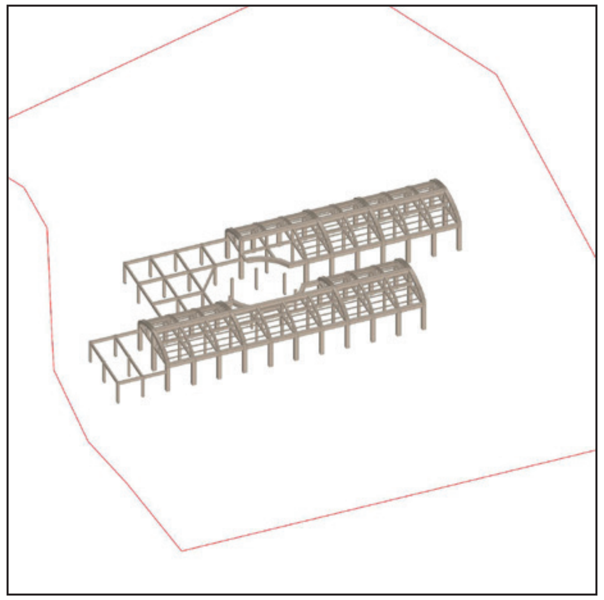








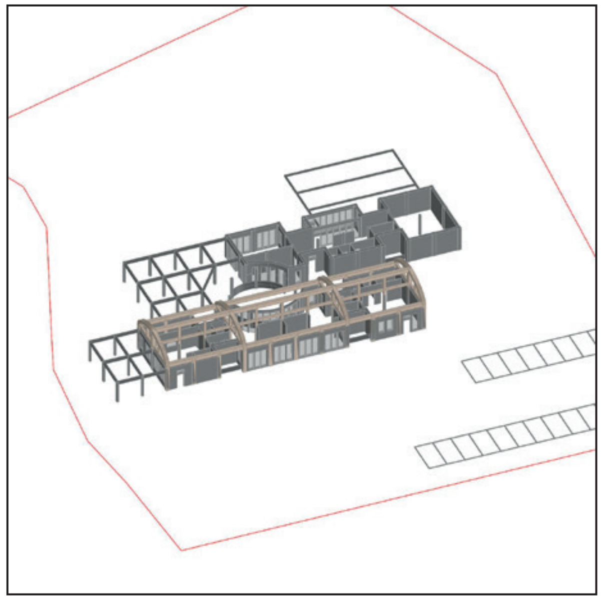




APPLIED TO MODEL

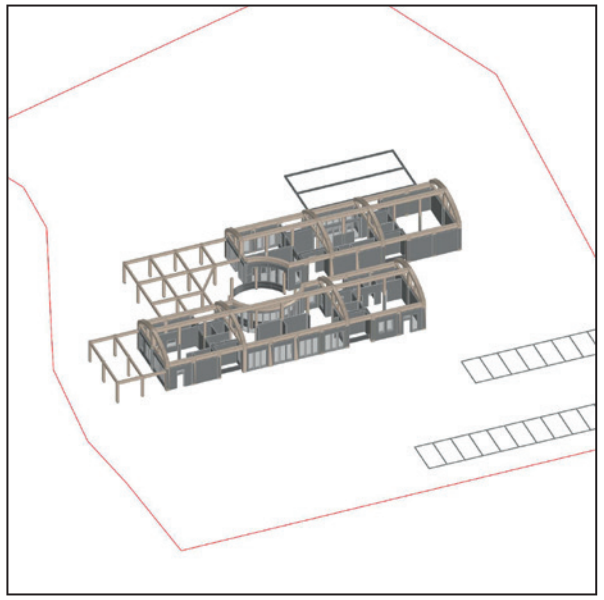
Structural Iteration 4

As a second concept, I experimented with a curved frame for the roof. Initially, I was concerned it might resemble a barn structure too much, but I was pleasantly surprised by how well it complemented the overall design.



