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TECHNISCHE UNIVERSITÄT WIEN
Vienna | Austria

Diplomarbeit

Algorithmic Design for Residential Housing Concept: Cologne-Mülheim
Generating design plan and floor plan in four steps: transform, select, determine and extrude

ausgeführt zum Zwecke der Erlangung des akadmischen Grades eines Diplom-Ingenieurs
unter der Leitung von

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eigereicht an der Technischen Universität Wien
Fakultät für Architektur und Raumplanung
von

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Matrikelnummer 01621448 (066 443)

Wien, am 23.03.2020

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Abstract

Since algorithms have become an essential tool in various fields today, the architectural process remains almost untouched by this development. An architecture project may involve lots of different parameters and more restrictions than the other fields, which makes the usage of algorithms complicated. Nevertheless, it is still to be expected that the architectural design can be effectively planned, with the help of computational technology. Thereby, discovering multiple options and logical solutions according to the rules in the design processes, where algorithmic methods can play a significant role, is the aim of this paper.

The starting point of this work was initiated in the summer term 2018 in the course of a design project „KORREKTOR (digital) "with Prof. Manfred Wolff-Plottegg at the Vienna University of Technology. In this thesis the digital-algorithmic outcome will be applied in an architecture competition, which is called „Conceptual Living 2018.19".

The aim of this work is to combine the geometry with spatial dispositions in the digital-algorithmic model and obtain different forms for a design plan for the site area and the floor plans of the building. The requirement of the "Conceptual Living 2018.19" competitions is to develop a suggested solution and visionary concept, while considering the current trends.[1] However, this approach led us back to the principles of flexibility in residential housing planning: incorporating lifestyle as well as situational needs of the users and react to a sustainable and resource-saving architecture despite the change of their working life and mobility. Therefore, the whole design project will be considered as a spatial system between rigidity and flexibility. This allows the rooms within the site area to be combined in order to adapt to the user's continuous wish for change and flexibility. In order to apply this principle variable to different processing areas, first a "layout generator" was developed. This is an algorithmic model that handles serial steps for space allocation, aimed at subdividing an area into different sizes. It is also able to sort areas into different categories, such as public spaces, private space and buffer zone. Due to the different frameworks of each project, this model can only be programmed as a prototype. As a result, the „ Layout generator" was further developed and applied as an additional application in the targeted processing area Cologne-Mülheim.

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1 https://www.kalksandstein.de/wettbewerb (01.11.2018)

Kurzfassung

Während algorithmische Anwendungen in den unterschiedlichen Gebieten ein wichtiges Instrument geworden sind, bleibt der Workflow von Architekten von dieser Entwicklung relativ unberührt Nachdem in der Architektur eine Unmenge von Parametern die Planung eines Gebäudes erfasst, ist der Einsatz von Algorithmen in der Architektur unterschiedlicher als in anderen Gebiete. Es ist jedoch weiterhin zu erwarten, dass der architektonische Entwurf mit Hilfe von Computern effektiv geplant werden kann, wodurch mehrere Optionen und logische Lösungen gemäß den festgelegten Regeln in den Entwurfsprozessen ermittelt werden können, wobei algorithmische Methoden eine bedeutende Rolle spielen.

Der Ausgangspunkt dieser Arbeit basiert auf einem Designprojekt „KORREKTOR (digital) mit Prof. Manfred Wolff-Plottegg an der Technischen Universität. Das digitale-algorithmische Ergebnis wird anhand eines Architekturwettbewerbes, „Conceptual Living 2018.19“, umgesetzt.

Voraussetzung für den Wettbewerb „Conceptual Living 2018.19“ ist die Erarbeitung eines Lösungsvorschlags und eines visionären Konzepts unter Berücksichtigung aktueller Trends.[2] Die Herangehensweise an dieses Projekt basiert auf dem Konzept der Flexibilität in der Wohnraumplanung: Die Gestaltung des Lebensstils und der Mobilität des Umweltdesignprojektes sollen als räumliches System zwischen Starrheit und Flexibilität betrachtet werden. Auf diese Weise können die Räume innerhalb des Grundstückes miteinander kombiniert werden, um sich an den ständigen Wunsch des Benutzers nach Veränderung und Flexibilität anzupassen. Um diese prinzipielle Variable auf verschiedene Verarbeitungsbereiche anzuwenden, wurde zunächst ein „ Layout Generator“ entwickelt. Dies ist ein algorithmisches Modell, welches serielle Schritte für die Platzzuweisung verarbeitet und darauf abzielt, die Räume in verschiedene Einheitengrößen zu unterteilen und nach verschiedenen Kategorien zu sortieren, wie z.B. öffentliche Räume, privater Raum und Pufferzone. Aufgrund der unterschiedlichen Rahmenbedingungen der jeweiligen Projekte konnte dieses Modell nur als Prototyp programmiert werden. Im Zuge dessen wurde der „Layout Generator“ weiterentwickelt, damit er für das Bearbeitungsgebiet Köln-Stammheim eingesetzt werden kann.

2 https://www.kalksandstein.de/wettbewerb (01.11.2018)

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Content

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1 Introduction

1.1 Problem statement

1.2 Research aim

1.3 Method

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1 Introduction

This thesis will explain how to apply algorithms to residential housing design. The goal of this project is to redesign and redefine a completed architectural project in an algorithmic way. As a consequence, the architectural project would be generated into diverse outcome through the algorithm based on the architectural conditions and design needs. This algorithm model is focused on the flow line in the architectural plan. Here, a simple 2D curve can be represented by the spatial flow in the space as flow line, and therefore transform the operation space into the layout plan of the place according to the geometric relationship.[3] In this thesis, I will continue to develop the concept of the flow line algorithm and explore the usage of this concept in the design of residential buildings. Finally, I will apply the new algorithm model to the architectural competition „Conception Living 2018 19".

With the development of computer-aided design software, there are more possibilities for designers to demonstrate their creativity. Normally, In the design process, the architect proposes the design concept at the beginning of the design as the framework of the whole design process and expresses their abstract design concept with 2D drawings. 2D drawing is a vital tool for connecting architectural planning and building sites because of its simplicity and clear expression. However, the complex design is often challenging for the architectural drawing process.

This concept of this thesis is devoted to combining the geometry definition with spatial dispositions, then summarizing them into an algorithm model and using this algorithm model to generate a layout plan that can be directly applied in the architectural task.

The algorithm model in this paper aims to continue the advantages of 2D image representation, simplify the different factors in the building site and classify the design process into different steps. This will be done by generating different 2D graphs between different steps. Moreover, the input of each steps in the algorithm model can be changed by the user according to the difference in building site conditions or case requirements.

The thesis will be divided into three parts; literature reviews, algorithm models and layout generators. Firstly, the literature reviews from the current architectural algorithm design tools and the example from conceptional living will be reviewed and analyzed. The second part consists of the establishment of algorithm model as well as the prototype of Layout generator, and the third part is the implementation of the Layout generator in the architectural competition „Conceptional living".

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3 The starting point of this work was initiated in the summer term 2018 in the course of a design project „KORREKTOR (digital) "with Prof. Manfred Wolff-Plottegg at the Vienna University of Technology.

1.1 Problem statement

In the past few years, the development of computer software has changed immensely. Using computer aids to complete the entire architectural design process is very common nowadays. On the one hand, architects rely on the advantages of computers in terms of graphics computing. On the other hand, they do not trust computer software, which are highly automated in their ability to accomplish the results of certain design tasks. After all, the main role of an architect is not only to answer a single question, but usually, to find a solution of compromise under multiple conditions, or even conduct assessments on their own.

An algorithm is a method that uses certain steps to solve a problem for computer calculations or data processing. Different from general architectural computer-aided design, the algorithmic design must define the rules of design demands first. Due to the particularity of the design interface (computer programming), only if each design step of the entire design process can be defined in detail and accurately, will the computer generate the corresponding results.

In the establishment of „Layout Generator", the algorithmic model in this thesis, the design process of an architectural project will first be simplified into four steps, based on the algorithms, rough standards, and goals from the spatial flow design project. After that, these four steps will be defined with multiple clear graphical diagrams as input and output data, in which the tangible building structure will be also simplified into geometric figures and these geometric figures will be parameterized according to its definition in architectural design.

This is done so that these design options can be understood more intuitively with the help of those graphical expressions whether these steps are presented in the expected form or not. When the algorithm due to different situations must be modified or certain steps need to be changed, it is helpful for designers to think graphically during the design process. It can also allow designers to have a comprehensive perspective of the relationship among various design approaches to explore the logic conflicts. In order to be more flexible, the architect can add, reduce or change the design steps within the algorithm during the design process. Those steps are based on the analysis of different architectural design cases. Therefore, designers can use the Layout generator to transfer the other design approaches to generate results as well as adjust input parameters according to the design requirements.

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1.2 Research aim

In terms of the extensive use of algorithms in various professional fields, there has been a limited focus on architectural design. I hope that this work can provide a different aspect of the design method apart from the traditional design process. This will be exhibited by combining architectural analog and computer algorithms together, by quantifying and qualifying the design steps, and providing the possibility of modification within certain operating restrictions.

The goal of this thesis is to create a digital building model which combines the idea of conceptual and collaborative living, in which the 2D curves could be used to generate 3D models as well as advanced building parameters. The Layout generator is not only a parameterized model for only a unique solution, but also includes a series of steps that can be adjusted for different construction conditions under certain rules. Through a series of understandable processing steps, the content of the architectural design could be more specific.

1.3 Method

As a starting point of this work, the idea of spatial flow will be applied to establish an algorithm model, a "Layout Generator", in order to demonstrate the conceptual and collaborative living proposal from the Zukunftsinstitut. The living space in the future should be conceptual, and various ideas must be put forward in response to the impact of technology and social evolution. Therefore, different architectural designs will be extracted in order to reflex the dynamic of our lifestyle[4]. The concepts of these designs will be parameterized, embodied in the interface of the visual programming language Rhino-Grasshopper as an algorithmic model. It has the potential for the designer to tackle or modify their architectural analog as well as their concept.

The workflow of the Layout Generator is described as below:

1. Simplify and abstract the design concept of „conceptual and collaborative Living“ as geometrical conditions or definitions.
2. Apply those geometrical conditions or definitions in an appropriate way in the Layout Generator.
3. According to visual feedback and the goal of design concept, adjust the results of each step.
4. Generation of the results and comparison of their architectural key figures.

4 cf. https://www.zukunftsinstitut.de/fileadmin/user_upload/Publikationen/Auftragsstudien/publication.pdf, S6. (01.11.2018).

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2 Analysis

The design process of an architectural project is very complicated. It consists of various factors, and as such, the designer has to propose different solutions, and then go through the screening to get the comparatively better options. Therefore, the purpose of my work is not to propose the effective and best solution that can directly generate a building plan but to use the advantages of the computer to summarize the designer's ideas into an algorithm in an organized way as an auxiliary tool for architectural design.

The literature review and research of this thesis are divided into two parts. The first part starts with the introduction of algorithm design, then introduces the spatial flow algorithm briefly. After that it compares various algorithms building auxiliary design tools, and the characteristics of different tools, in order to combine the spatial flow algorithm to construct the layout generator's framework.

The concept of the Layout generator is to convert first the building lot into a number of rectangular squares and then use a curve simulating the spatial flow of people. This will be completed by selecting the rectangular squares, thereby distinguishing the different areas of the building lot for the generation of the room layout plan of the building, that consists of the idea from conceptual and collaborative living competition, which will be the focus of the second part of the literature collection.

Firstly, the definition of conceptual and collaborative living will be clarified as well as its impact on architectural design. Then the process of how can we achieve those ideas within our design project will be discussed. According to the framework of the layout generator, different examples of architectural projects will be listed and analyzed, such as the Jilin Street Motorcycle Apartment in Taiwan, Share House LT. Josai located in Nagoya, Japan......etc. Those various architectural concepts and the design decisions in each reference case will be simplified into the geometrical relationship and added into the steps of the layout generator, in order to appropriately adapt to various conditions of building lot.

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2.1 Algorithmic design in architecture

What is an algorithm? The nine-century Persian mathematician Al-Khwarizmi defined algorithms, which is a method to solve problems in a series of precise and fixed steps. This series of steps is a set of well-defined and simple instructions. It takes a clear input in order to produce a certain output.

Using CAD in architectural projects simplifies the design process, but if a project with numerous constrains becomes complex, it requires more experience and increases the working period. Hence, several researchers have looked at different possibilities of integrating interactive designs and the use of algorithmic workflow, such as the generative design tools, which are built into projects or their installations.

The algorithm design focuses on the establishment of the steps in the application in order to obtain the design results through the adjustment of the set parameters. At the same time, because the formulation of an algorithm aims to split a problem into several simple steps according to the user's settings, the usage of computers can provide effective assistance in this aspect due to its advantage at calculating repeated and large amounts of mathematical operations. Therefore, we can apply this method to computers, using different programming languages or softwares to solve this problem.[5] Although algorithmic design has the potential to solve complex problems and to provide a logical solution, its implementation in a project is not easy due to different conditions and specifications. This can result in an application problem within the planning process. In order for the algorithms to generate design results, based on the designer's needs, these requirements must first be translated into a language that the computer can understand. As humans plan architectural designs, we tend to consider the structural parts of our design such as the walls, floors, roofs, and so on.

This thesis will use the Rhino-Grasshopper interface to compose an algorithmic model which can be applied in residential housing design. Rhino-Grasshopper is a visual programming language developed by McNeel & Associates. As a plug-in for Rhino 3D, Rhino-Grasshopper's operating environment provides users with diverse and varied 3D shapes and 2D planar drawing designs in different fields of architecture, engineering, and product design. The principle of workflow with Rhino-Grasshopper is to define a virtual model and to change the parametric condition of this model to achieve the design needs by the user. Different from other programming languages, in the operation interface of Rhino-Grasshopper, there is no need to write textual code. Instead, the user can select different logical instruction elements present in the software system and combine them depending on the required design requirements. This produces intuitive and logical geometric results directly on the Rhino 3D interface.[6]

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5 cf. Arturo Tedeschi: AAD_ALGORITHMS-AIDED DESIGN,(2014) , Via Montecalvario 40/3 - 85050 Brienza (Potenza) Italy, ISBN: 978-88-95315-30-0, S 22

6 cf. http://grasshopperprimer.com/en/, (01.10.2019).

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2.1.1 Software used in thesis

Rhino-Grasshopper

The parametric design is a method, in which the creator firstly defines the operation steps, based on the different geometrical and mathematical relationships between values, points, lines, and faces. These are all established by different script components in the computer. After that, the algorithmic model generates the design results, following the specific terms of the parameters and their relationships. The modeling requires logic as well as a mathematical approach; otherwise, the particular shape generated by this method would lose its flexibility to modify it´s basic form because of the complexity of the generated models. Therefore, under the interface of the Rhino 3d modeling software, the Finnish programmer David Rutten developed a visual programming language, called „Grasshopper“, which is based on algorithmic logic. Through the implementation of the Grasshopper, designers can modify, establish, and combine diverse basic geometry with built-in tools within the application for different design demands. The algorithmic model can generate steps, which are based on programming logic that provides designers another approach apart from the traditional design method.[7]

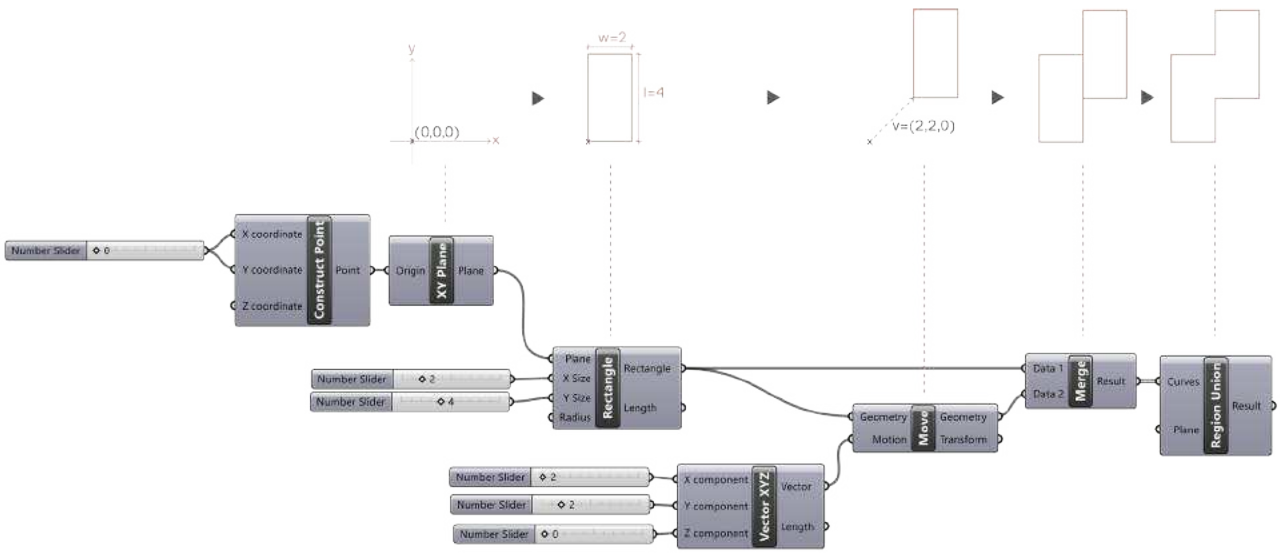

Fig. 1 A polygon created with Grasshopper
Firstly, I place an XY plane at the point (0, 0, 0) and create a rectangle with length 2 and width 4 on this plane. After that, I move this rectangle with vector (2, 2, 0), then merge those two rectangles together and use the region union component to combine them as a polygon.

The Layout Generator also adopts this way of thinking, and it is expected to simplify the concept of conceptual as well as collaborative living and divides it into different geometric relationships. This is important in order to provide the designer a logical way to find the suitable typology of residential buildings. Through this process, the user can clearly use the parameter of the value to influence the outputs, and also to improve the flexibility of the use of these design tools.

7 cf. Arturo Tedeschi: AAD_ALGORITHMS-AIDED DESIGN,(2018) , Via Montecalvario 40/3 - 85050 Brienza (Potenza) Italy, ISBN: 978-88-95315-30-0, S 15-30

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2.1.2 Concept: spatial flow algorithm

The concept of spatial flow algorithm concerns the use of space efficiently in order to meet the demands of the functions as well as user requirements of the design. At the same time, it is important to establish an open and flexible grid system for planning. Thus, the main aim of the space can be more adaptable and easier to reconfigure.

The design of a residential housing project is based on the type of dwellings and the circulation area within the building. The dwellings, in terms of space and geometry, are less flexible; therefore, in order to maximize the efficiency of the room layout, the first step of the Layout generator will be looking at the building area and then dictating the form and shape of the building. After that, fundamental to the algorithmic model is the relationship between spatial flows and the living area´s mobility. Public space represents an important area of a community, as it adds to the social interaction within neighborhoods and visual contacts with the surrounding environment. These decisions are viewed in six steps from design procedure of the algorithm: analysis, building outlines as well as flow line, grid, room dimension, room program and floor plan layout.

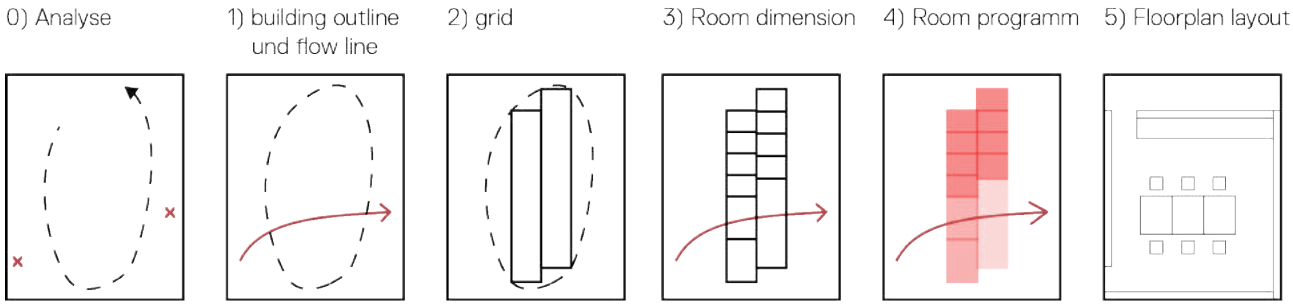

Fig. 2 Design procedure of the algorithm

Nevertheless the data input, the assumption building area will be transformed through the algorithmic model into a grid system. Then it will change the dimension with the flow line, and after those blocks will be classified into different areas, such like, the circulation area, living area, and common area. In the end it will be generated into a floor plan.

Therefore, the changed complete diagram drawing will be generated as the outputs from each step in the algorithmic model, so that the design demands and its corresponding solutions can be viewed step by step with several discrete but fixed operations.

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2.1.3 Literature review

The establishment of the algorithm model in this thesis will be divided into three aspects, namely, input data, operation process, and output data. In architectural design, the input data is the information, which is known, such as the number of required room or the size of the building site. The operation process consists of how we use our various design choices and how that input data is manipulated. Finally, we can obtain corresponding results like the 2D architectural drawings or 3D architectural models with the help of computer calculation to find the output data.

Kremlas

Kremlas is a good example of an algorithmic design tool. It´s input data consists of the number of rooms, the size of the room as well as the relative position of each room. Kremlas will generate a complete room plane according to the geometric relationship of each room.

Kremlas is the result of a research project, whose purpose is using and exploring different algorithms to solve layout tasks in the building environment. A generative circularly coupled design environment will be developed, which allows flexible definition and exploration of the search space rather than simply pairing and comparing the optimal parameters under a single condition. This is unlike other creative computer-aided design methods or developed building systems that only produce graphical inspired results for the design. Thus, the operating system of Kremlas can generate the available room layout directly, based on the input data and parameters entered by the user. This result of the different outcomes in Kremlas is a clearly defined output data, and is referred to as the room layout. Moreover, the mixed-use of the algorithm is also an important issue of Kremlas, which has options such as ball packing, the k-D tree Voronoi diagram...etc,. Different algorithms are used to develop the comprehensive interface of Kremlas. The following image is the Kremlas operating interface.[8]

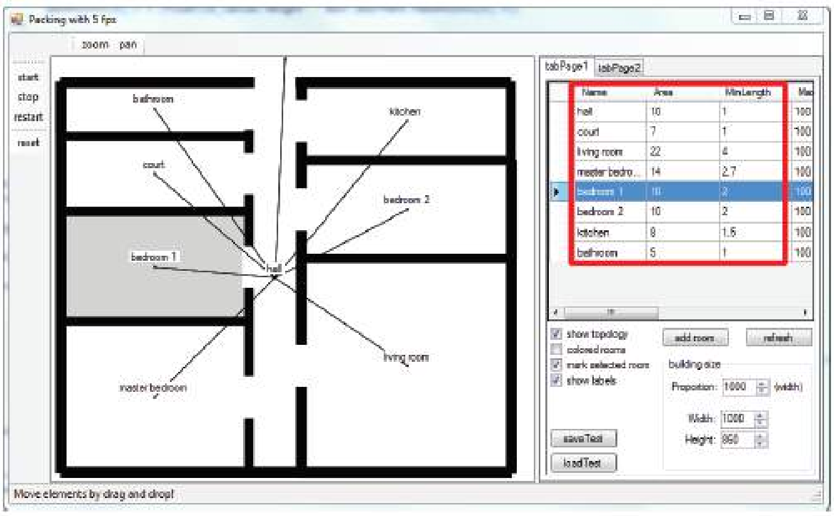

Fig. 3 After the import of required rooms and its sizes, the Kremlas can generate a geometrical solution of room layout according to the required room adjacencies (topology)

8 cf. Dirk Donath, Teinhard König, Frank Petzold: KREMLAS Entwicklung einer kreativen evolutionären Ent wurfsmethode für Layoutprobleme in Architektur und Städtebau,(2012) , Verlag der Bauhaus-Universität Weimar, ISBN: 978-3-86068-471-9, S 20,S21

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A layout is an arrangement of various elements for a particular purpose in a given space. Layout problems can occur in many areas. In traditional design (non computer-based support generation system), when solving the floor plan layout problem, it is usually important to come up with some design concepts first. These concepts must be considered satisfactory to meet all the criteria defined in the design task. Developed solutions, using this design assumption, will be continuously reviewed and refined throughout the process. The premise of the program is to reduce the complexity of the design task by using it as the universal solution as much as possible. These concepts or models provide a framework for the floor plan layout design. This workflow can be described as a top-down design strategy, in which the functional requirements are usually subordinate to task statements. Besides that, the creative development of design tasks is largely independent of functional optimization under this approach.[9]

In contrast, the solution to automate design tasks with the computer-aided layout design method has nothing to do with design intent or subjective thinking. Rather, some criteria must be considered when solving layout problems. For example, elements should be as non-overlapping as possible and their organization should be as spacious and efficient as possible. Nevertheless, it should be noted that the design task cannot be solved only by the optimization method because it´s intent cannot or can only be partially realized. Therefore, different algorithmic applications in the Kremlas project have revolved around a strategy which allows the user computer-aided layout design flexibly to combine and interact with different algorithms to optimize and generate floor plans.

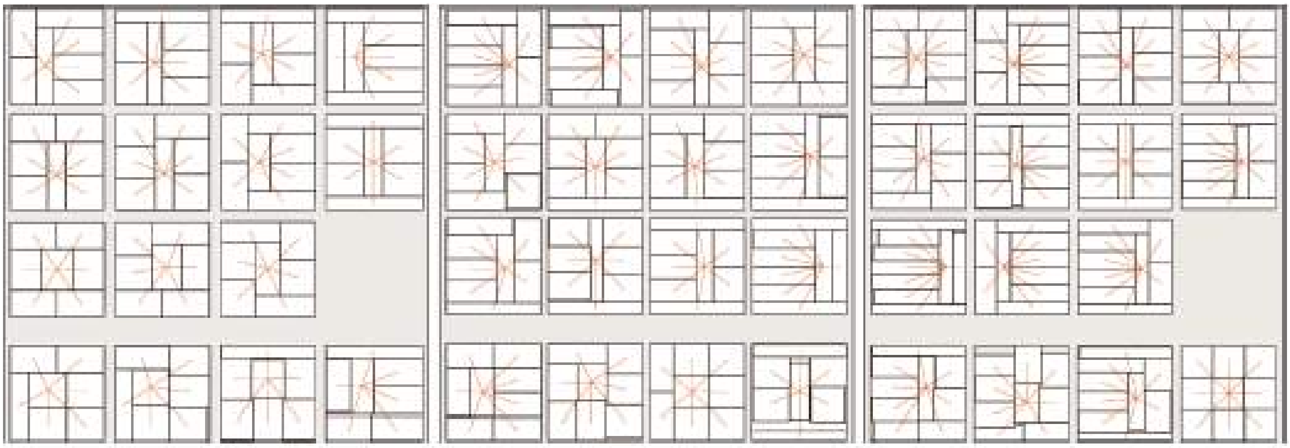

Fig. 4 Possible results after the adaptation of different requirements

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9 cf. Dirk Donath, Teinhard König, Frank Petzold: KREMLAS Entwicklung einer kreativen evolutionären Entwurfsmethode für Layoutprobleme in Architektur und Städtebau,(2012) , Verlag der Bauhaus-Universität Weimar, ISBN: 978-3-86068-471-9, S 157-S159

Eva

The other similar software is Eva, whose system is similar to Kremlas. The main difference is that Eva can further import input data, such as various types of circulation and building site areas. However, the final generated result is based on the combination of the circulation area and the type of the building form. As an IT tool for architects and planners, Eva was jointly launched by SWAP architects and Caramel architects in 2017. It can also save time in the early planning stages in terms of room function planning, the diverse developing possibilities of the building site, and building plan drawings.

In the operation interface, Eva allows the import of a room function program from an excel list. After that, the required room area will be displayed from this list in tables and charts. Then those room blocks will be placed in the room plan, in accordance with different criteria and possibilities of building regulations. This can be represented in instances such as lighting conditions, building typology or the outline of the building. Additionally, Eva can generate several suitable room layout plans at the same time and allows the user to move as well as adjust the position of the room blocks within the plans manually. [10]

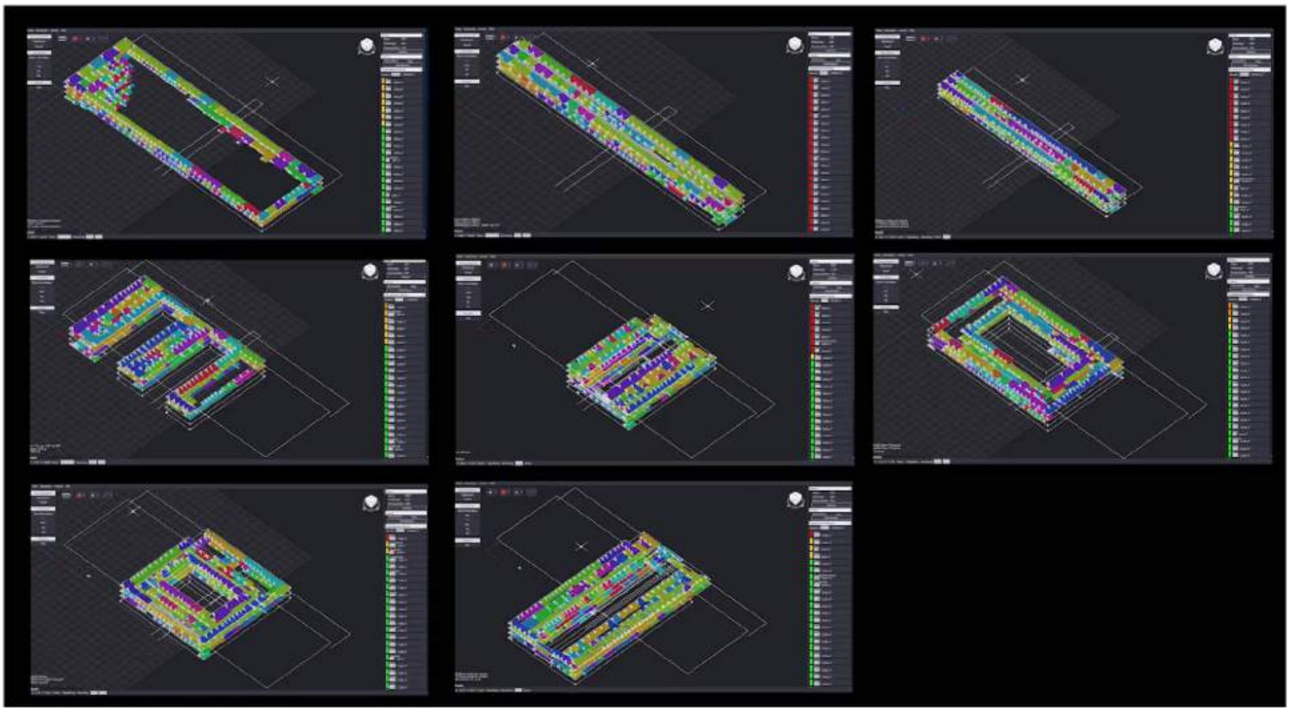

Fig. 5 EVA can generate layouts according to different typologies

10 cf. http://www.rapidlayouting.com/de/, (10.10.2019).

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2.2 Conceptual and Collaborative Living

The planning of residential housing focuses on the functions of architecture and space itself. When we compare today's built environment, there is constant pressure by the increased pace of mobility and society. Thus, it shifts the requirements of architectural structure. As a result, various aspects of future prospects have to be taken into consideration and discussed.

Conceptual Living: Reconfiguration, Simplicity, Instant Privacy

Conceptual Living can be described as follows: *"People increasingly design their living environments to match the stage of life they are in as well as to meet their situational needs and attitudes."* [11]

The Zukunftsinstitut, one of the leading institutes for trend and future research in Europe published a paper called the "Management Report Conceptual Living" which discusses a alternative to current architectural standards. This consists of three areas of innovation: reconfiguration, simplicity, and instant privacy. Reconfiguration represents the desire of flexibility and change, which shows the needs to meet the fast paced lifestyles of the future. As a result, it suggests a re-definition of the concept of the traditional function of rooms within a home. For example, a living room at night can be used as an office during the day. The previous grid room system will be replaced by flexible zones and furnishing will provide functionality and enable people to redesign their living space within shorter intervals redefining the concept of architecture.[12] Simplicity ensures people can reconfigure their home frequently and easily. The space and furnishings have to be designed for intuitive and quick combinations in order to create a new room layout, which can be adapted to people´s individual lifestyles. [13] The third trend is instant privacy. Through the unique design, private homes could be considered as an alternative accommodation during traveling. This tendency has lots of similarities with the simple function and is otherwise known as the plug-and-play principle. People seek a home away from home and expect to be inspired by other people´s living environments. [14]

Collaborative Living: Decentralized and Externalization

"During the Information Age, we learned and internalized through social media, how to share and exchange. Now these collaborative cultural techniques are also transferred to our daily living. Availability and access instead of ownership is the feature of those Shareness-Trends, and they are turning our previous ideas of living upside down. In the future, we will no longer live in fully

11 cf. https://www.heimtextil-blog.com/en/conceptual-living-an-analysis-of-living-redesigned-compiled-in-the-2014-heimtextil-management-report/ (01.11.2018).

12 cf. https://www.zukunftsinstitut.de/fileadmin/user_upload/Publikationen/Auftragsstudien/publication.pdf, S 6, (01.11.2018).

13 cf. https://www.zukunftsinstitut.de/fileadmin/user_upload/Publikationen/Auftragsstudien/publication.pdf, S 12, (01.11.2018).

14 cf. https://www.zukunftsinstitut.de/fileadmin/user_upload/Publikationen/Auftragsstudien/publication.pdf, S 16, (01.11.2018).

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equipped apartments, but keep only the most important personal and daily necessities for private living space - while others will be simply outsourced. Living wills become decentralized!" [15]

People, who have longer working hours, may not have enough time to stay at home. The needs of their house will have changed. From cooking in the kitchen to a luxurious bath, almost every living function in our home could be externalized. From the architect´s point of view, the quality of living in the future will no longer be dependent on the size of an area. As long as it includes the functions and opportunities for every-day errands inside the house as well as the surroundings of their home as well it will be sustainable.[16]

With those expansions, current issues in planning consist mostly of the struggle to adapt to the needs of work and life balance in modern society. "Conceptual Living" is not only the concept of individuality; it should also contain variations of house forms according to new family structures. A system that offers suggested solutions and visionary approaches towards the development of residential building projects in architecture and design is a much desired concept. All these aspects for the future, represent the need for our living space to be adapted to our rapidly changing lifestyle. This essay "Algorithmic Design for Residential Housing concept" is intended to provide the answer of conceptual and collaborative living. The concept defines a new regulation of spatial relationships in house typology that has the potential to continuously generate as well as to adapt occupants´ living environment. Therefore, this chapter will address the spatial function of the building in three parts, namely, the circulation area, the dwellings, and the mixed-use rooms. Moreover, they represent my three concepts of „Conceptual and Collaborative Living", encourage connective relationships between neighborhoods, externalization of living functions, and enhances the reconfiguration.

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15 cf. https://www.zukunftsinstitut.de/fileadmin/user_upload/Publikationen/Auftragsstudien/publication.pdf, S 12, (01.11.2018).

16 cf. Gatterer Harry, Baumgartner Michael, Seidel Adeline, Varga Christiane: Zukunft des Wohnens,(März 2013) , Robert-Koch-Straße 116 E 65779 Kelkheim, ISBN: 978-3-938284-72-8, S 30

2.2.1 Concept

Encourage Contact: The Corridor System

The central idea of this chapter is to create a vibrant public space reflective of the lifestyle of the community in order to meet the demands of complex and socially diverse individuals. Community residential housing is an urban-planning concept. It concerns the public properties of a community, encouraging resident interaction, and is built in reference to its social function. As a result, this assignment of residential planning has become a way to create a "communal life".

The corridor system provides continuous connection as an access point to the separate apartment units within the building. For this reason, it may be also an effective place for social interaction. The problem is that whether inside or outside, the location of the corridor, which is long and not easily managed, In order to save on costs, the access point of corridor system inside the building is usually narrow and placed in the middle of the building or as a buffer zone lies on the north side of the building facing the street, where there is no sufficient sunshine. Besides that, there are other critiques about the externally located corridor access. The openings of apartments are facing towards the corridor, for instance, facing the street, where the inhabitants of the neighborhood or the passersby can easily look into the living area of the apartments. Since the pathway provides the only function for comings and goings it needs to be incorporated within the design.

However, if we placed the corridor properly within the building and overcome those disadvantages, it may be a suitable element for the concept of collaborative living due to its mobility and efficiency of access. The dimensions and the functions of the apartment's entrance area would be taken into consideration due to its connection to the circulation area and the social interaction among the neighborhoods, the entrance area of the apartments represents a significant location of residential housing. This can be observed not only as a buffer zone facing the common areas but also as a semi-public space between neighbors.

Externalization of living functions: Mobility and the location of mixed-use rooms

Space usage can be planned differently and depends on the variety of the situation. A designers main questions in this case are: How long are we staying at this space? How many people are sharing this space? How can we connect those spaces?

Making the externalization of living functions more affordable are the key if we want to plan a collaborative community. Thus, the focus is on the increasing conditions for sharing spaces and communal areas, in order to make the whole community more attractive, and contribute to blur the boundaries between neighborhoods.

The apartments, communal areas, or shared spaces are developed together as a complex spatial structure that allows the residents of apartments an easier usage of the public space near their homes as an extension of their living place. Due to flexible working hours, the meaning of residen-

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tial housing has changed over the past years. It is not only a place after working, but also a place for working. A room can embrace and consist of more than one function. It is only dependent on the user as well as the installed infrastructure and access to the exterior. Therefore, the influence of the spatial flow within the building has to be taken into consideration in order to create a flexible and diverse layout. For example, a room with a two side opening facing exterior has more advantages in mobility than the room that has only one side. Hence, in my concept, the mixed-use room should be placed in the knot point of the circulation area nearby the access point of apartments in order to increase the accessibility of the space used. This creates an area which encourages a positive impulse within the living community.

Reconfiguration of living functions: Small apartment

The reconfiguration of space in modern residential architecture has been considered in the form of infrastructure element installation, the character of space is dependent on the function of these elements. The bedroom is the room with the bed; the bathroom is the room with the bathtub; and the kitchen is the place with a cooking plate. They all reflect a feature of space to satisfy our daily life activities. For us, building a closet or installing an IKEA kitchen cabinet is an easy and flexible way to configurate the function of the room. The reconfiguration of space is a strategy, which allows functions to be constructed as substance.

The change of such a multifunctional room has the meaning of connecting different functions with the same infrastructure installation. A home office or a living room can be rearranged to create the same space. After all, both have electricity, internet, and a table. Nevertheless, this is not easy to achieve with the involvement of more than one person. If we still want to pursue conceptual living in our communities, self-building is necessary. It allows residents to construct their home in way that decreases the cost, increases the flexibility of space to be used according to personal preferences, encourage trust and relationships during the building process and doesn't require outside help to complete. Moreover, the residents will not criticize their own work. Due to the externalization of residential functions, the housing spaces will be able to be reduced to small-scale apartments. As a result, the reduction in the residential area will make it easier to change interior design and to make home ownership more accessible.

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2.2.2 Research

Project: Faelledhaven residential complex, Kopenhagen, Denmark
Architect: DOMUS
Year of construction: 2006

The Faelledhaven residential complex project (2006) by DOMUS was given an approach to minimize the negative aspects of a long corridor system and turned them into positive aspects. Thus, the apartment units are arranged in a shelf system and are connected with the external access gallery. The façade, facing the entire green yard, consists of different elements such as windows, loggias, terraces, and balconies, which represent various types of apartments. The bridge access provides a way to a communal public space, which is a vibrant feature of the design. The pathway is wide enough to create a space for social interaction. As seen in the image below, the bridge and apartment units are connected with an extra platform. All these gaps and niches under the bridge construction provide a small buffer zone in front of the apartment entrances.[17]

Fig. 6 Façade of Faelledhaven residential complex

Fig. 7 Externally located corridor access

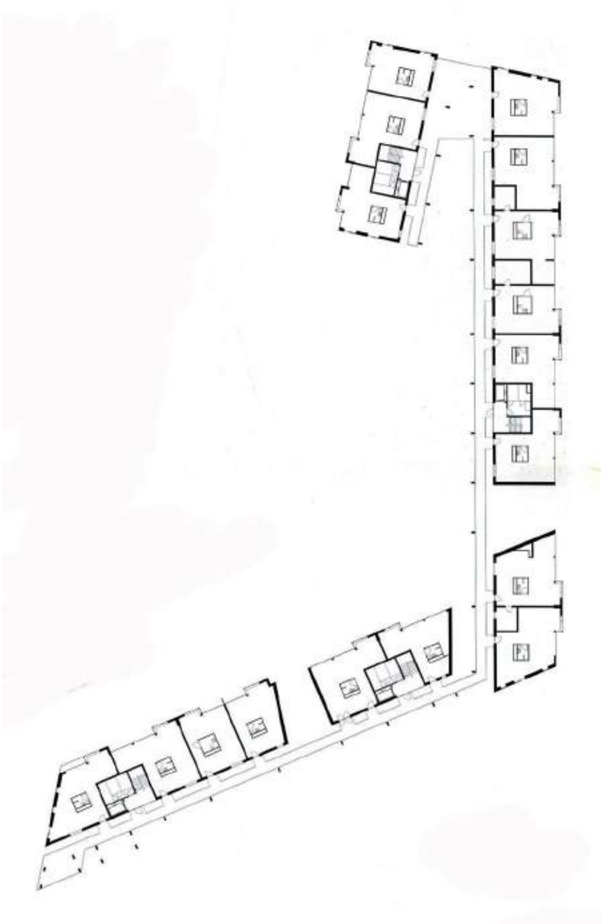

Fig. 8 Site plan

17 cf. http://domus.dk/node/39 (03.05.2019).

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Project: Bike apartment house, Taipei, Taiwan
Architect: Chia-Chang Hsu
Year of construction: 1968

The bike apartment house on Jilin Road in Taipei (1968) by the Taiwanese architect Chia-Chang Hsu, incorporates a concept that displays the dynamic spatial flow in architecture. This four-story property is located on three-way junction nearby main road, where the price of floor influences the room layout within a building. However, unlike the other apartment houses in Taipei, the architect came up with a different solution; an external access spiral parking ramp with apartment units on each floor. It created a wide space with a general stairwell and allows for more natural light, and fresh air. Furthermore, the residents can directly ride their bikes from the main road to the entrance of the apartment. In this case, the spiral parking ramp is not only an extension of the road, but it is also well-functioning and another lively public space among residents. Additionally, it combines at least three functions, walking, parking, cycling and entrance. In comparison to the other apartment houses in the city, the entrance of apartment has the ability to gather those four groups of people at the same time. [18]

Fig. 9 Front view of apartment

Fig. 10 Spiral parking ramp

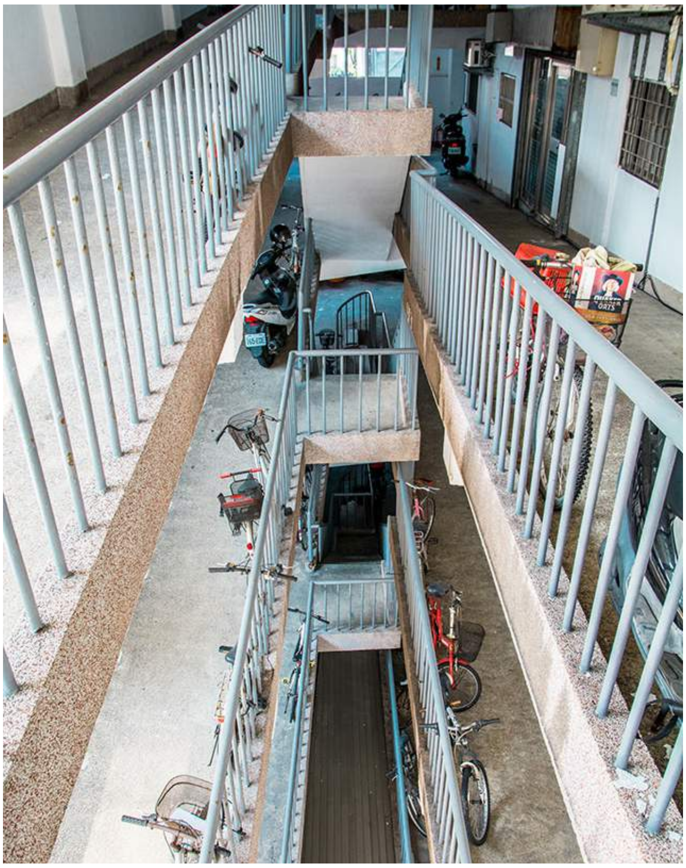

Fig. 11 External access spiral parking ramp with apartment units

18 cf. Ching-Chih,Lee (李清志). (2013). *Bike apartment house*(摩托車公寓). http://www.businessweekly.com.tw/KArticle.aspx?id=50061 (03.05.2019).

Project: NE apartment, Tokyo, Japan
Architect: Nakae architecture
Year of construction: 2011

The Japanese architecture office Nakae has created a direct open space in the middle of an apartment house. It is built for the residents to have easy access from their motorcycles to the main road. Moreover, it also encompasses the connection of the center of the complex and each apartment unit. The public space of this project and the previous two examples demonstrated their quality through a minimize floor area and a created communicative and dynamic space within the building. By observing these examples, we can figure out that the dimension of access plays a significant role when considering the social interaction dynamic within residential housing. Not only does an enlarged access area have the ability to contain more people, it also has more possibilities to increase its functions of living. The entrance of NE apartment is actually the garage, and has become a social place for many of the motorcycle enthusiasts. [19]

Fig. 12 Inside view

Fig. 13 Entrance as social place

Fig. 14 Model of NE apartment

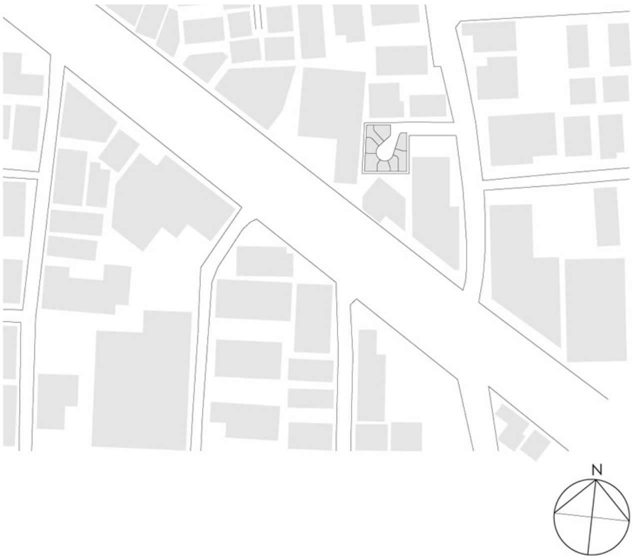

Fig. 15 Site plan

19 cf. http://www.nakae-a.jp/works/2011/02/ne-apartment.html (03.05.2019).

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Project: Share House LT. Josai, Nagoya, Japan
Architect: Naruse Inokuma Architects
Year of construction: 2013

Share House LT. Josai is a share house, which is designed by the Japanese architectural firm Naruse Inokuma Architects in Nagoya, Japan. In Japanese city there is low birthrate, and young people generally get married later. Hence, the share house has become very popular in recent years, where young people are encouraged to gain independence without actually having to buy their new place. Living together, sharing family responsibilities and various social events are promoted, with the community rejecting the idea of private family living. What is special about this project is that the spatial distribution is planned in three dimensions as the layout of the interior space. In addition to the individual's bedroom, all other spaces in the building are planned as shared/mixed-use spaces. The size of each individual room in this share house is 12.4 square meters. Meanwhile, the total floor area is divided by the number of residents, which is only 23 square meters and includes diverse mixed-use spaces as well as social areas.