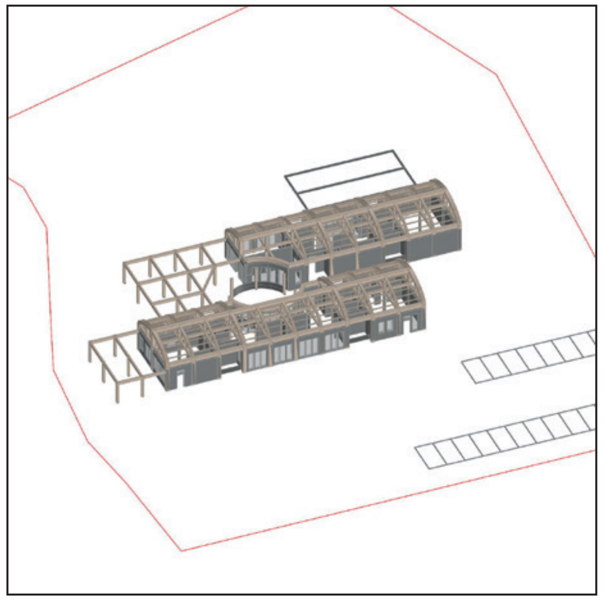
Structural Iteration 5

This iteration followed the same structural approach as the previous one. When applied to the entire building, the curved frame proved to be a strong fit, reinforcing the overall concept effectively.



Structural Iteration 6

After refining the structure with additional details, it feels well-designed and promising. I like how the frame interacts with the curved sections of the building mass, creating a few interesting spatial qualitites. While I'll take some of these ideas forward in future iterations, the curved concept might be better suited for another project. However, I'm glad I explored it!



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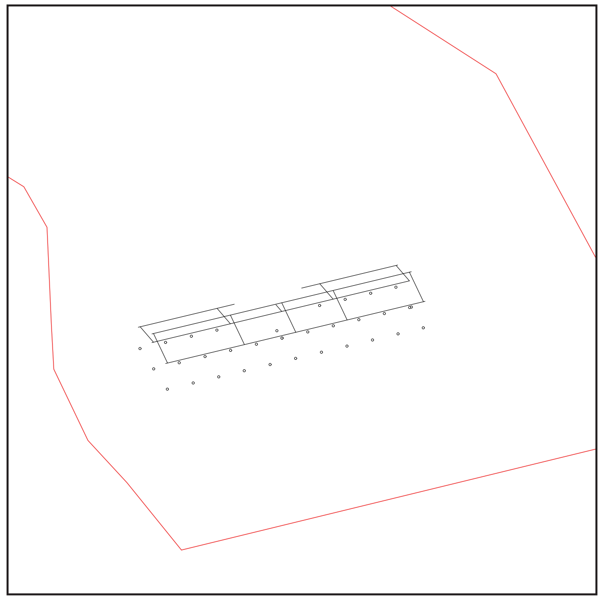
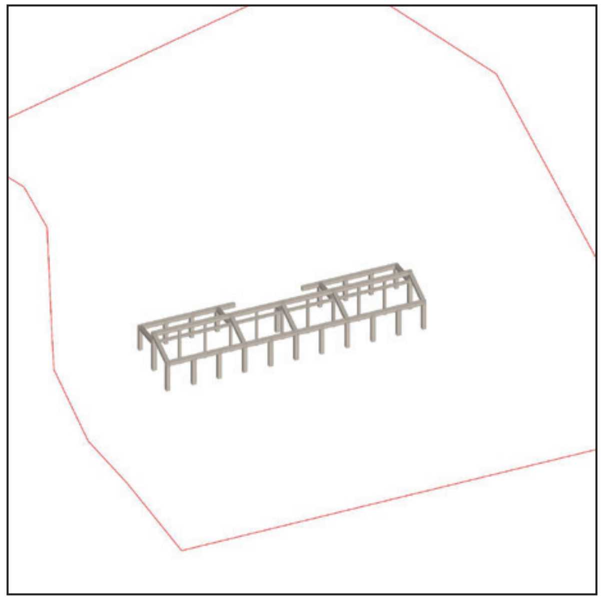
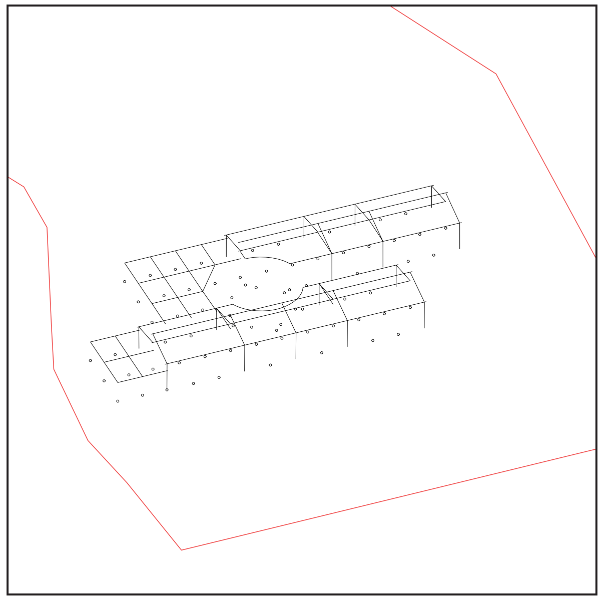
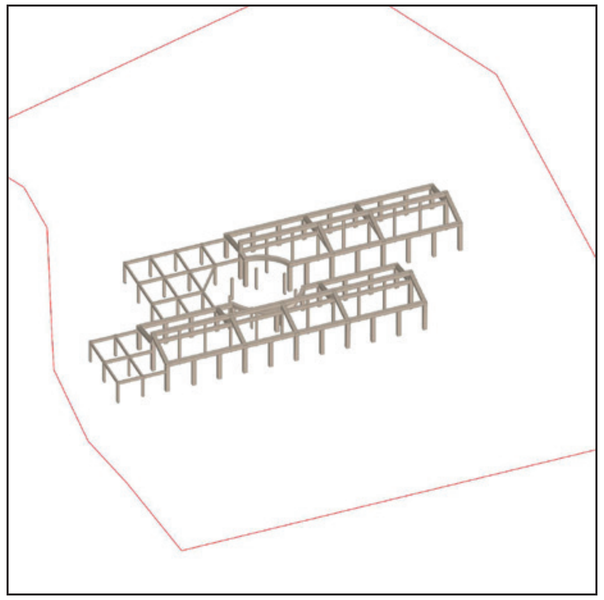
INPUT