Different from other share house designs, there is not only a common dining space in the center of the building of Josai share house, but also different spaces that are suitable for a single person to use within times of privacy. This means, that the sharing space areas are scattered in different corners of the building, and are not limited to the kitchen or the living room. As the shared space is integrated with the whole indoor circulation space, the inhabitants can engage in diverse social activities from different corners of the building, for instance, dining, resting, chatting....... etc. Through the visual connection within the building, the open kitchen, the dining space, the circulation space, the stairs, and the private corner are connected with each other. Therefore, the residents can easily combine the shared space outside of their room as an extension of the private space according to their personal needs.[20]

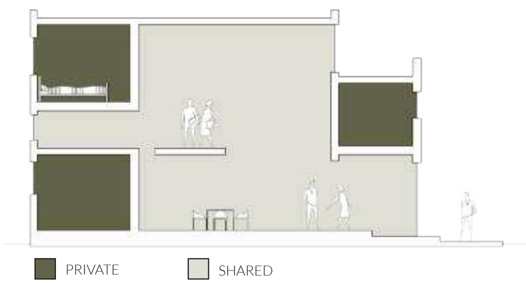

Fig. 16 Section plan

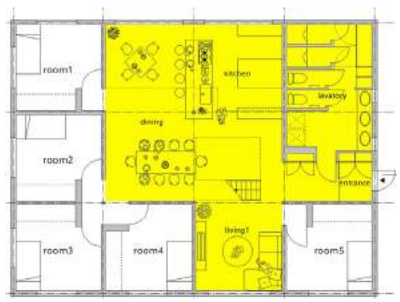

Fig. 17 Ground floor plan


Fig. 18 Share place within the building


Fig. 19 external appearance of Josai share house

20 cf. http://www.narukuma.com/ (Zugriff am 10.01.2019).

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Project: Tila Housing, Helsinki, Finland
Architect: Pia Ilonen, TALLI Architects
Year of construction: 2011

This six-story apartment in the Arabianranta district of Helsinki is located southwards through a fully glazed façade and is connected with a balcony running the whole width of the space. It contains 26 loft apartments. The basic residential unit is 102 square meters wide and five meters high. Moreover, the design concept of this apartment complex adopts an open building system. After the architect planned the overall residential structure frame, the interior decoration, room compartment and bathroom equipment of each residential unit was designed, constructed as well as installed by the residents themselves.

However, the original intention of this design was not only to provide a loft-type architectural form for the inhabitants, but to increase the possibility of the incorporating the inhabitants own design in accordance to their lifestyle. Therefore, the most basic building structure was used. The central concept of Tila is to design each apartment as a “large habitable room“. The architect minimized the infrastructure, which is needed for each “large habitable room“ and left only the drain of the wet space as well as the water supply and water isolation. All this provided the residents the option to choose, whether or not to build a gallery structure in this large room. In this case, the role of the architect is not just one of planning, but of also providing assistance to the resident‘s DIY (Doing in yourself) project. The primary aim is that the residents get the best service for minimum costs and maximum space. [21]

Fig. 20 external appearance of Tila Housing

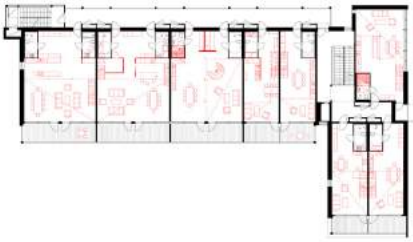

Fig. 21 floor plan

Fig. 22 Inside view

21 cf. www.talli.fi (Zugriff am 10.01.2019).

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3. Layout generator

3.1 Transform

3.2 Select

3.2.1 Main corridor path curve

3.2.2 Secondary path curve

3.2.3 Staircase path curve

3.3 Determine

3.3.1 Circulation zone

3.3.2 Residential zone

3.4 Extrude

3.4.1 Structure element

3.4.2 Building data

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3. Layout generator

The following concept was established and defined according to the topic of “Conceptual and Collaborative Living”. This architectural project is specified by three separate identifying factors; the mobilization of mixed-use rooms, a well-established circulation area and a small scale apartment to building generator layout. Through the use of an algorithmic model, the goal is to establish an open grid system, so that space can be more adaptable and easier to reconfigure. The main concept of a layout generator is to transform the current input curve of a building into a geometric square curve. This will be done by adjusting the geometric square curves into the architectural plane as the output of the generator using the available spatial flow as the adjustment curve.

The four design decisions from chapter 3 have also been restructured into four steps; transform, select, determine and extrude. In the first step, in order to represent the new spatial flow, the specific constraints of the site area will be transformed into housing blocks. Then, the specific curve within this output will be selected by the simplified spatial flow curve as the circulation path curve. After that, the output of step 2 (circulation path curve) will be subsequently applied in alliance with the output of step 1 (assumption housing blocks) to determine the output in step 3, the basic layout „s“. The basic layout „s“ will be extruded into a complete digital 3D building model in step 4.

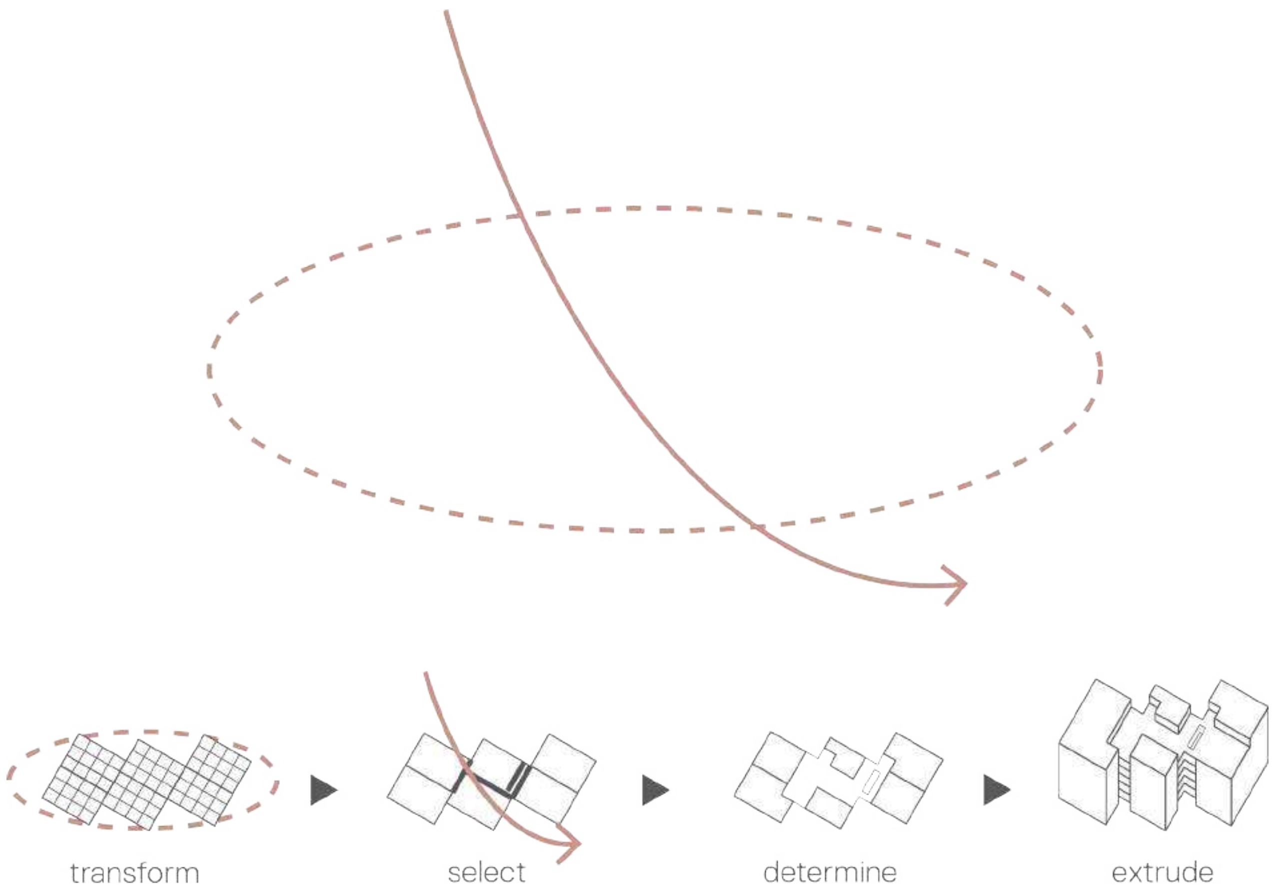

Fig. 23 four steps of Layout generator

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3.1 Transform

After performing site analysis, sketches of the diagrams and graphics are created in order to understand the relevant information of the given environment. This includes the neighborhood context, circulation area, the topography of build environment and basic morphology of design. Firstly, a summarization of those curves as an approximate assumption outline for the new building area must take place.

As seen in the diagram below, we start out with a close periodic curve and transform it into a set of rectangles curves as assumption housing blocks. In order to change the view direction of the assumption housing blocks, they must be rotated from their centroid to adjust the edge of each rectangle curves on the perimeter of the whole transform polygon curve. The proportion of blocks is important in regards to the Layout generator as it affects the mobility and connectivity of the room layout. After the set rectangle curves are generated to approximate the geometry form of input curve, those blocks will be rebuilt in an open grid system. Then they will be subdivided into new blocks so they can be adjusted by changing the size of the subdivided unit.

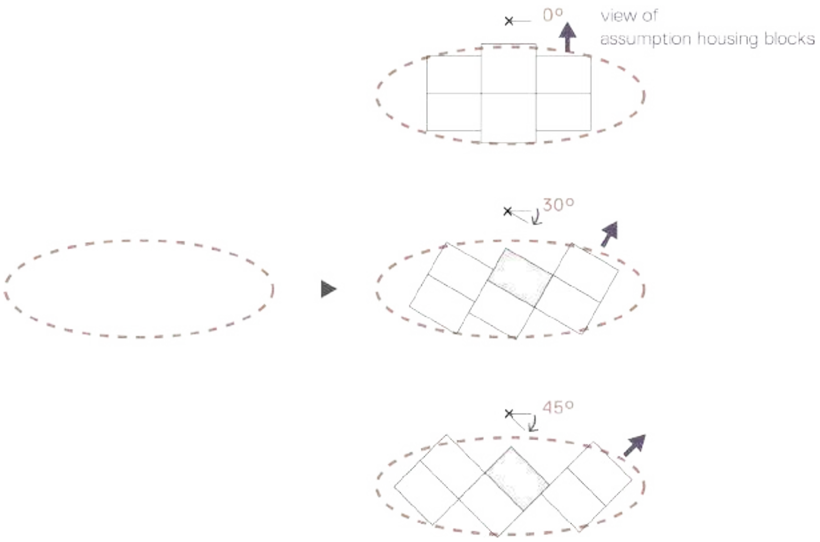

Fig. 24 views of assumption housing blocks

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Design procedure:

1. Input: Approximate assumption outline of the new building area

2. Parameter: Angle x°
   Rotates the assumption outline from its centroid A with angle x°

3. Parameter: Width (W)
   Distribute the rotated assumption outline from its centroid A to its right and left direction with the width (W)

4. Select the second intersection points of the first line and the first intersection points of the second line, create blocks with those two points

5. Parameter: Width (W) and Length (L) of the subdivide unit.
   Adjust the assumption housing blocks in open grid system, and divide them with input parameter.

6. Rotate the blocks from their centroid A with degree -x°.
   Output: assumption blocks and subdivided units

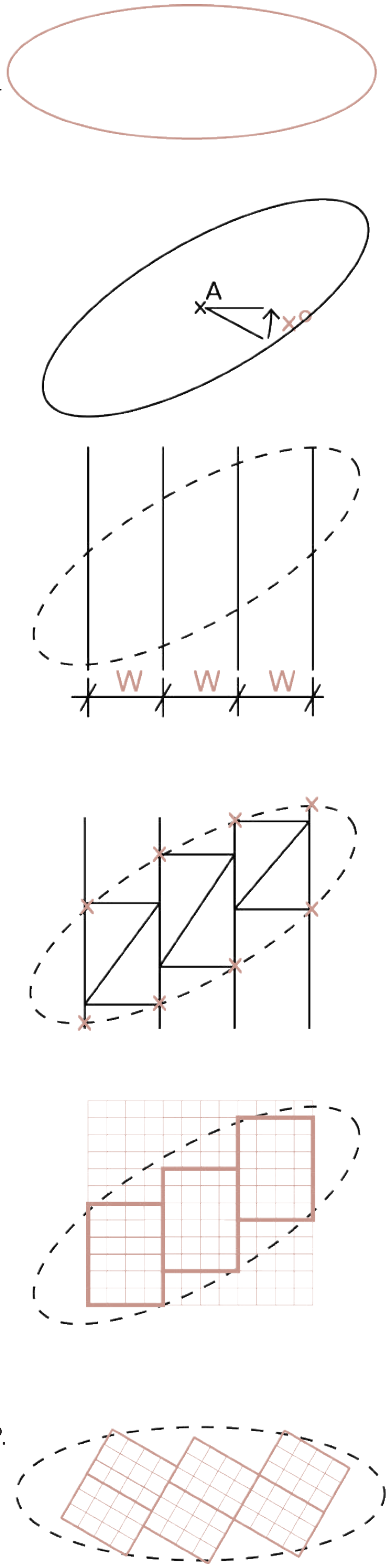

Fig. 25 Design procedure step transform

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Distribute the rotated assumption outline

In the first step, the assumption outline of the new building area is put into a rectangle. The width of the rectangle is the maximum distance between the X coordinate of points on the curve and the length is the maximum distance between the Y coordinate of points on the curve. The centroid of this rectangle curve is then found and applied as the center, then rotated on the input outline curve to the desired angle. After the post-rotated outline curve is shifted into another bounding box. Then, the width of the bounding box is extracted, and then the width is divided into the same length of segments that are needed. This makes it perpendicular to the sides of the other rectangle edge and is how the width of the assumption housing blocks is determined.

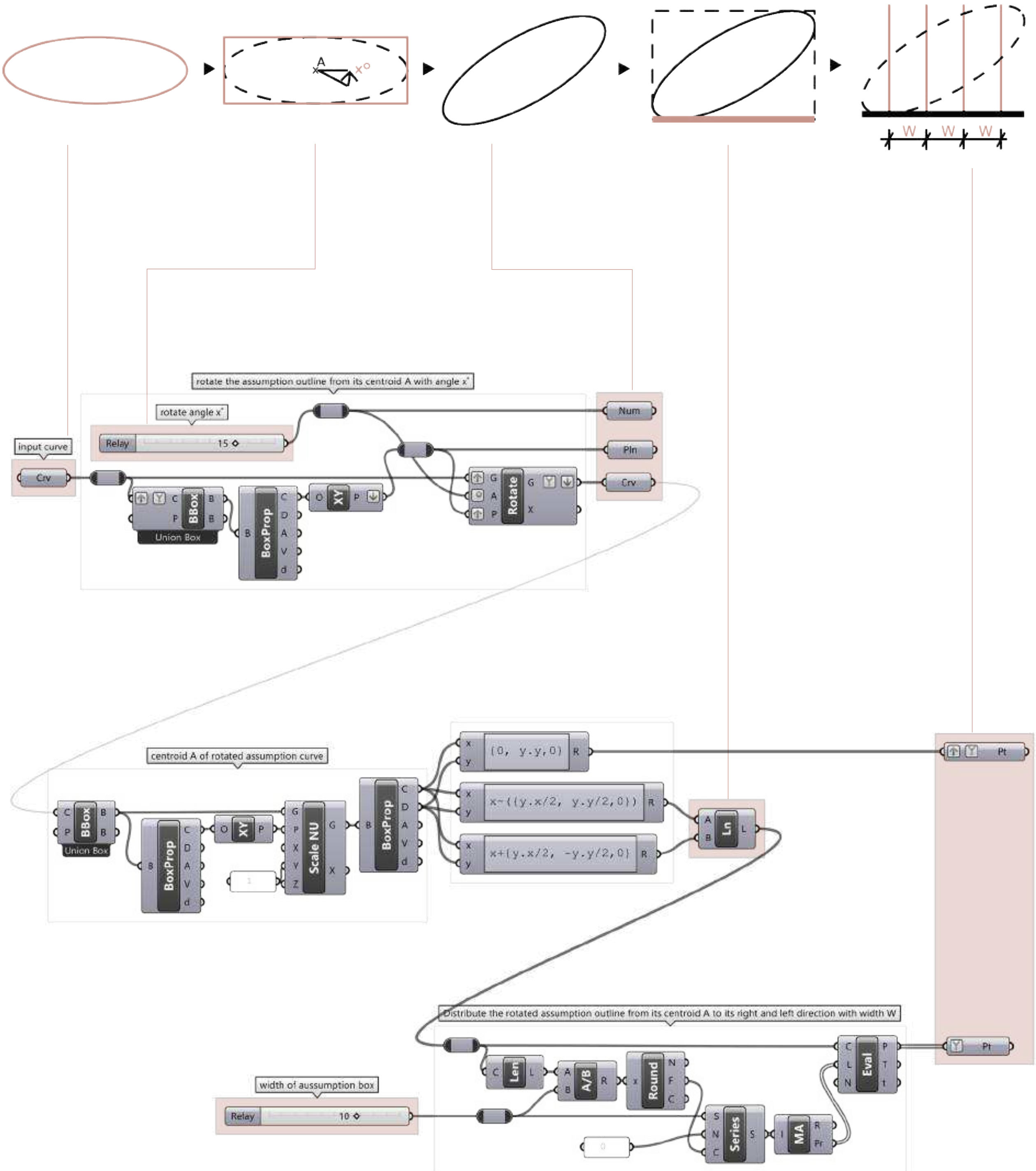

Fig. 26 Distribute the rotated assumption outline

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Create the blocks according to intersections on rotated assumption outline

Then, those vertical lines, which are generated from the edge of the bounding box, into rectangles, will be converted. This will be done by dividing the vertical lines on the bounding box into two groups. The first group is all vertical lines except the last one; the second group is all the vertical lines except the first vertical line. After that, the intersections of vertical lines are removed and the contour curves are selected from both sets. Then, the intersections on the nth line of the first set of vertical lines are placed. Lastly, the intersections of the nth line on the second set of vertical lines are placed, and the two middle points among the four are selected, in order to create a distinct rectangle, as shown below.

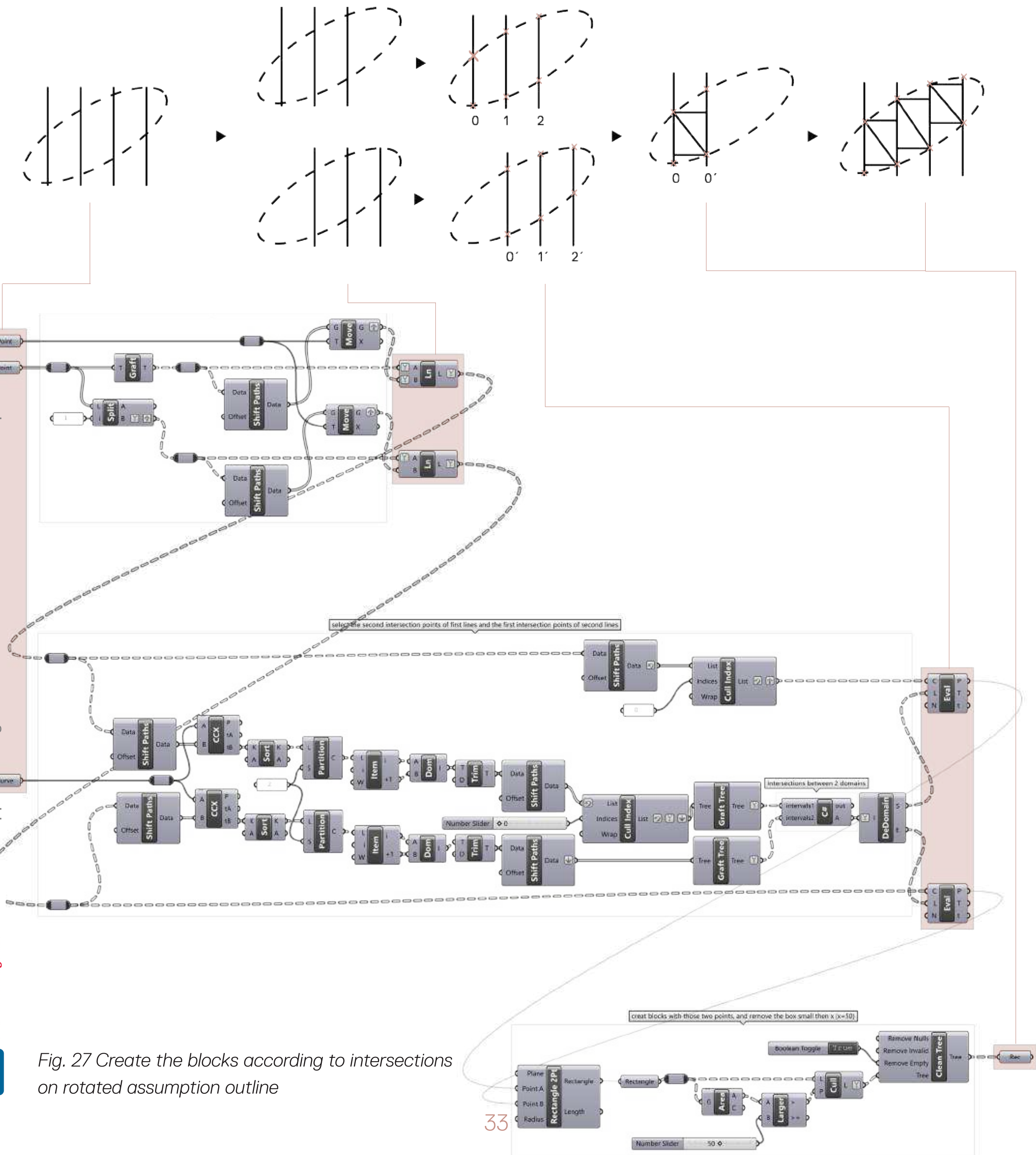

Fig. 27 Create the blocks according to intersections on rotated assumption outline

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Adjust the assumption housing blocks in grid system

In this step, the rectangles that have been generated by the outline curve into assumption housing blocks are adjusted and subdivided. This is done by selecting one certain point of each generated rectangles as reference points and then comparing their value on y-axis in order to get the lowest point. One must also set the length and width of the subdivide unit of assumption housing blocks and use it to calculate the new length, width and reference points. The length and width of the new rectangles are the approximate value from the original (L x W) with the new (L x W) of the subdivide unit multiple. Each position of new reference points is also on the approximate value from its original distance from the lowest reference point on the x and y axes (and width) of the subdivide unit multiple.

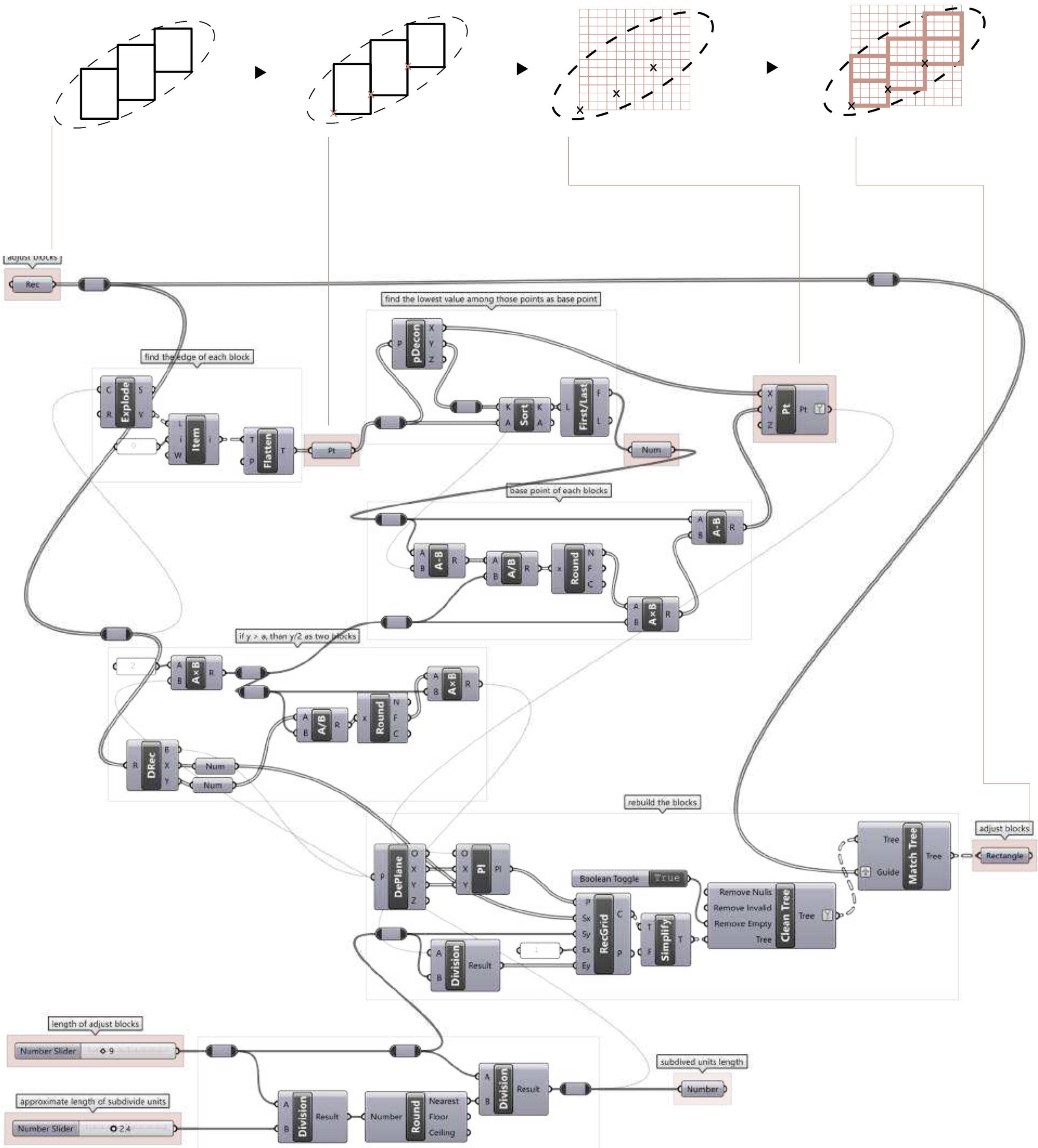

Fig. 28 Adjust the assumption housing blocks in grid system

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Step transform output: Assumption blocks and subdivided units

Finally, the assumption housing blocks are rotated back in the opposite direction from the center of the original outline curve as the output of the first step.

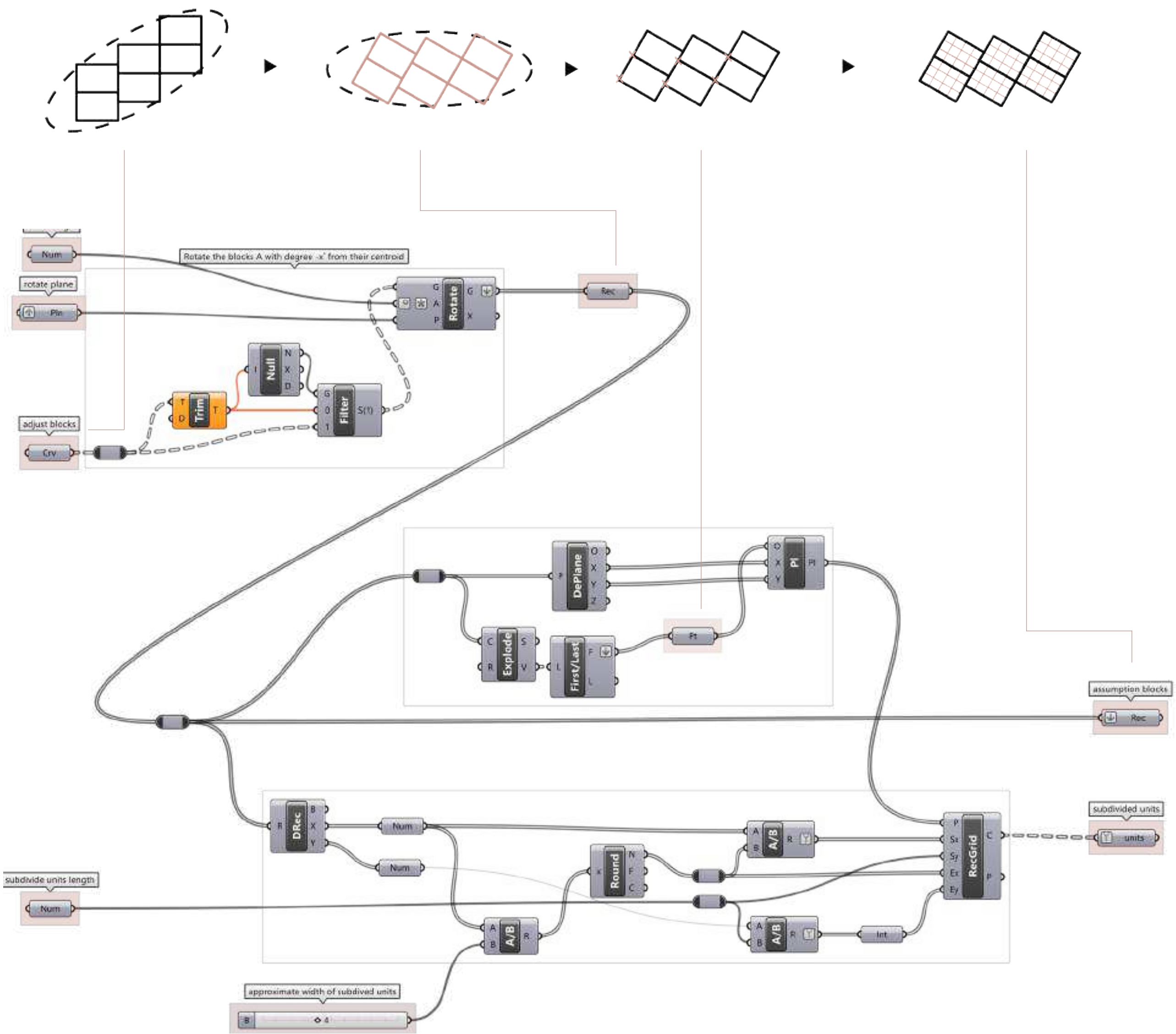

Fig. 29 Step transform output: Assumption blocks and subdivided units

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3.2 Select

In the second step of the process, an analysis of the intersection events among assumption housing blocks will be conducted. The specific curves for circulation area and residential area will be extracted and used to select the subdivided units. Lastly they will be combined into different closed curves as a basic building layout as the output data for the next step.

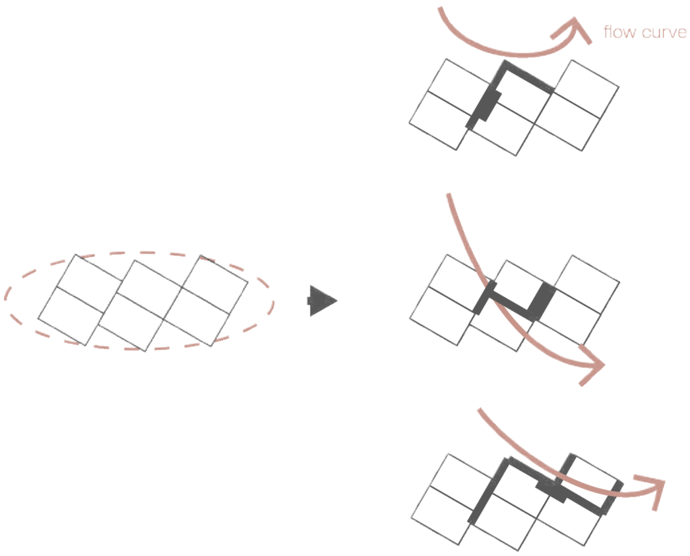

Fig. 30 Step select

Corridor access is one of the most effective options of connection for a residential building. In mathematical terms, this is done by connecting every unit with the shortest continuous polyline segment. Despite its effectiveness as a place of social interaction, there are some disadvantages of corridor access. One case being the entrance of each housing unit, where the openings are located directly to the main corridor or the location of the staircase, which is usually too far from certain housing units. In order to solve those problems, in this design, a semi-public space will be created between the corridors as the main access to the residential entrance. Hence, the initial state of the location of the main corridor must be provided so that the further output data can be generated within the assumption housing blocks curve. The flow curves will be used to select the line segments of the assumption housing block curves as the possible position of the main corridor. After that, the main corridor curve will be extended to the remaining blocks, which are not in contact with the main corridor curve. The extend line segments will be named the secondary path curve, and then the staircase curve will be generated from the secondary path curve.

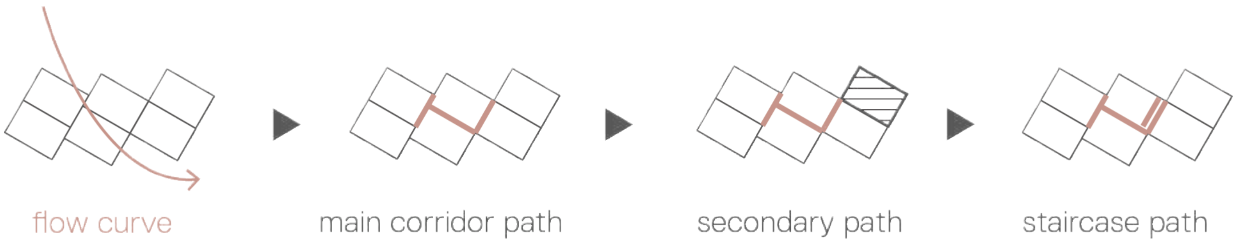

Fig. 31 three different paths will be extracted in step select

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Design procedure:

1. Input: flow curve

2. The distance sorted between each segment of the assumption housing blocks and flow curve, in order to find the nearest curve segments.

3. The nearest curve segments are selected, and combined as a main path curve.

4. The shortest combination that connects all remaining blocks as secondary path curve is then selected.

5. Then the secondary path curve is offset and scaled as a staircase curve.

6. The main path curve, secondary path curve and staircase curve are then combined to create a circulation curve.
   Output: circulation curve

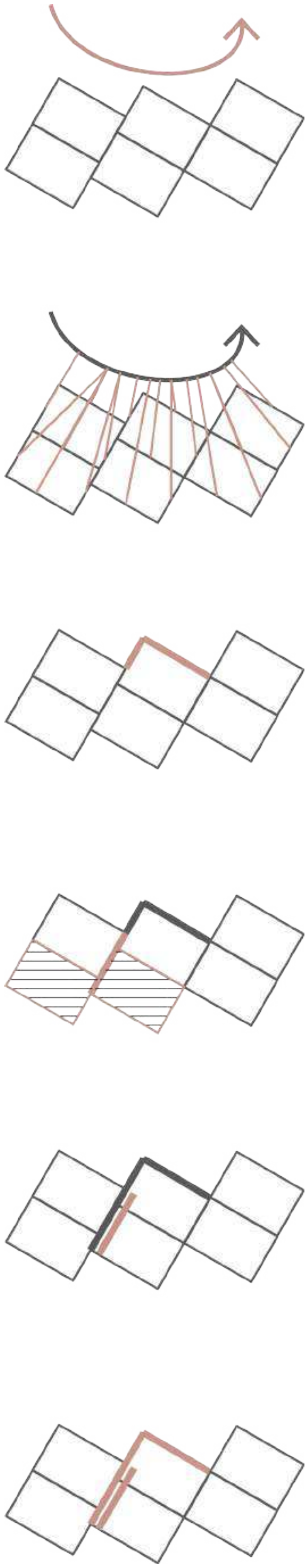

Fig. 31 Design procedure step select

3.2.1 Main corridor path curve

In this section, the spatial flow curve will be converted to the line segments on the assumption housing blocks. The first step is to find the distance between the midpoints of all the line segments from every assumption housing blocks and the spatial flow curve. Then the number of line segments is set and amounts as the parameter to select the line segments. These have the shortest distance from the spatial flow curve as main corridor curve.

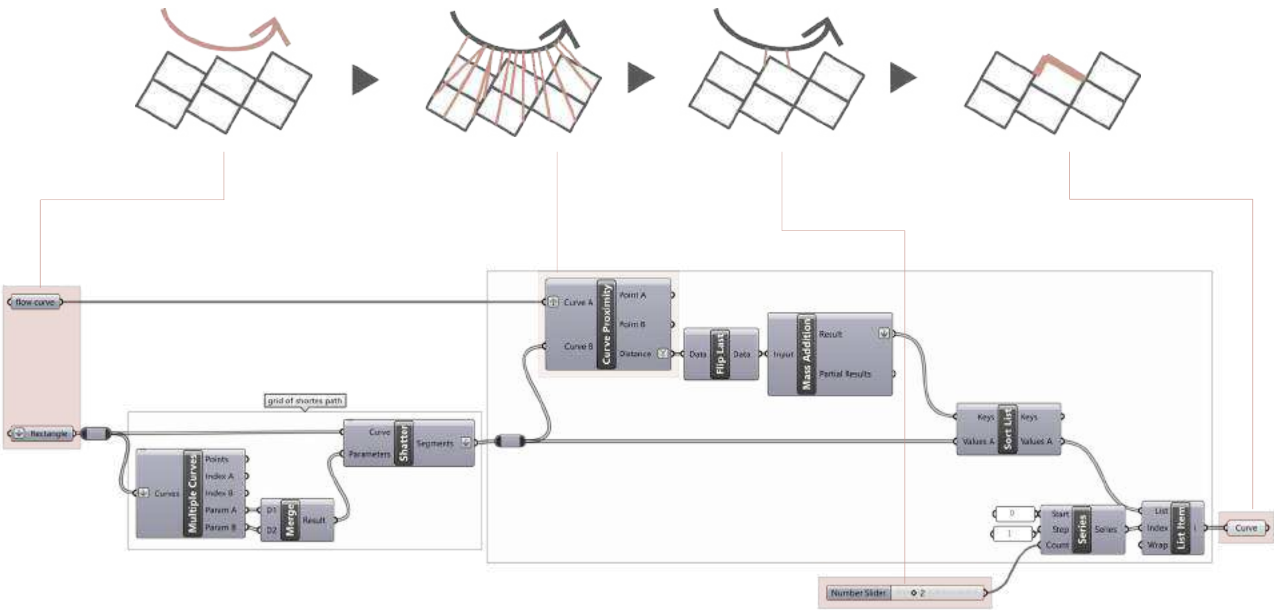

Fig. 32 Main corridor path curve

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3.2.2 Secondary path curve

The next step is to find the shortest combination of the possible secondary paths, which pass through all the remaining blocks as shown below, in order to find an ideal combination. After finding the combinations, the total length of each combination is calculated. After that, the value of total length is sorted in order to find the smallest one. Furthermore, the k-combination has to be reduced in order to avoid an unnecessarily long computation time.

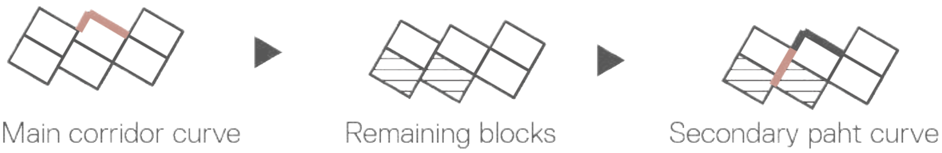

Fig. 33 Secondary path curve

Remaining blocks

After determining the main corridor curve, the next focus is between the main corridor curve and the remaining blocks. These remaining blocks are assumption housing blocks that are not connected with main corridor curve. First, the intersections from every assumption housing block curves are and the main corridor path curve are extracted. These newly extracted intersections are now applied to see if they are on the assumption housing blocks. Once the remaining blocks are determined, one can easily see on the diagram below that they are not in connection with main corridor curve.

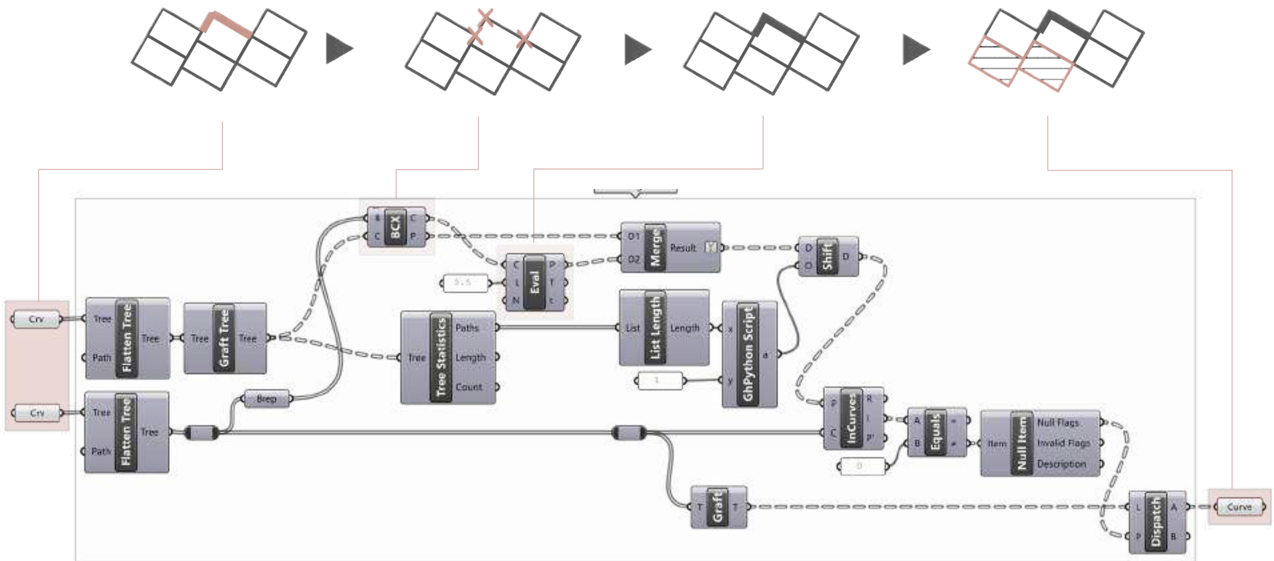

Fig. 34 Remaining blocks

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Possible secondary paths on assumption housing blocks

The next goal is to find the efficient path within the „assumption housing blocks“. First of all, one must assume that these paths will connect the intersection of remaining blocks. Then, the intersection is extracted among assumption housing blocks after an inclusion test of remaining blocks curve for those intersection points is done. Additionally, the intersection points from assumption housing blocks and the outline curve are also found. Lastly, a list is created that contains both the intersection points on the remaining blocks and on the outline curve.

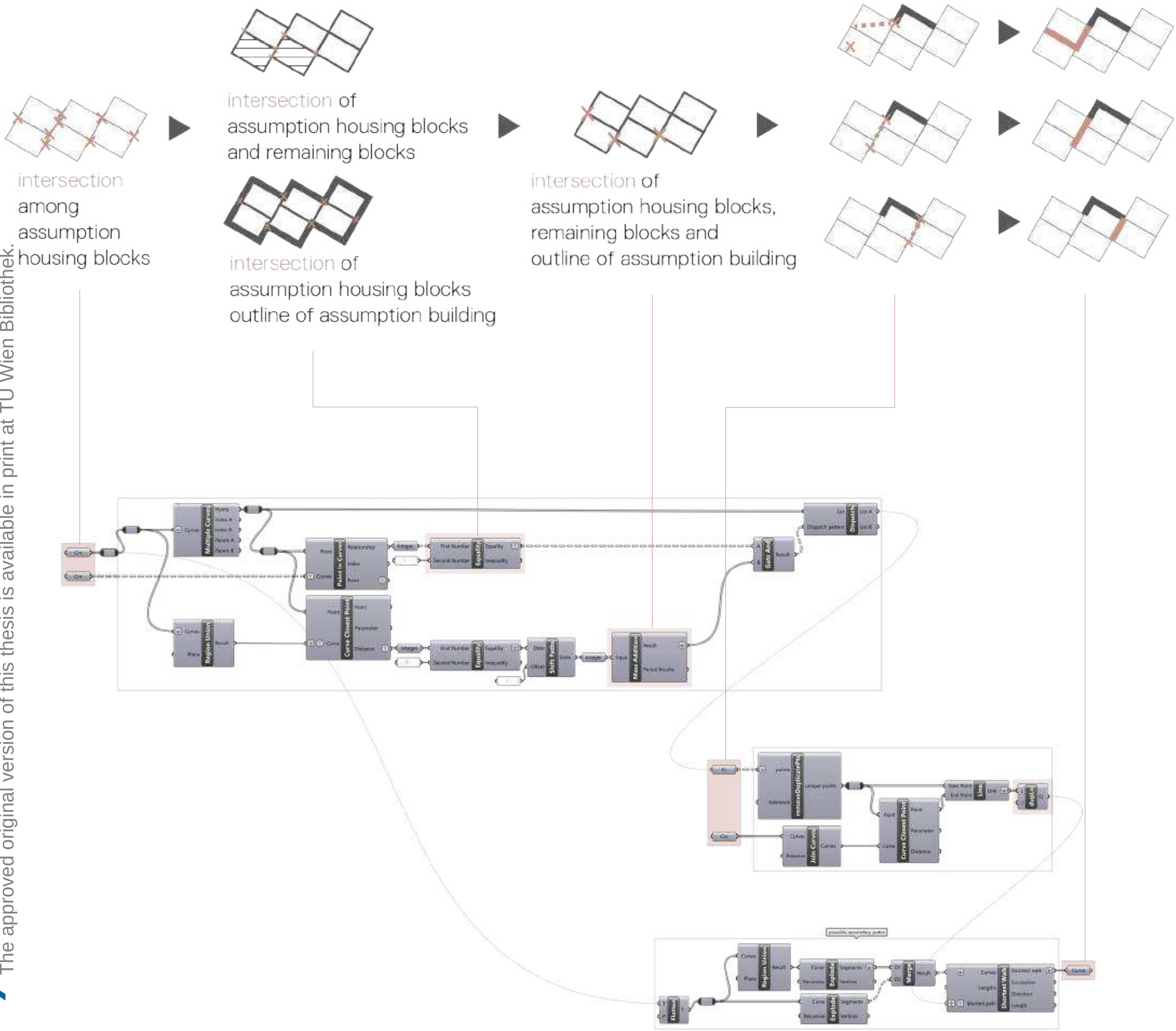

Fig. 35 Possible secondary paths on assumption housing blocks

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The shortest path combination that connects all remaining blocks

After extracting the possible secondary paths on assumption housing blocks, in this step the goal is to determine the shortest path that passes all the remaining blocks within the combination of all possible secondary path curves. Firstly, a list of the intersection events of each secondary path with the remaining blocks needs to be made. Once that is created, a secondary path combination that also passes all the remaining blocks will be selected. Finally, the shortest path among these secondary path combinations will be found.