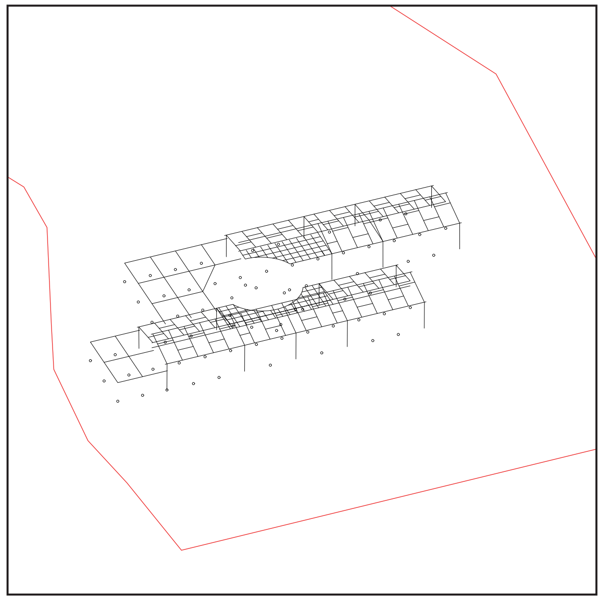
3D OUTPUT

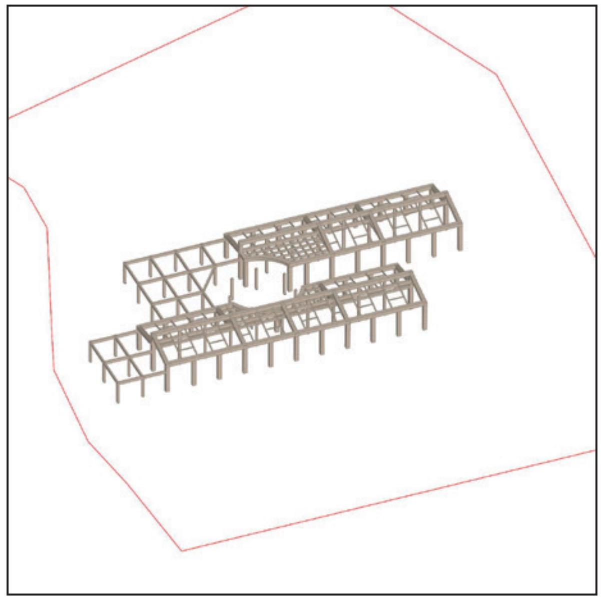








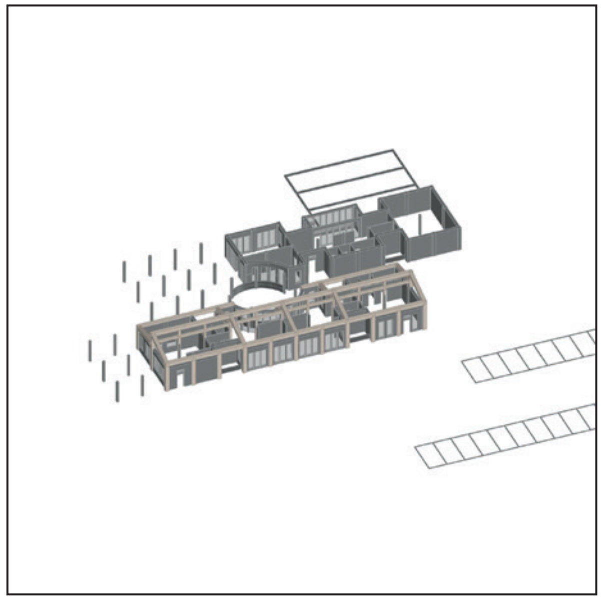




APPLIED TO MODEL

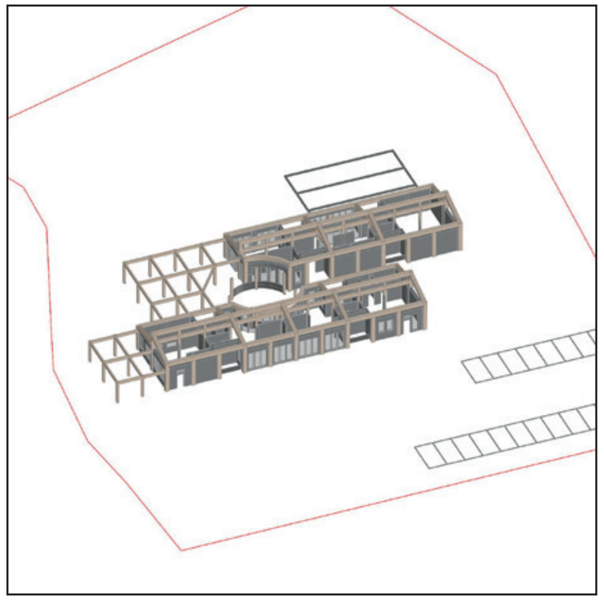
Structural Iteration 7

Throughout the design iterations, I had a straightforward structural concept in mind - a framing system that allows light to enter from above on the south side. Since the building's form was developed based on a column grid, the structural frame could be consistently repeated with only minor adjustments, ensuring both stability and flexibility. This concept draws qualitites from the two earlier structural concepts, the rigidness and logic of the first one while it stays playful like the second structural concept.



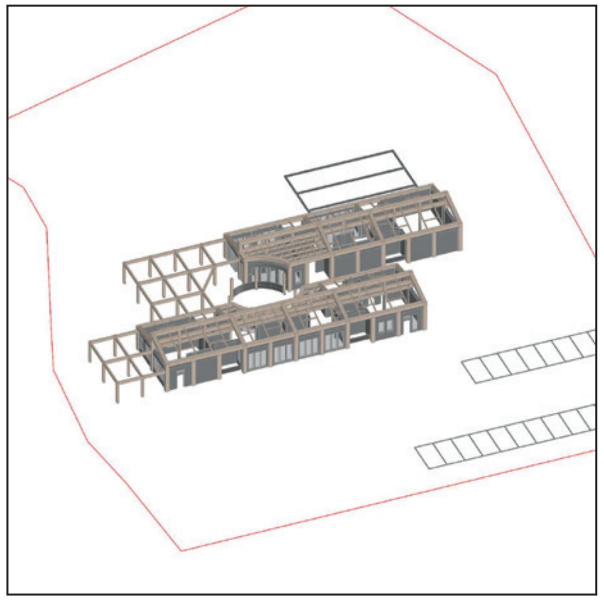
Structural Iteration 8

After developing this structural concept, I applied it to the entire volume to evaluate how it integrates with the overall design. While the result is visually appealing, it became clear that the dimensions need further refinement when viewed alongside the building mass. Since the frame carries the main load, the exterior walls may also require re-dimensioning to ensure structural balance and sustainable efficiency.



Structural Iteration 9

This iteration focused on refining the structure and adding details to enhance its integrity and credibility. While the dimensions still need further adjustment, the overall system feels solid and functional for now. Next step will be to integrate the main building mass to fit the structure in more detail, while making tweaks to both structure and mass.



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