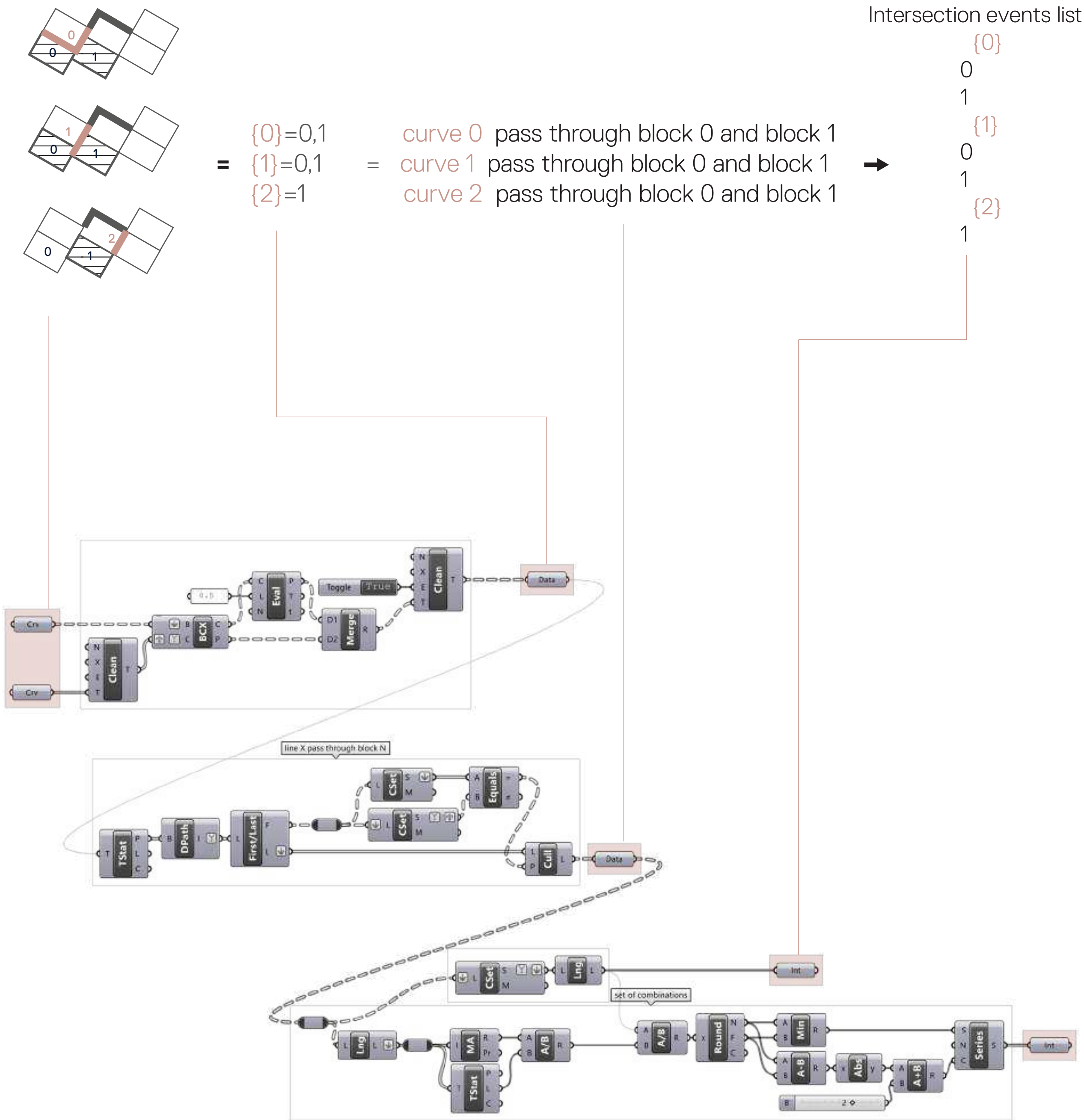

Fig. 36 The shortest path combination that connects all remaining blocks

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combination of all possible secondary path curves	Intersection events list	List length of Intersection events list	If combination connect with every blocks	Length of each combination	Shortes combination
C_1^3= {0},{1},{2}	{0}	{0}	{0}	{0}	{1}
	0	2	T	10	
	1	{1}	{1}	{1}	
C_2^3= {0,1},{0,2},{1,2} =	{1}	2	T	5	
	0	{2}	{2}	{0,1}	
	1	1	F	15	
C_3^3= {0,1,2}	{2}	{0,1}	{0,1}	{0,2}	
	1	2	T	14	
	{0,1}	{0,2}	{0,2}	{1,2}	
	0	2	T	9	
	1	{1,2}	{1,2}	{0,1,2}	
	{0,2}	2	T	19	
	0	{0,1,2}	{0,1,2}		
	1	2	T		
	{1,2}				
	0				
	1				
	{0,1,2}				
	0				
	1				

C_1^3= {0}=0,1 {1}=0,1 {2}=1 = curve 0 pass through block 0 and block 1
curve 1 pass through block 0 and block 1
curve 2 pass through block 1

C_2^3= {0,1}=0,1,0,1=0,1 {0,2}=0,1,1=0,1 {1,2}=0,1,1=0,1 = curve 0 and curve 1 pass through block 0 and block 1
curve 0 and curve 2 pass through block 0 and block 1
curve 1 and curve 2 pass through block 0 and block 1

C_3^3= {0,1,2}=0,1,0,1,1=0,1 = curve 0, curve 1 and curve 2 pass through block 0 and block 1

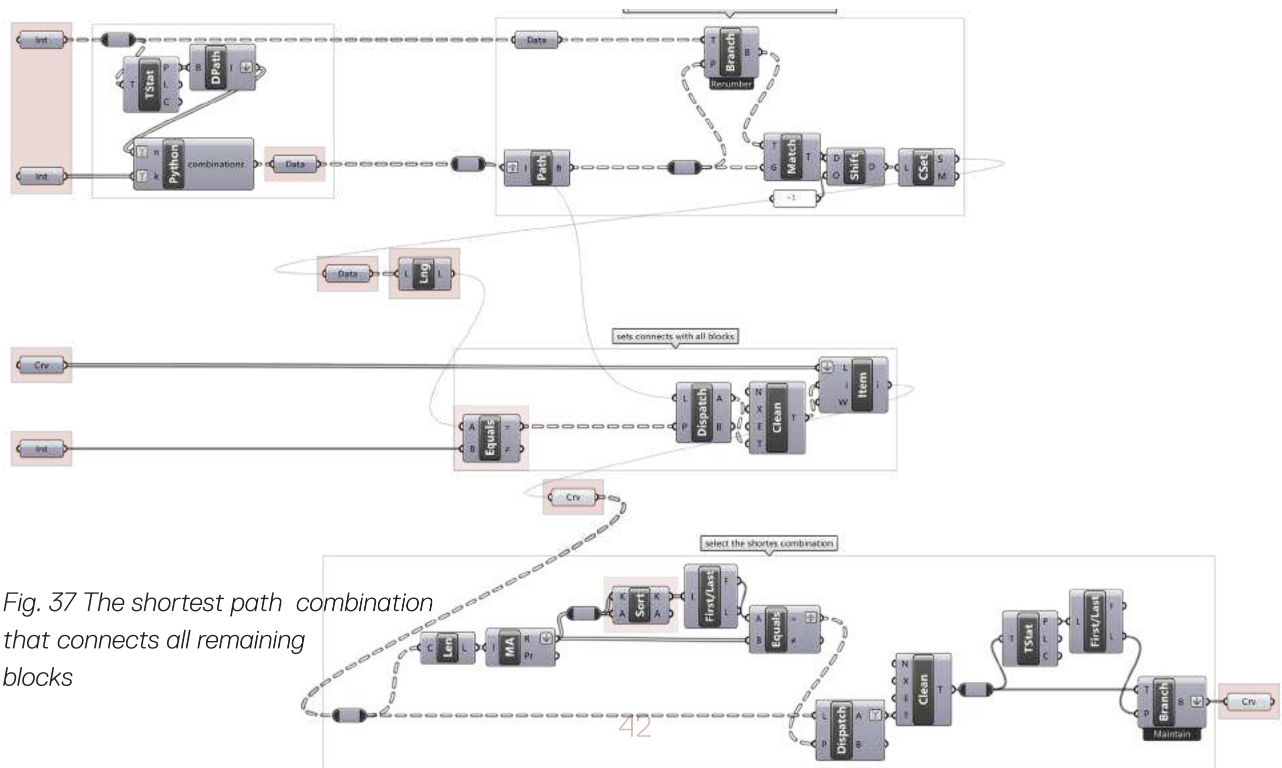

Fig. 37 The shortest path combination that connects all remaining blocks

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3.2.3 Staircase path curve

In the building layout plan, the staircase area is the node of the vertical connection of the building. In order to strengthen the connection between the residential communities and improve the shortcomings of the traditional corridor system, a stair area is placed in the secondary circulation area. This has several advantages. First, the secondary circulation area will be at the entrance area of the dwellings. This will prevent the staircase from being in a dark corner of the building, which will improve the vertical sight connection between the entrance areas of each floor. In order to execute this design, the secondary path will be selected and moved parallel to its original position.

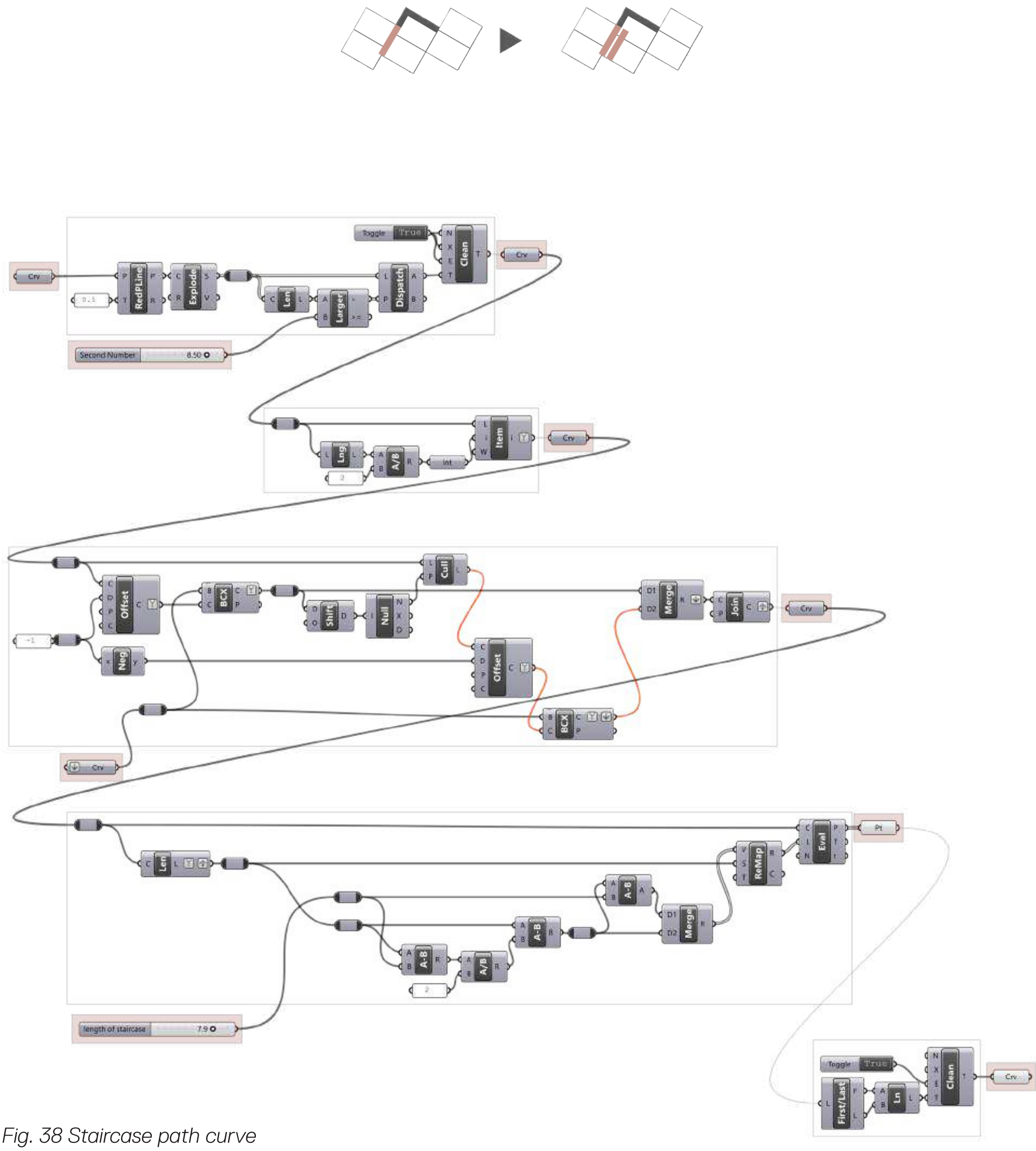

Fig. 38 Staircase path curve

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3.3 Determine

In this step, the circulation curve which was generated from step 2, will be used to select the subdivided units. It will determine the circulation area of the whole building, and furthermore help to shape the living area as a whole. This is essential within successful collaborative living practices. A collaborative community needs to have enough space for the externalization of daily living functions, and these are collaborative spaces that provide a place of social interaction.

Hence, the location is an important factor, in the determination of common room within the building plan. The relationship between each room and private side curve will be applied to determine the location of common room. Additionally, the edge of assumption residential building will be divided into private side curve and public side curve. The segment length of the private side curve will be touched by the room on the basic plan and is inversely proportional to the segment length of the public side. This means that one room will be in contact with the private side curve or public area more than the other room. This concept is applied to each of the room curves in this step, in order to create a basic layout with circulation area, common room, and dwelling rooms.

After generating the basic layout, the total number of the dwellings applied depends on the demand. This is divided by the room number of basic layout in order to get the number of floor as quotient. A simple calculation is used to get the amount of floors, the amount of rooms, number of rooms on roof, room number of basic layout, room number of each floor.

Fig. 39 Step determine

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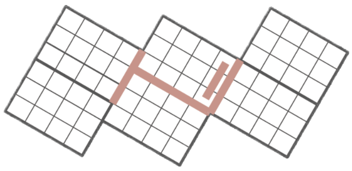
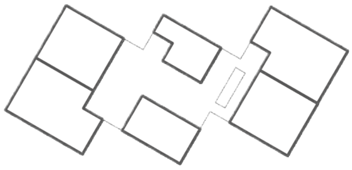
Design procedure:

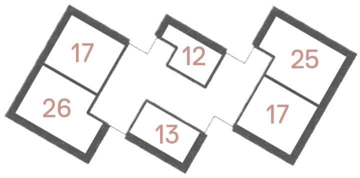
1. Select the subdivided units with circulation curves



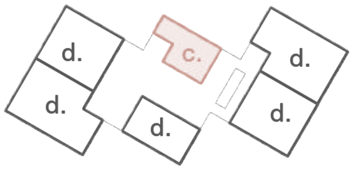
2. Combine the selected subdivided units as the circulation area



3. Measure the length of each block that overlaps with the assumption building outline



4. Parameter: amount of community room
   Use the value of length to determine community room, the smaller value is community room.



5. Parameter: the amount of room
   Divide the expected amount of room by the actual amount of basic layout to get the quotient as the amount of floors and the remainder as amount of room on roof.
   Output: basic layouts

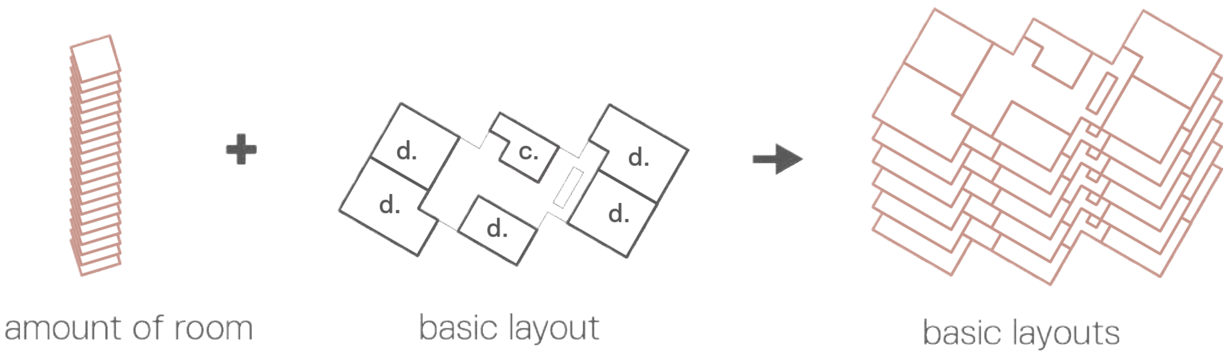


Fig. 40 Design procedure step determine

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3.3.1 Circulation zone

In this step will use the circulation path curve to separate the residential and circulation zones within the assumption housing blocks. This will consist of the main corridor path curve, the secondary path curve, the staircase curve, and the assumption housing blocks curve. Firstly, the main corridor path curve and the secondary path curve will be used to select subdivided units. This is done in order to separate the circulation zone from the residential zone and place the staircases in the circulation zone. Then the selected subdivided units will be further merged and combined into a basic building layout.

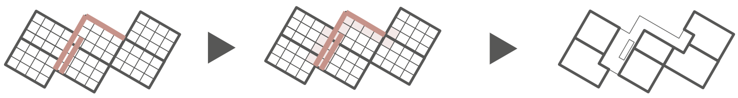

Fig. 41 Circulation and residential zone

These three different paths (the main path, the secondary path, and the staircase path) will be used to select the subdivision grid.
First they will be rearranged into three groups: the circulation path (main path + secondary path), secondary path, and the staircase path. Then the subdivision grids that intersect or overlap with these three groups of paths must be found. To get to the intersection or overlap with the circulation path as the circulation area, they must be accessed individually. As seen below, the squares that do not intersect / overlap with the circulation path represent the living area. The squares that intersect / overlap with the secondary path are the secondary area, and the squares that intersect or overlap with the staircase path are staircase area.

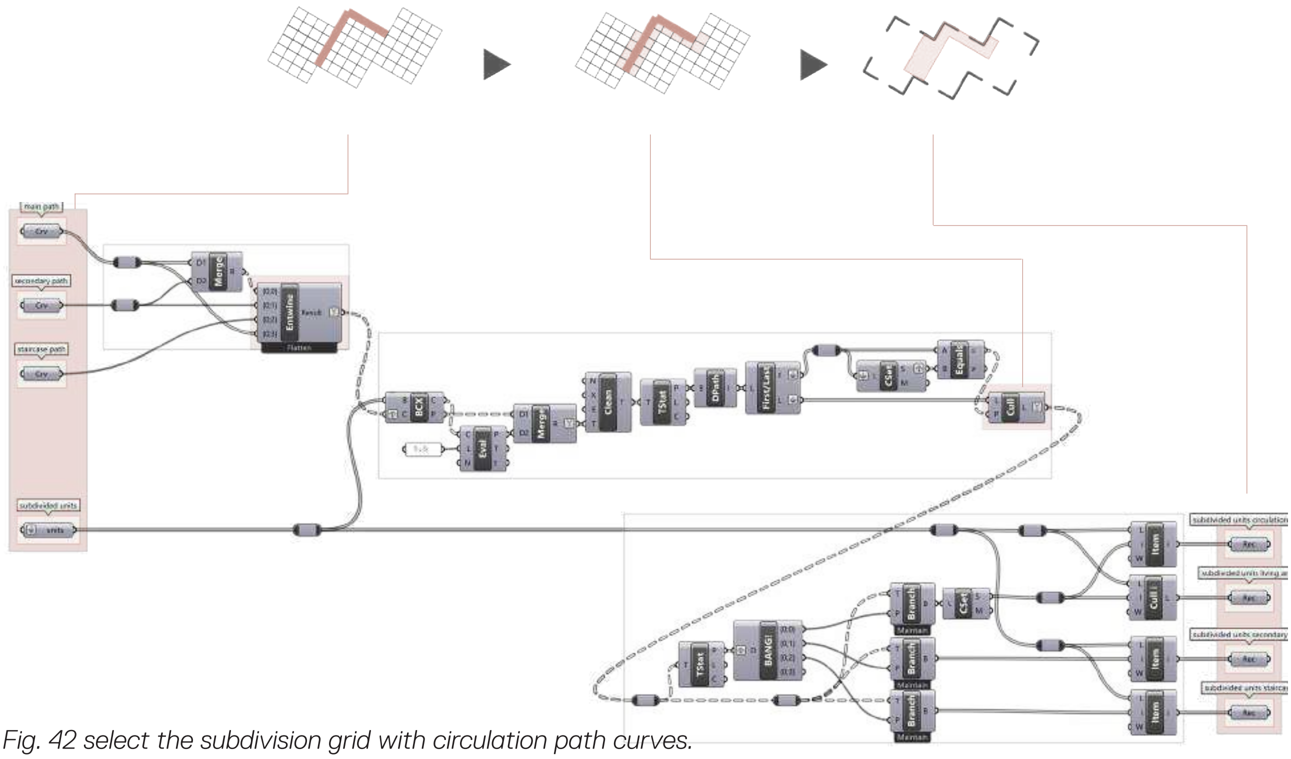

Fig. 42 select the subdivision grid with circulation path curves.

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Adjust the staircase area curve from subdivided units into two rectangles.

First, the subdivided units, which are selected by the staircase path are combined into quadrilaterals, and the side lengths of each quadrilateral compared. The length of the quadrilateral is fixed on the Y-axis with one corner of the quadrilateral as the origin while the width is fixed on the X-axis. Then each adjusted quadrilateral is divided into two long strips in the direction of the X-axis.

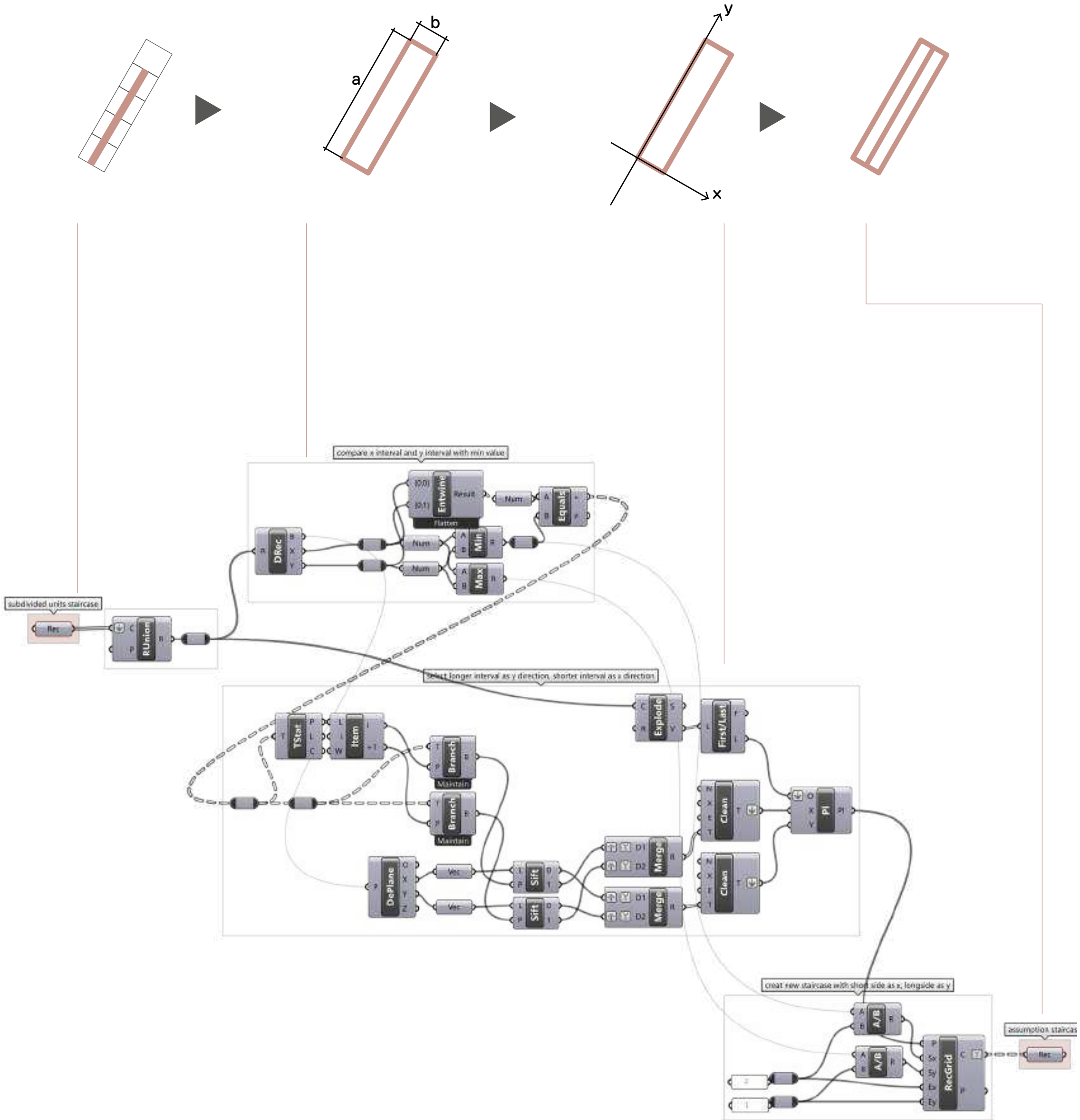

Fig. 43 Adjust the staircase area curve from subdivided units into two rectangles.

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Select the staircase rectangle

First, the selected living area subdivided units are merged into polygons according to the location of each assumption blocks. After that the two assumption staircase strips, which were generated in the previous step, are used to test the contact with the living area polygons. The strip that is in contact with the living area polygons is then filtered out. After the selection, the long strip can be deformed to the length according to the designer's needs. Finally, a Boolean operation is implemented on this strip with both merged circulations subdivided units and the secondary subdivided units. This ensures that the circulation area and the secondary area can be generated.

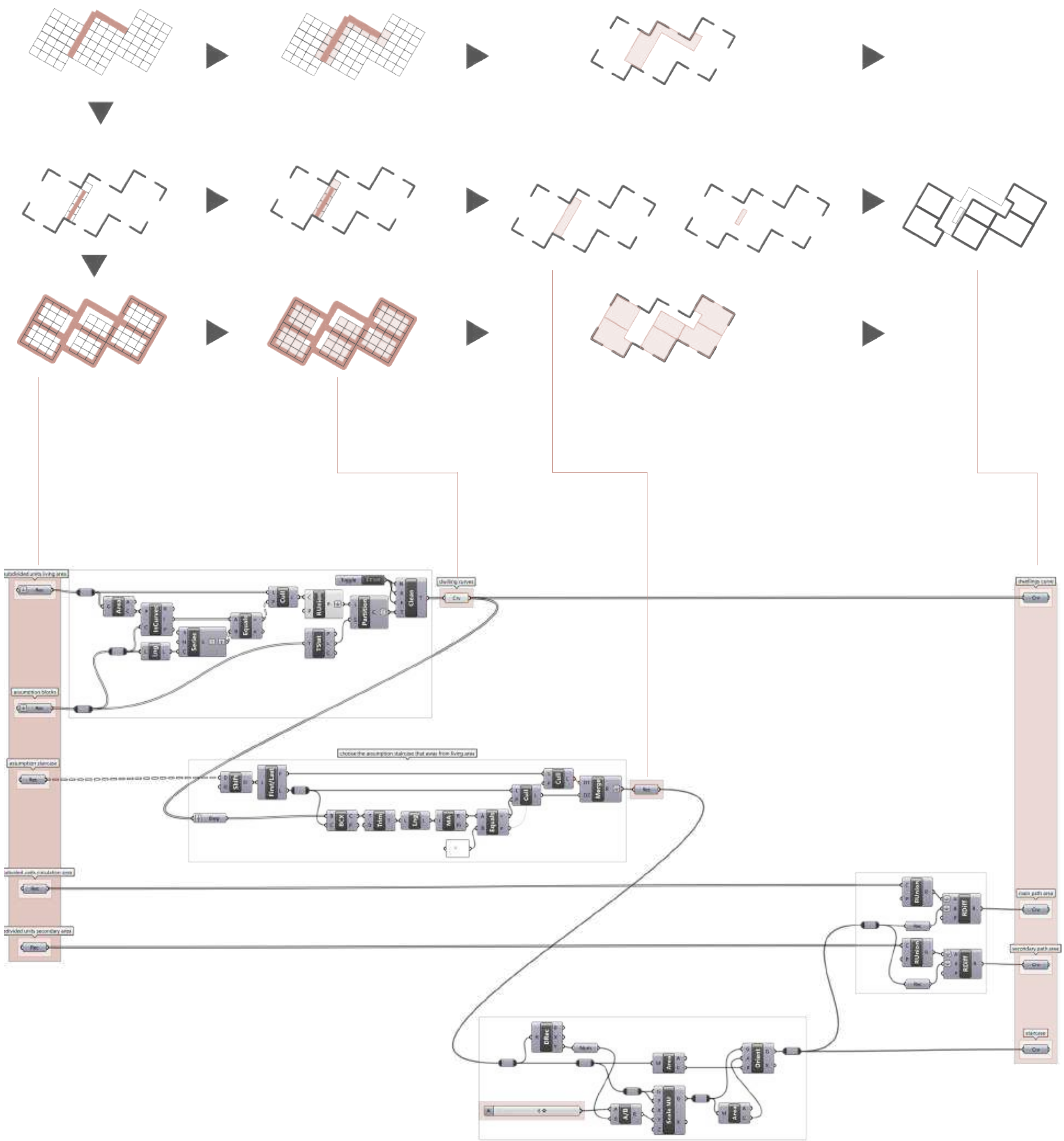

Fig. 44 Select the staircase rectangle.

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3.3.2 Residential zone

As the basic building layout is generated, the length of each living area polygons on the assumption building outline will be measured. The room that has the shortest length is selected on the building outline as the mixed-use room. This means that the room has the most contact with the circulation area, hence, the accessibility of the space is optimum, thereby increasing the usage rate of the living area.

Measure the length of each living area polygon on the building outline

Firstly, a test is performed to determine whether the length of each side of the building outline overlaps with the living area polygons. Then the total length of the overlaps is calculated from each living area polygons (if the living area polygons do not overlap the building outline, mark it as „zero"). Then those lengths will be used to separate the dwelling curves and mix-used room curves according to the designers need. These living area polygons that have longer lengths of overlaps are known as dwelling curves. Otherwise, it will be transformed into a mix-used room curve instead.

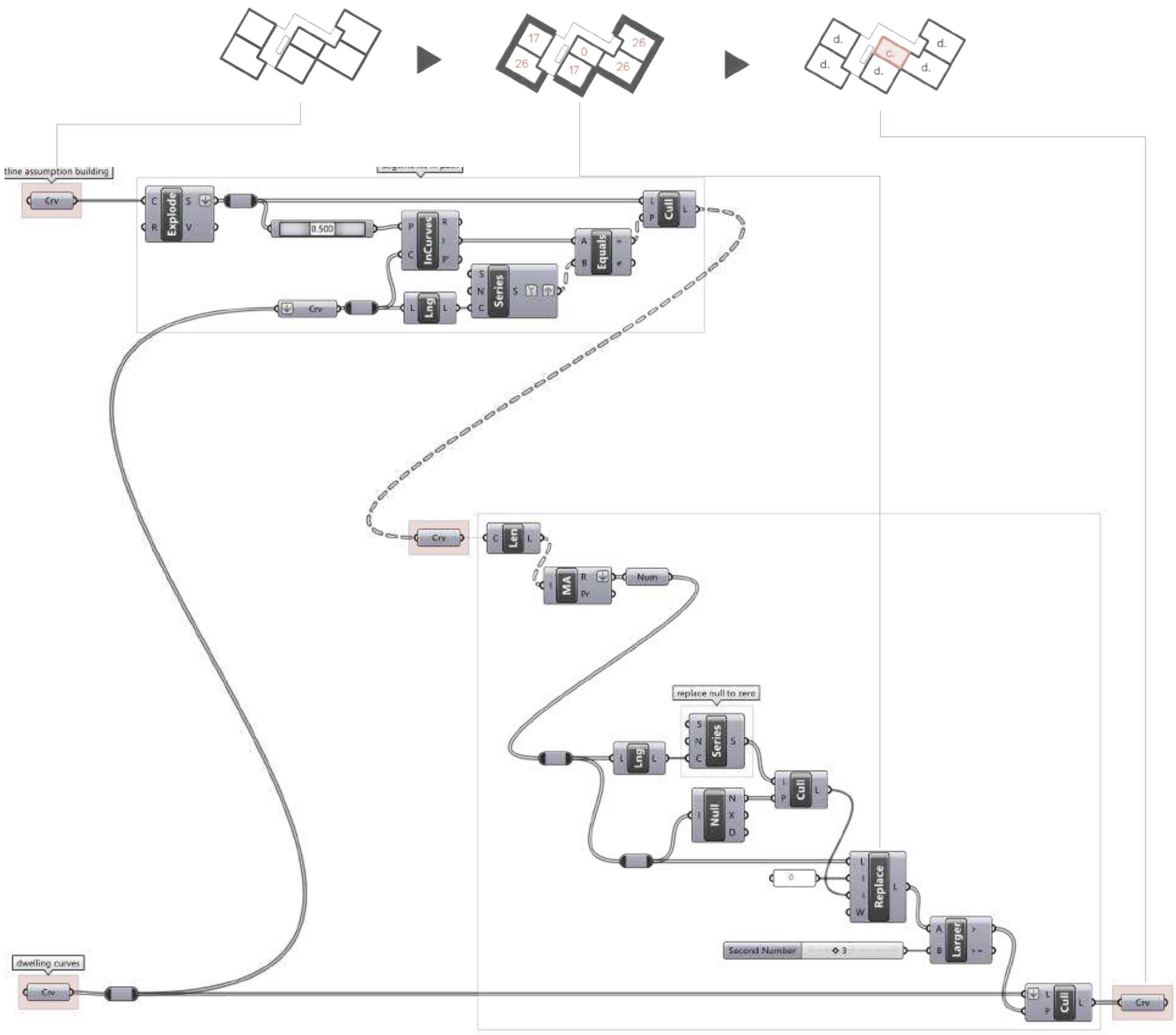

Fig. 45 Measure the length of each living area polygon on the building outline.

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Sift out the dwelling curves within the higher floors

In this step, the dwelling curves will be shifted within the higher floors, so that the sunlight from the lower floors will not be blocked. This is done by dividing the preset number of dwellings by the number of dwelling curves on the basic layout as the number of residential floors. Since it is possible that some of the dwelling curves within the higher floors could be shifted despite the quotient of division from the dwellings, two more floors can be added to the assumed number of floors. The reasoning behind sifting the dwellings is to ensure that it is aligned with the angle of the sun. The building's projection will extend as the building height increases; therefore, by moving the outline from the dwelling of the basic layout parallel (offset) it will change the projection of the dwelling curves. As shown in the figure below, intersecting results will be achieved, if these parallel lines from one dwelling intersect or overlap with other dwelling curves. This result can be used to sift out those dwelling curves that intersect with parallel outlines from other dwelling curves.

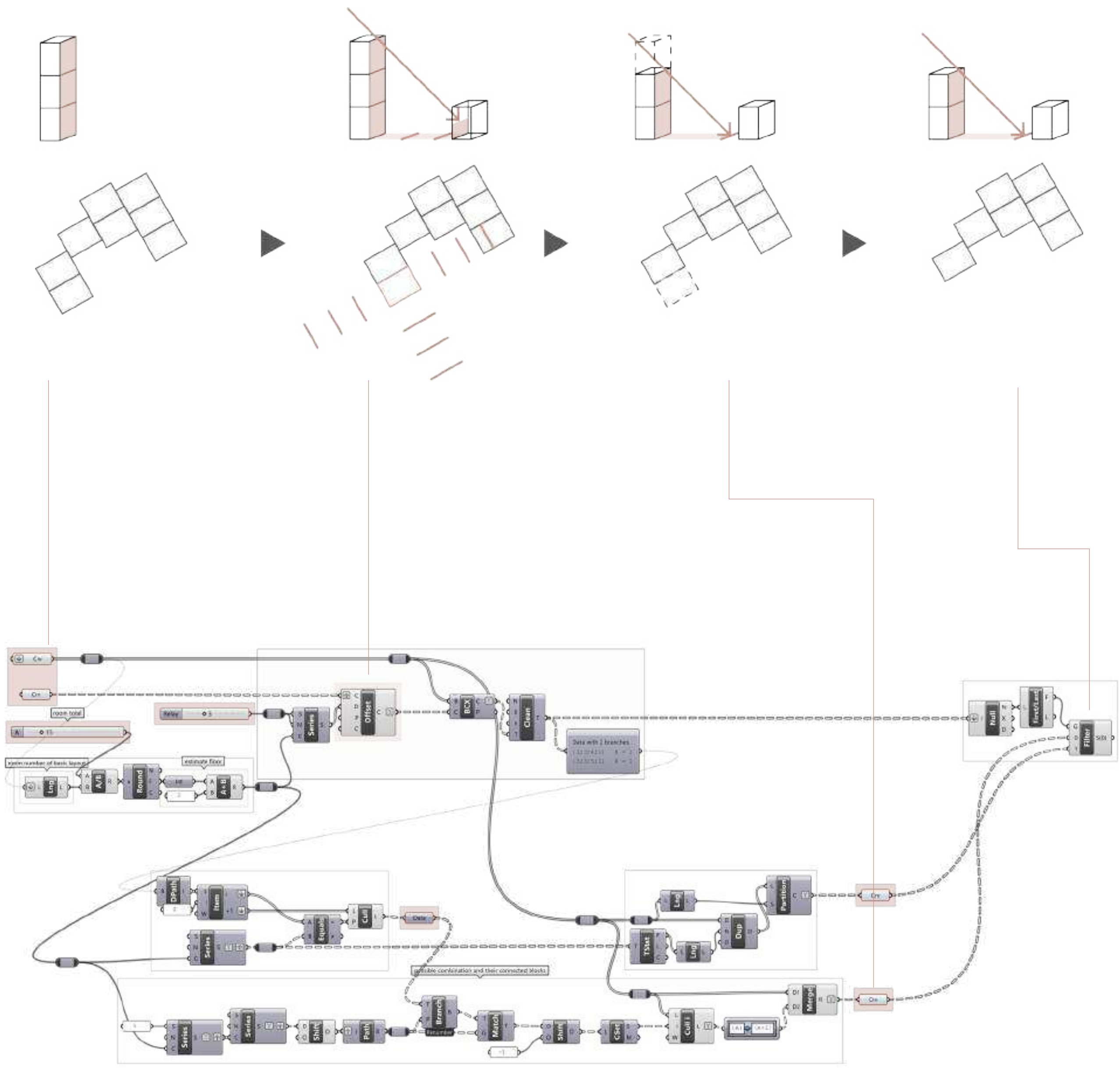

Fig. 46 Sift out the dwelling curves within the higher floors.

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Divide the expected amount of room by the actual amount of basic layout to get the quotient as the amount of floors and the remainder as amount of room on roof.

Of course, there are also cases where the parallel lines of the dwelling outline on the sides of all dwelling curves do not intersect with other dwelling curves. Therefore, when dealing with high floor dwelling curve filtering, another set of basic layouts should also be generated based on the number of assumption numbers of floors. After the assumption numbers of floors will be applied to generate the dwellings curve from each floor and do the intersection test of the dwellings curve´s parallel outline with other dwelling curves. The real number of dwellings will be subtracted from the number of the dwelling of basic layouts, among which the number of floors closest to „zero" is the number of real floors generated by the preset number of dwellings.

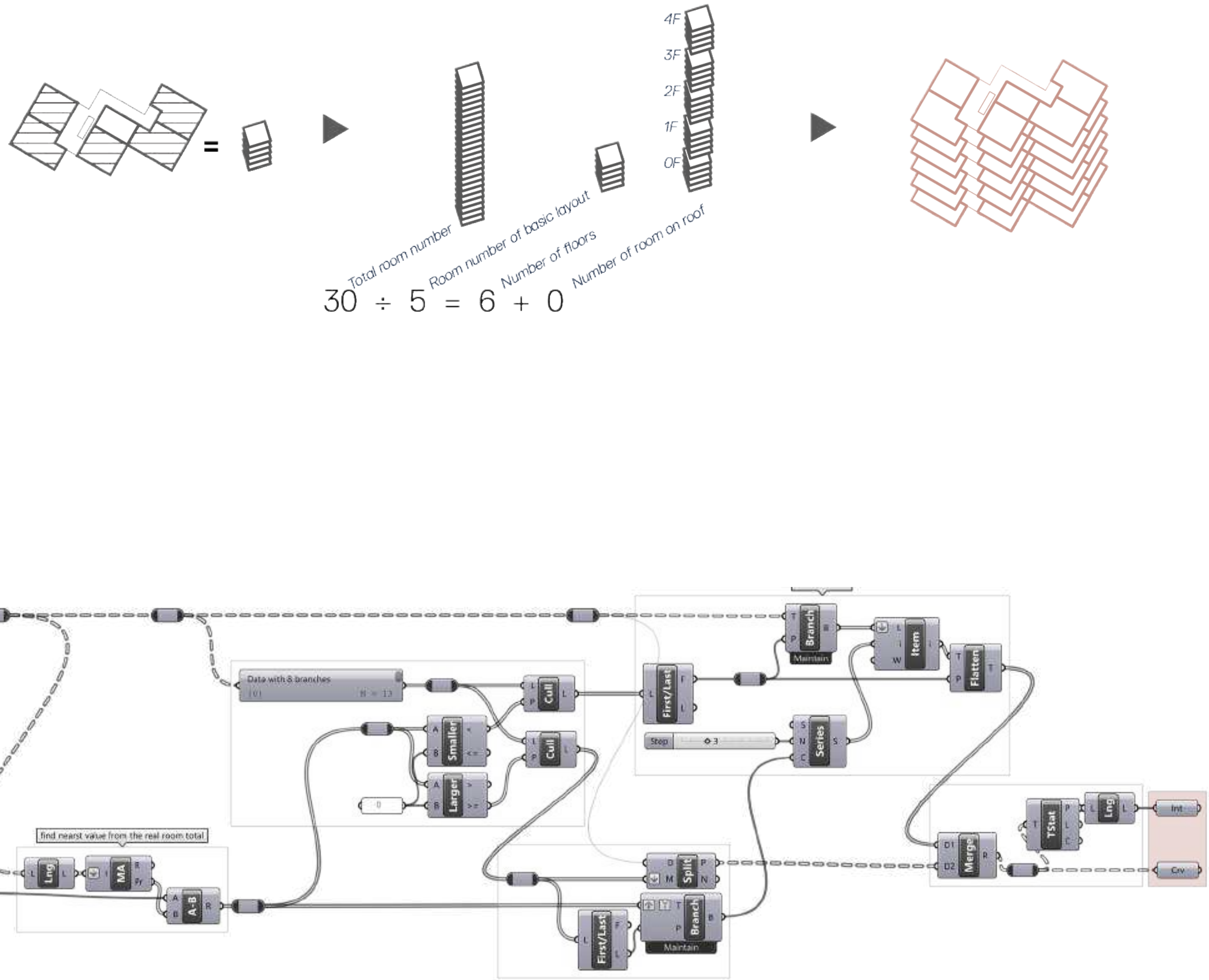

Fig. 47 Divide the expected amount of room by the actual amount of basic layout to get the quotient as the amount of floors and the remainder as amount of room on roof.

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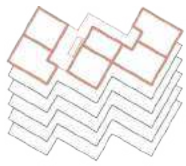
3.4 Extrude

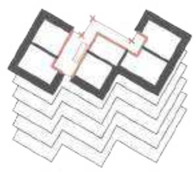
During this approach the goal is to transform the 2D curve from basic layouts into different face of polygon. These represent different structure elements such as the façade, column, load-bearing walls, stairs and ceiling. Once all of the structures of each face from model are determined, the key figures of project can be calculated, such as the floor space (GRZ), floor area ration (GFZ), gross floor area (BGF), net floor area (NGF)….etc.

Design procedure:

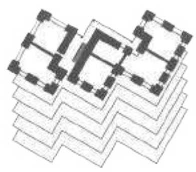
1. Input: basic layout"s"



2. Sort the line segments into facade line segments, load the structure line segments, entrance line segments, corridor line segments and find the position of the column.



3. Transform them into building structure.



4. Calculate the key figures of project according to 2D building layout and 3D model.

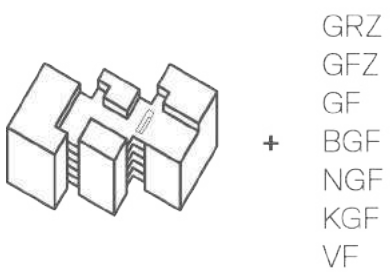


Fig. 48 Design procedure step extrude

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3.4.1 Structure element

After using different methods to generate three different 2D planar curves in the fourth step, we will further generate these 3D models. This is done from the curves which represent the circulation area, living area, and staircase.

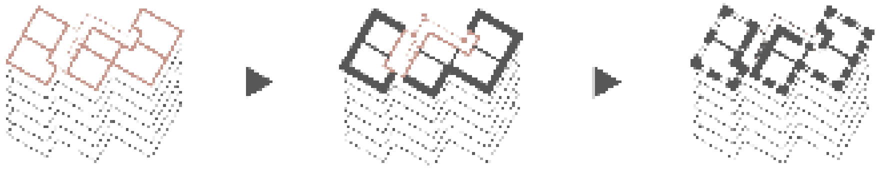

Fig. 49 Structure element

Slab

In this step, the curves in the basic layouts, the circulation area curve, the secondary area curve, and the living area curve will be transformed into the 3D slab. In basic layouts, the dwelling curves have been classified into „date path" according to the floor, so in this step, we can easily transform the dwelling curves of each floor by combining the required floor thickness and the height of each floor. In addition to the floor slabs, the topmost dwelling curve will have to be identified in the basic layout and moved up one floor. This will serve as the roof. Note, that the order of floor slabs from the circulation area and the secondary area can be arranged differently according to the designer's needs.

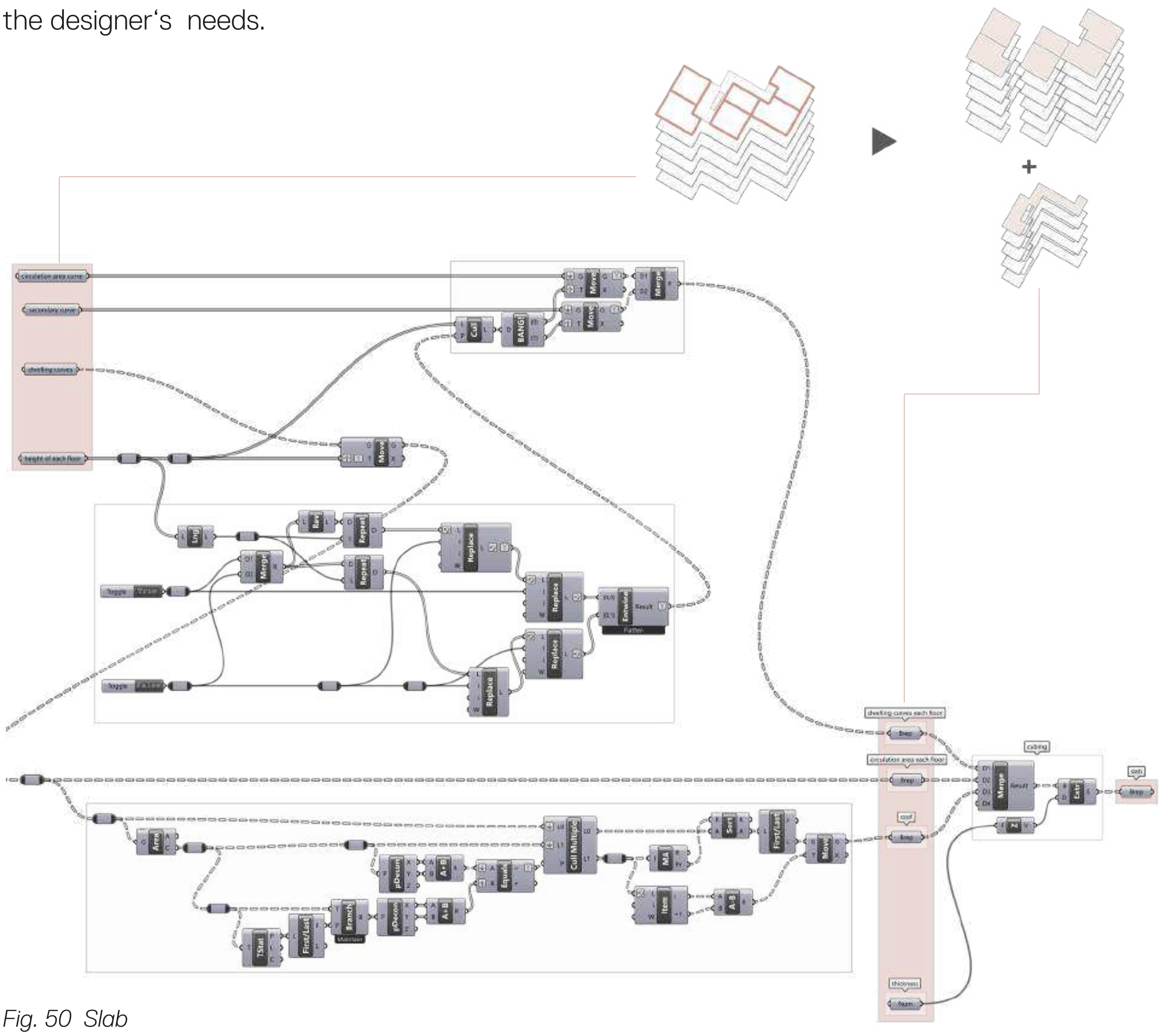

Fig. 50 Slab

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Stairs

The generated stair block will be converted into a sloping plate connecting the upper and lower floors. First, take the short side of the stair curve, and then move it to the defined floor (0,1,2,..., n-1). Then take the opposing short side and move it to the height of the first floor (1,2,3, ..., n) on the defined floor. Once that step is complete, connect the two short sides into a quadrangular plane.

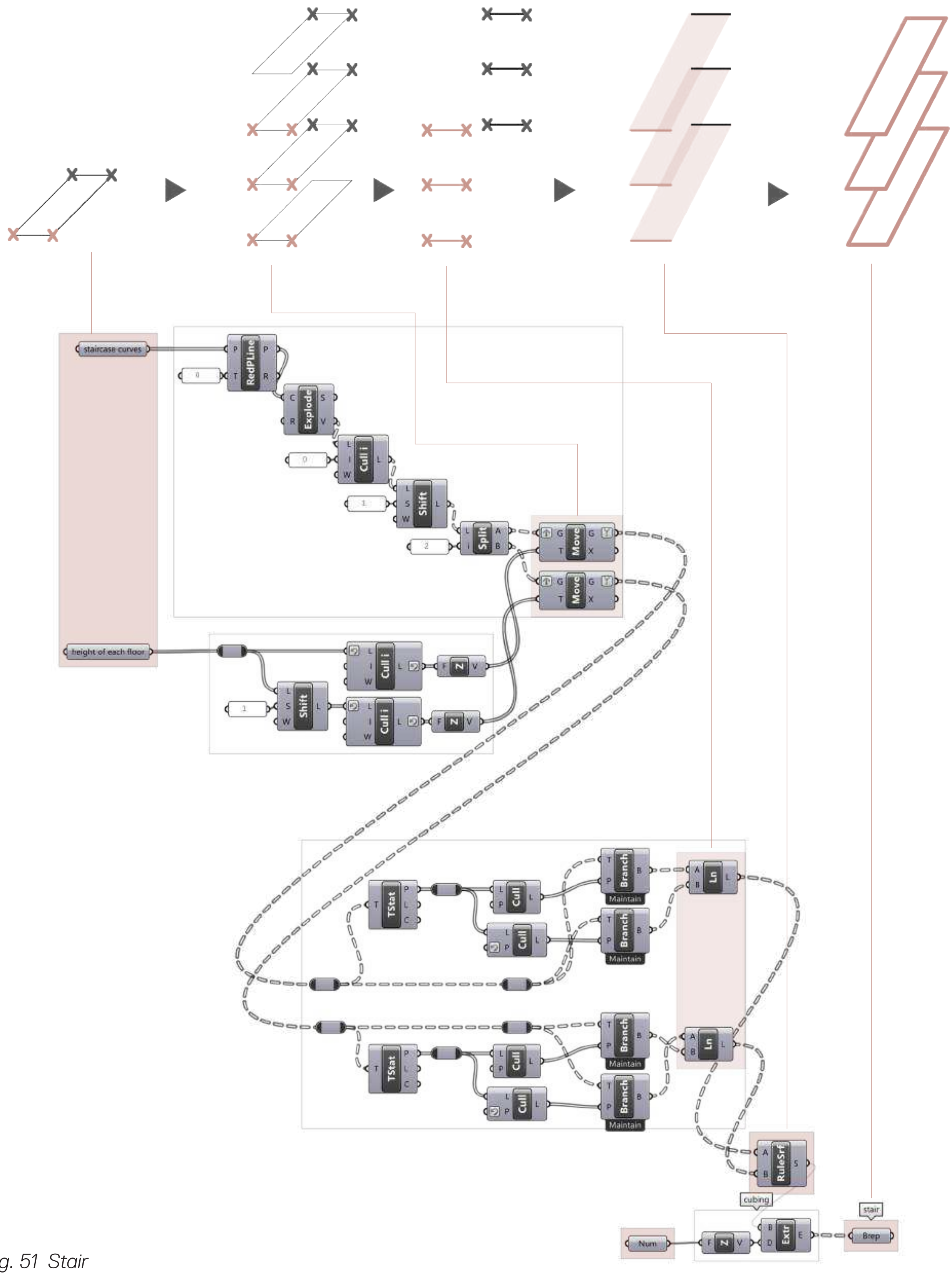

Fig. 51 Stair

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Column

In order to improve the transparency of the circulation area and increase the apparent diversity of the building, a truss structure will be applied in the circulation area. The pillars need to be generated at the vertex of the assumption dwelling curves on the circulation area curve. After obtaining these points at the center, four quadrilaterals will be generated as assumption column curves and be tested in order to determine whether the quadrilaterals are located in the circulation area curve or not. Then a quadrilateral will be selected that is located in the circulation area curve as the column curve, and eventually, will be used to generate a column at the required column height.

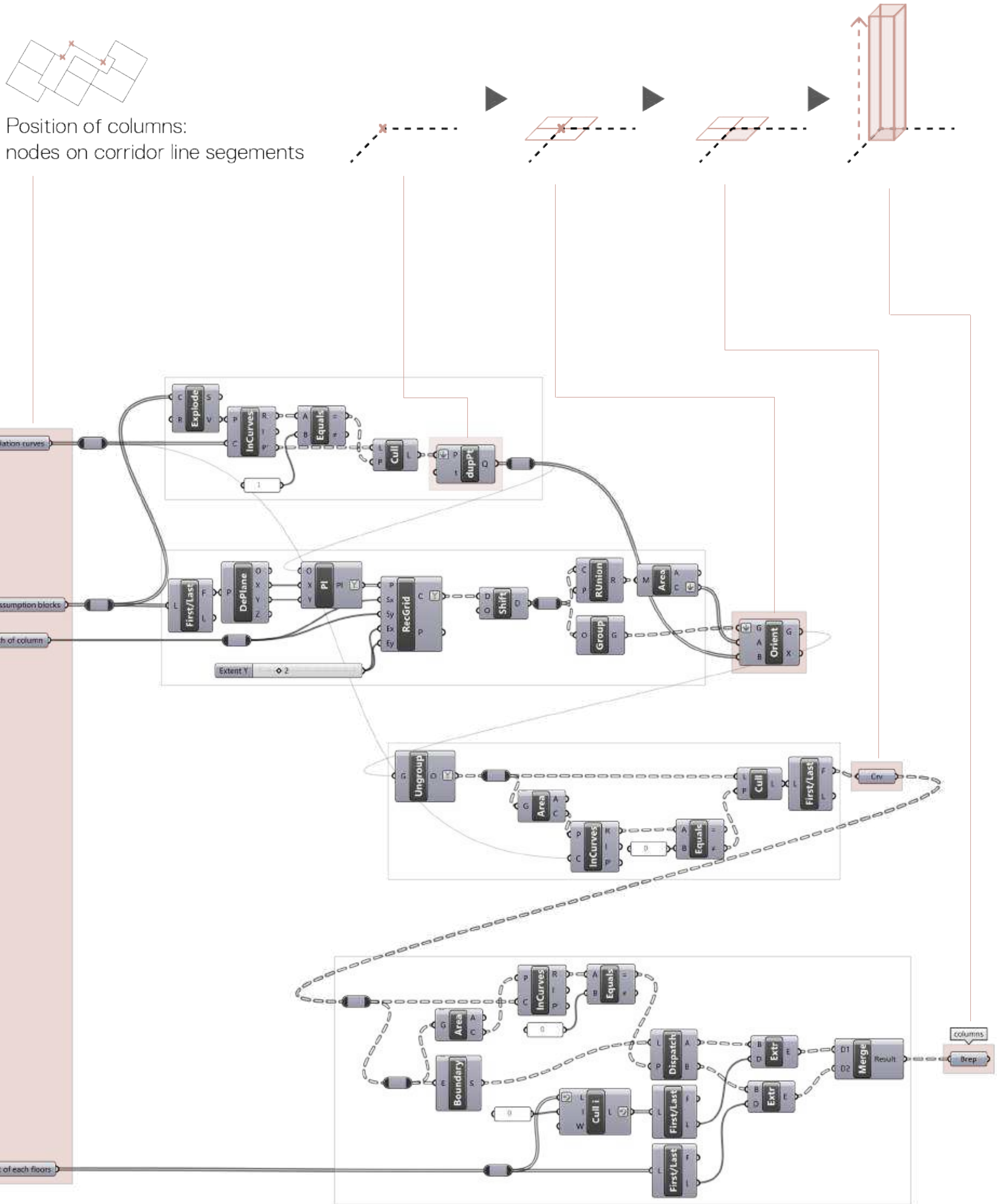

Fig. 52 Column

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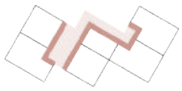
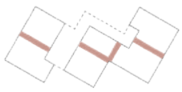
Wall

The generation of the wall is divided into two steps. The first step is to find the wall curve representing the exterior wall, the load-bearing wall, and the wall of the entrance of rooms in the basic layout. The second step is to generate these three types of curves into the wall construction.

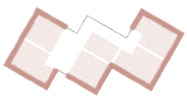
The circulation area curve and the dwelling curves in the basic layout are both merged from the subdivided unit curves. As such it is important to identify and access the segments of these curves. By testing the intersection of those particular line segments, it is possible to determine the order of the line segments located both on the circulation area, living and wall curves of the entrance of rooms. Meanwhile, as the positions of the dwelling curves are arranged in a certain order, the load-bearing wall curve can be determined with the overlap test of the dwelling curves. This is done by testing whether each dwelling curve overlaps with the next dwelling curve. Finally, in order to obtain the exterior wall curve from the basic layout, the load-bearing wall curve and the wall curve overlapping the living area curve and circulation area curve is excluded. After wall curves have been generated, the wall curve can be transformed into a wall according to the required height. And according to this project's needs, the wall curve of each segment can be transformed into a quadrilateral that includes a transparent opening in a geometric relationship.



entrance line segments: line segements lie both on circulation curves and housing blocks



construction line segments: overlapping line segements among housing blocks



facade line segments: line segements lie both on housing blocks and building outline

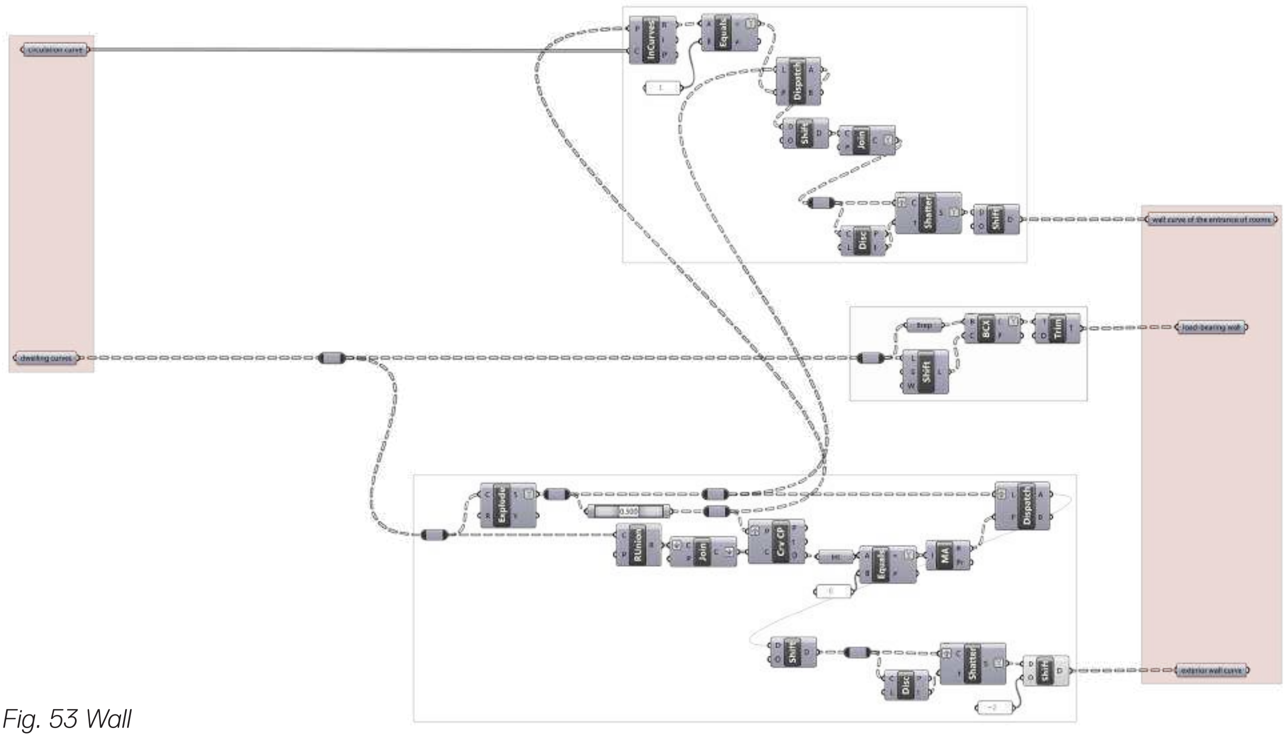


Fig. 53 Wall

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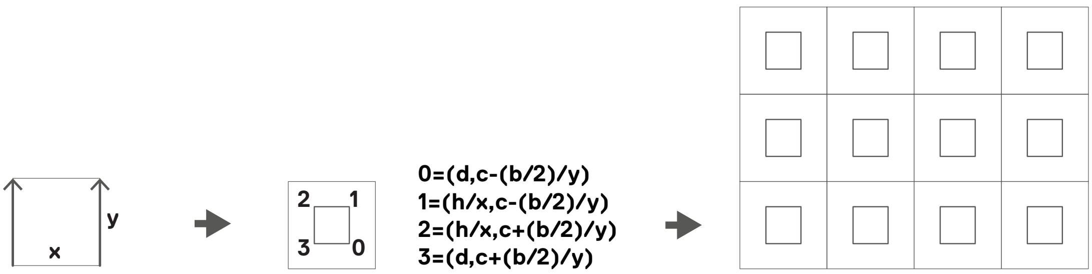
Façade

After those wall curves have been generated, they can transform the wall curve into a wall according to the required height. According to this project's needs, the wall curve of each segment can be transformed into a quadrilateral including a transparent opening in a geometric relationship.

select the red line segement x and extrude the line segement in z direction with y

creat an polygon with seven points, where 1234 means the entrance of the dwellings

0=(0,0)
1=(0,a-(b/2)/y)
2=(h/x,a-(b/2)/y)
3=(h/x ,a+(b/2)/y)
4=(0,a+(b/2)/y)
5=(0,1)
6=(1,1)
7=(1,0)



0=(d,c-(b/2)/y)
1=(h/x,c-(b/2)/y)
2=(h/x,c+(b/2)/y)
3=(d,c+(b/2)/y)

split the black line segemnt into unit x and extrude the line segement in z direction with y

creat an small square inside the big square as an unit of punctuated façade

façade of the building

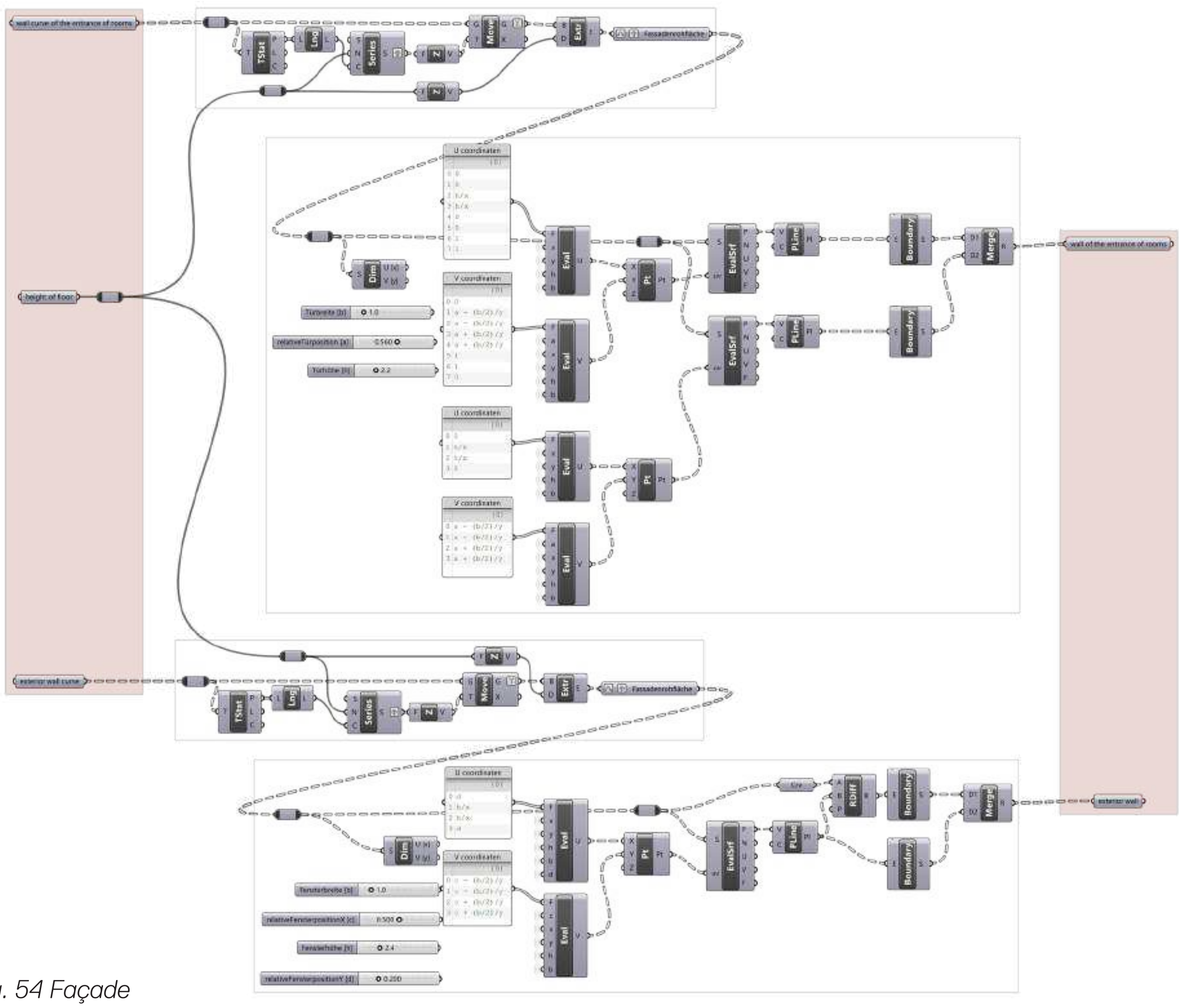


Fig. 54 Façade

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3.4.2 Building data

After the slabs, beams and columns, structural walls, etc., are constructed, those building structures have been created one by one. Furthermore, simple mathematical operations can be used to obtain building data.

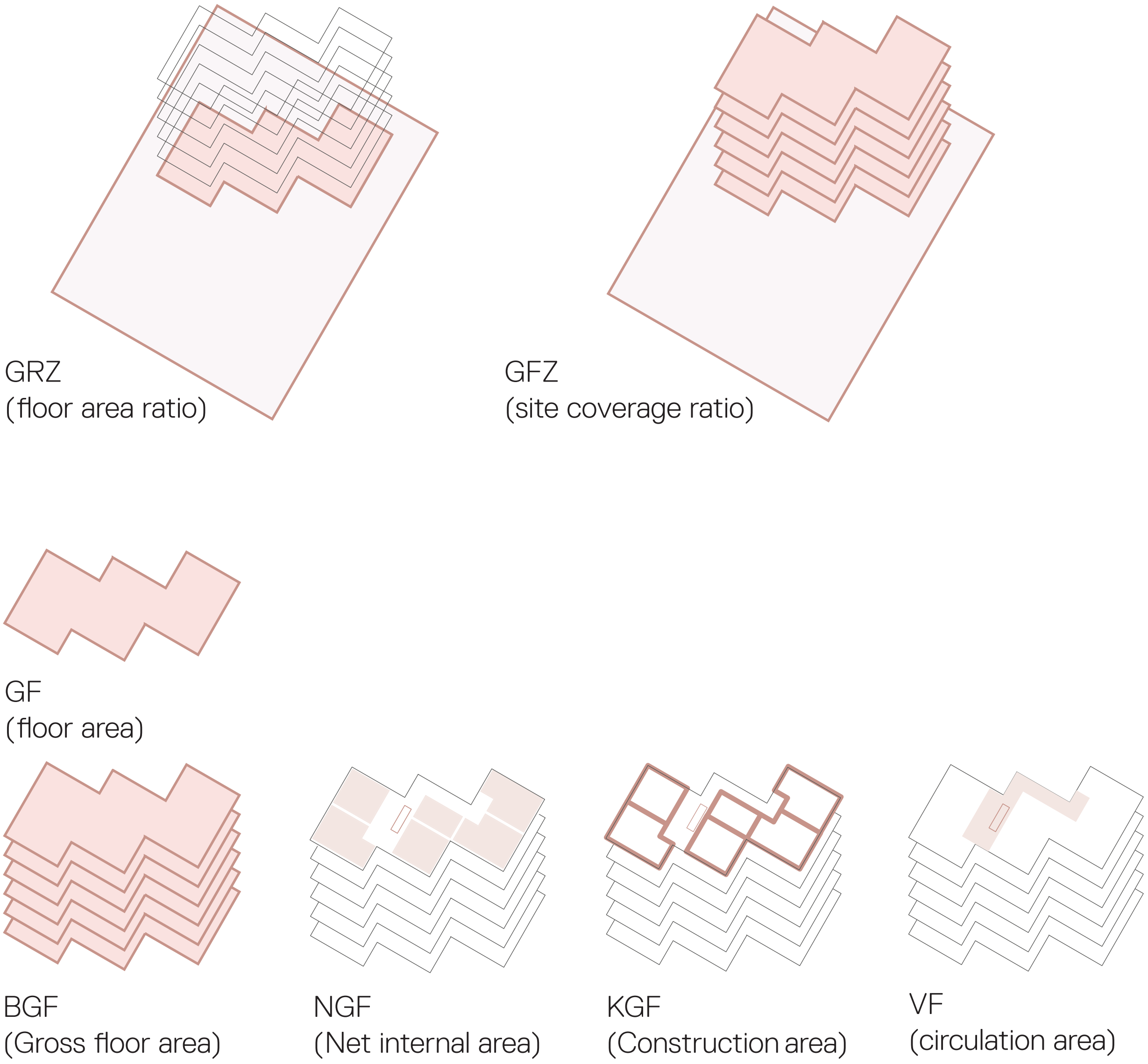

Fig. 55 Building data

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Different input curves and parameters can produce completely different results through the Layout generator. The purpose of the Layout generator is to reduce repetitive drawing works and to ensure that the corresponding results match the design approach. After establishing the layout generator, the next step is to be able to develop and demonstrate the executable model for practical applications. The current featured design will be created with the generator and submitted in the architecture competition „Conceptual Living 2018.19" for testing purposes.

The building lot, which was supplied by the architectural competition committee, will be analyzed and simplified into a site analysis diagram. This analysis is based on the design's needs and the neighborhood's relationships. As a part of the analysis both the input curves and parameters will be extracted, after which they will be imported into the layout generator under the Rhino-Grasshopper interface. The committee also requires that the reconstruction of existing buildings be included in addition to the ones that will be newly constructed. In this case, the input required in each operational step depends on the existing building conditions. These will be shown in generated drawings listed in section 4.2. After that, the building coefficients and floor plans are compared in section 4.3. Those are created according to different inputs, so that, design options can be created according to different geometrical relationships. In addition to the computed and algorithm processes, the tangible key figures will also be evaluated and listed. These will provide a different aspect that can be seen within the final generated result.

The operation steps of the Layout generator:

1. Inputs: Analyzing and finding the required inputs and parameters,
2. Application and parameter: Adjusting the inputs and parameters with the result of site analysis.
3. Outputs: The generation of the drawing,
4. Comparison and evaluation: Comparing the outputs according to their different inputs,

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4.1 Inputs

The architectural competition „Conceptual Living 2018.19“ was organized by the Bundesverband Kalksandsteinindutrie e.V.. The aim of this competition is to design a residential housing community in the Cologne Mülheim- Stammheim area based on future residential housing conditions and trends. This chapter will analyze the following three topics; urban development, urban context, and building structure, in order to obtain the input curves and parameters from the given building. These results will be needed in order to successfully operate the building layout generator tool. The building lot that will serve as the model for this design is located in the Stammheim area on the right bank of the Rhine. Stammheim is an administrative district in the Mülheim district of Cologne. It has many green areas, which are highly favored by potential buyers and is especially suitable for young families. The building itself is divided into new one-row residential communities or single-family houses. Another positive, is the good public transport network and nearby B8 highway which makes the location perfect for commuters.[22]

The Campus Rheinufer is also located within a large green area, between Nathan-Kahn street and the Stammheimer Ufer on the banks of the Rhine river. Northwest of the plot there are multiple schools such as the community primary school Ricarda Huch and the Erich-Gutenberg vocational collegen to the north and northeast. In the southeast, there are mostly 1 to 2 story single-family homes. Those plots are stretch from Nathan-Kahn street to the banks of the Rhine, on an incline of about 2 meters. The building's plot is mainly accessed via the Nathan Kahn street and the Stammheimer Ufer which has both a sidewalk and a bicycle path. Besides that, there is a walkable path between the west side of the base and the school campus, which links Nathan-Kahn-Staße and Stammheimer Ufer. Lastly, the Cologne-Stammheim S-Bahn station can be reached in a 15-minute walk away.[23]

The goal of Campus Rheinufer is to enable a new architecture project to be harmoniously integrated into the neighboring communities. This will be done using the advantages of the plot itself, such as the lush riverbank landscape which residents would enjoy. The large green space condenses the residents and brings them together, in order to create a collaborative and conceptual community.

An ideal building component for residential, industrial and commercial buildings, sand bricks are a natural and recyclable material which is are compliance with current environmental regulations. It can be accurately used to construct building spaces according to various design requirements. The high density of the lime sandstone bricks can effectively soundproof, which provides privacy within a composite residential building project. Due to the choice of materials, the building in the Rhineufer campus is based on a load-bearing structure in combination with a truss structure in

22 cf. https://www.kalksandstein.de/wettbewerb (01.11.2018)
23 cf. https://www.kalksandstein.de/wettbewerb (01.11.2018)

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the open corridor area.[24] Due to the design principle of the passive building, the main façade with the large load-bearing wall and opening will face the southwestern side; the Rhine Riverbank. The northeast side of the new building will be the backyard of the entire campus. There is an open corridor which will be created to encourage an overall sense of community and showcase the overall dynamic of the architecture.

Fig. 56 Location: Cologne Mühlheim-Stammheim

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24 cf. Klaus Kinold : 25 Jahre KS Neues neues Bauen in Kalksandstein,(1994)

4.1.1 Urban development

The site of the housing development lies on the right bank of the river Rhine in Stammheim, which is a part of the district of Cologne-Mülheim in Germany. Cologne belongs to the largest metropolis in the Rhine-Ruhr with over 10 million inhabitants. It is the largest city in the metropolis Rhine-Ruhr and the fourth most populous city of the country. Cologne is also famous for the Cologne Cathedral as well as other historical monuments. In 2017 alone, 5.8 million overnight stays were booked and there were 3.35 million arrivals.[25]

Besides that, Cologne accounts for about 550,600 vehicles registered in the country. 86 % (474,600) of them are passenger cars and are growing at a high annual rate of 11%. This data points to a growing and greater vehicular population in the future.[26] As such, road congestion is the norm and will likely be enhanced as the city grows. In order to combat this issue, the development of public transport within the city has greatly increased in the past decade. This includes upgrading the existing light rail network and a implementing a new project named “Nord-Süd Stadtbahn” which is currently under construction.[27] The results of these measures anticipate easier accessibility and multimodal choices of mobility moving the city away from private to public transport.

As per the 2017 statistic, Cologne has recorded a steady population increase in recent years. The city has a population of about 1 million people; accommodated within about a 405 km^2 space with a density of 2,700 persons per km^2.[28] In the past years, immigrations to Cologne have increased and as such the demand for rental apartments or self-occupied houses is rising. As a result, the pressure on housing market is growing significantly. In the recent years, the city government has pushed forward with new development strategies such as the densification of the western sectors of the city rather than the earlier favored sprawl towards the downtown area.[29] On this account, the Cologne government has made a series of urban renewal plans to promote the reuse of urban idle space and to meet the demand for housing.[30] A once industrialized area located on the right side of Rhine River will be further developed in the coming years, as a part of a municipal government-led urban renewal program in order to bring changes and promote the entire city. The core of the project is to redevelop former industrial areas. In addition to working on these scattered factory sites, the government will build a forward-looking new urban area, which will be directly placed at the Rhine River bank. As a district of Cologne, and due to its geographical location, Stammheim naturally will also be included in this series of plans.

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25 cf. https://www.cologne-tourism.com/plan-inform/service/trade/statistics/2017/ (01.11.2018).
26 cf. https://ratsinformation.stadt-koeln.de/getfile.asp?id=656070&type=do& (01.11.2018).
27 cf. https://www.nord-sued-stadtbahn.de/projekt/index.html (01.11.2018).
28 cf. https://www.stadt-koeln.de/mediaasset/content/pdf15/statistik-einwohner-und-haushalte/1084795_k%C3%B6lnerinnen_und_k%C3%B6lner_in_2017_ew_nks_1_2017.pdf (01.11.2018).
29 cf. https://www.portal.uni-koeln.de/sites/uni/images/Forschungsmagazin/Magazin_01_2015/F365_zukunftsstadt.pdf S 6, (01.11.2018).
30 cf. Wohnungsmarktbeobachtung Nordrhein-Westfalen Köln Wohnungsmarktprofil 2018 (01.01.2019).

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Fig. 57 Figure-ground diagram

4.1.2 Urban context

The Green Space will service as starting point of Campus Rhine bank.

The base site of campus Rhine bank also lies in Stammheim, Cologne. This area is characterized by a homogeneous structure of the urban function. Similar to the residential area located in the north and south, the neighborhood will mostly consist of residential buildings and some local stores. The plot of this design project is located south of the Stammheim on the right bank of Rhine River, between Moses Heß Street, Nathan Kahn Street, and Stammheimer Ufer. The plot used to be a sports field as well as a general green space for the local community. Hence, this project will consider the green space of the community center as a starting point to configure the plot without affecting the communities original functions. Secondly, in addition to the main green space in the base center, three smaller green spaces will be planned on both sides. This way, the spaces can be connected in a series to form a striped green zone which can serve as a buffer zone between the new and the old buildings. The green space on the southeast side will be planned as an open parking lot. On the eastern sides of the plot there are two 3-story buildings which are residential. Since both lie separately on edge of the base site, they will need to be „connect"ed to the new and the existing building around those green spaces. Meanwhile, the campus will also have various entrances to better connect to the Rhine bank, the school on the northwest, Nathan Kahn Street and Moses-heß Street. This will furthermore increase mobility and accessibility within the neighborhood. The new building blocks will lie parallel with Rhine bank on the southwest side of the campus. In order not to block the existing buildings from the view of the river, the gaps of the spatial will be placed between the new buildings, therefore creating a new path in the courtyard to the Rhine bank. There will also be a second axis along the assumption new building area and the green space in the backyard.

Step „Bridge"

In order to emphasize the connection and transparency within the campus Rhine bank, the main entrance of the campus on Moses-Heß Street is marked with the sky bridge as a connection between two existing buildings. On the southern side of the base site, the open corridor between the new buildings over the central axis of the courtyard will be created as a new entrance on the bank's side of the Rhine. This differs from the prototype of the layout generator. During this implementation, an extra step will be applied after the general step 1, which will be named "bridge". It allows the layout generator to generate a sky bridge between two assumption building blocks.

Inputs of layout generator

Since the layout generator will need certain inputs in order to be computed, concrete polylines will be used to allow manipulation by the layout generator. These requirements are compatible with the result of the site analysis. With the configuration of green spaces and the planning of a route within the campus, the assumption new building area and the spatial flow curves, will be sketched, so that, they can both be applied as input curves into the layout generator.

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4.1.3 Building structure

The advantage of the layout generator is that the approximate floor plans and building coefficients can be generated right away with some simple geometric lines. This feature will be demonstrated in this section and a comparison of different input curves will be shown. After the base analysis, different inputs and parameters will be gotten. The most important of them will be the assumption building curve and the spatial flow curve. In this chapter, I will generate three layout plans according to different assumption building curves and spatial flow curve. The other parameters, such as building structure, the number of rooms etc., will remain unchanged. The building structure will be generated in step 4 of the layout generator.

A 40cm load-bearing outer wall construction has been chosen as the support structure. It has a southern façade with high-format floor-to-ceiling window opening enables which provide optimal illumination for the living area. The spacious loggias with glass sliding doors provides both an indirect buffer zone between the living area and outdoor spaces, as well as protection from sunlight and allows a natural night cooling of the rooms. The load-bearing outer walls ensure a free, reversible room layout in the small apartments. The apartment partitions within the building block can be moved without structural intervention, as they do not interfere with the bottom structure or tie to the raw ceiling below. Due to those design concepts, each residential unit could be given spatial flexibility to react to changing space requirements.

Fig. 58 Site plan analysis: find the assumption area of new building.

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4.2 Application and Parameter

There are two big differences between this building site and default situation in the building layout generator. Hence, the two existing buildings on the site will be transformed into simple geometric block curves. They will then be applied in the associated building layout generator's steps. This will be done first as the input curve from the building layout generator's second step and then continued according to the original steps.

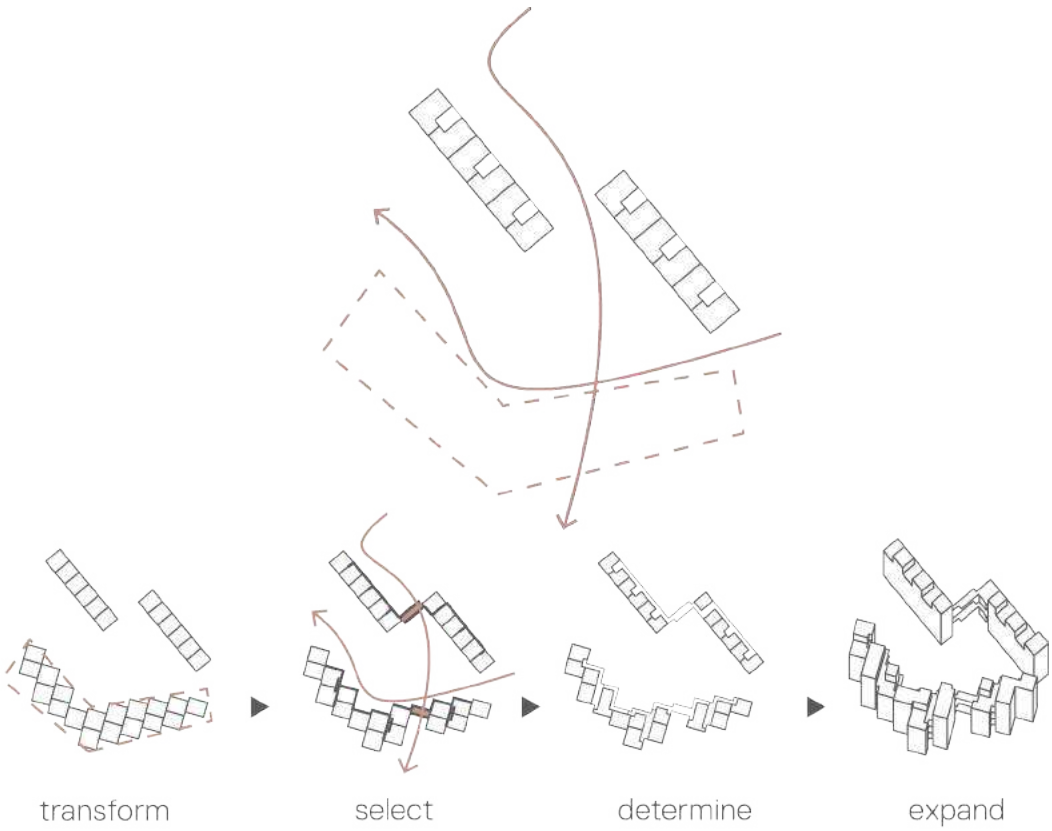

Fig. 59 4 steps of Layout generator

Secondly, since the design involves more than one building, the spatial flow in the building base will be more complicated to adjust than the prototype of building layout generator default. Thus, a derivative step is added in the first step to process (the bridge step) so it can use spatial flow curves to create the sky bridges which connect the housing blocks.

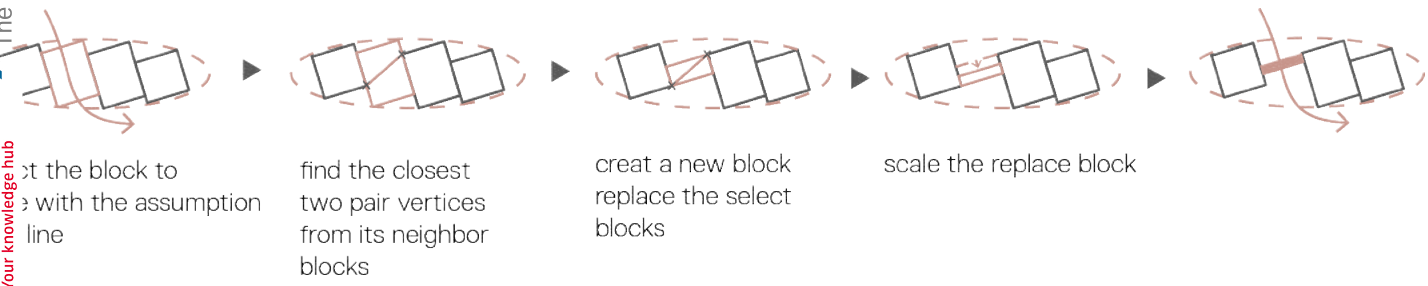

Fig. 60 Plug-in Bridge

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4.2.1 Transform

As chapter 2.2.1 described, the assumption housing blocks are transformed from the outline of the new building area according to the site's analytic diagram. The next steps concern finding the outline of new building area, transforming it into assumption housing blocks and then subdividing them into a suitable length. An 8 m length and 10 m width was chosen for each of the assumption housing blocks. It is also possible to select specific assumption housing blocks with a flow curve and scale them into bridge blocks. This is done in order to create a walking path through the buildings and to increase the transparency and connectivity within the building site.

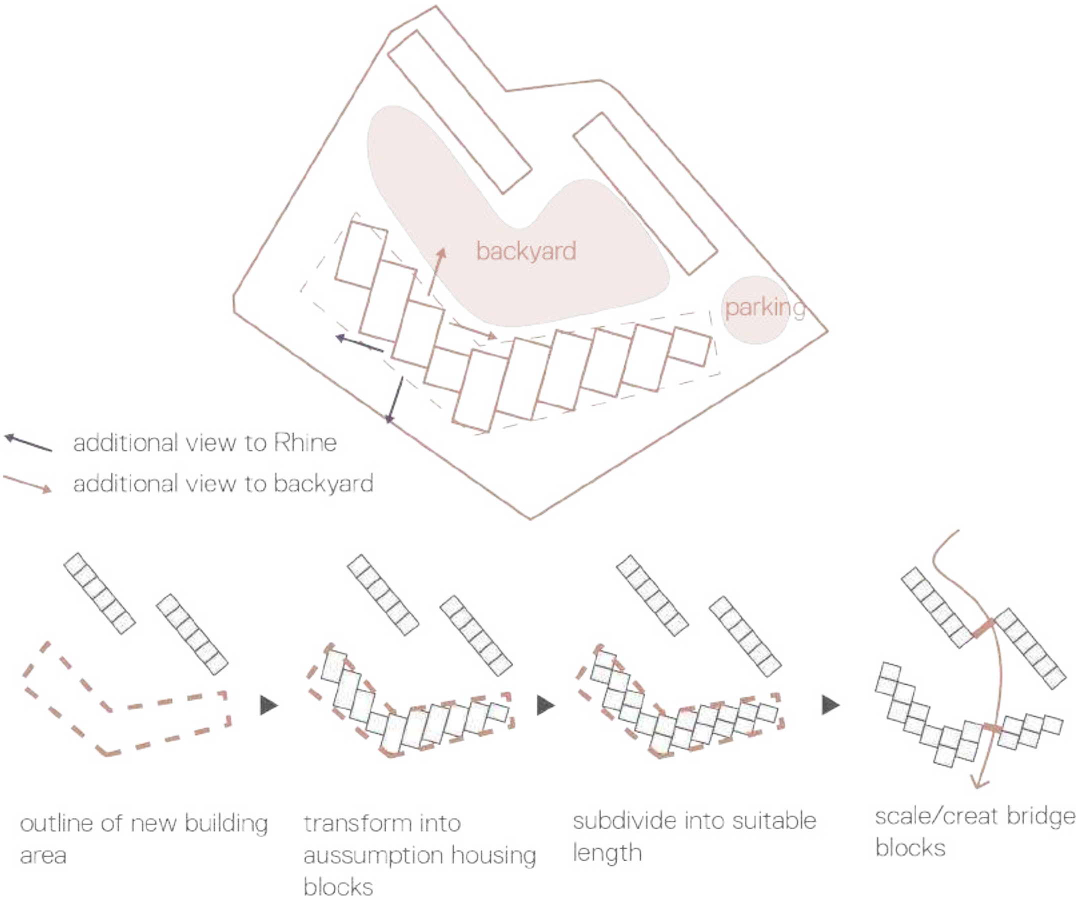

Fig. 61 Step transform

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4.2.2 Select

The key concept in this thesis is to generate the room layout according to circulation area within the building. The circulation area gives access to both apartment units and serves as a effective public place for social interaction. As described before, the generation of a circulation path curve is a progressive process. First of all, depending on the distance from the flow curve, some of the line segments of the assumption housing blocks that are close to flow curve will need to be selected as main path curve. After that, the main path curve will be applied to generate the secondary path curve. This means the shortest combination of the polyline set that connects will be with both the main path curve and the remaining unconnected blocks. In case of ventilation and to ensure satisfactory visual orientation to the Rhine in the circulation area, one end of each secondary path will be located at the edge of the building polygon. As the secondary path curves are generated, the line segment can be chosen that is in the middle of each secondary path curve as staircase curve.

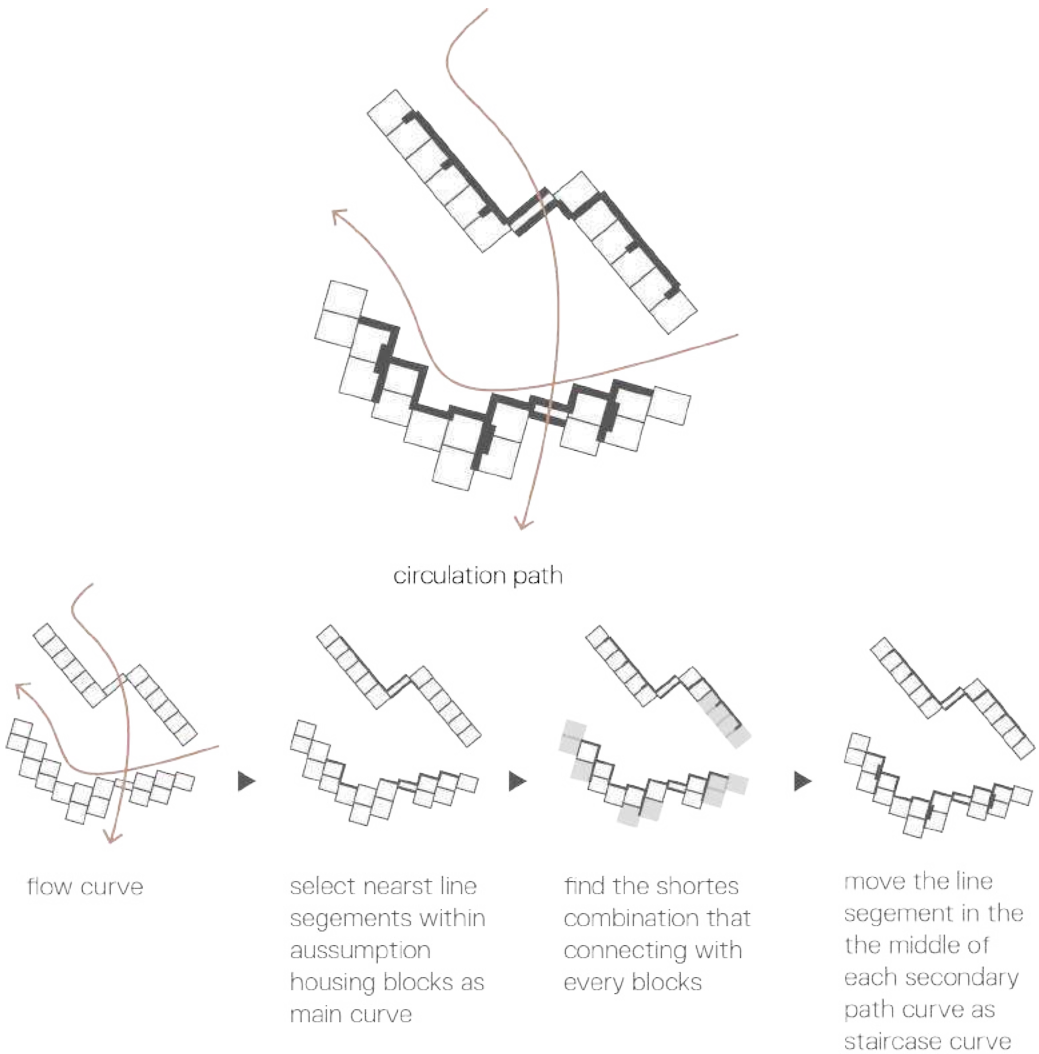

Fig. 62 Step select

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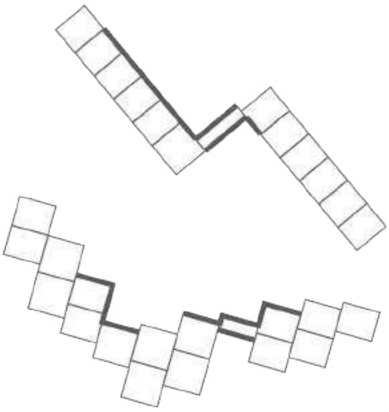
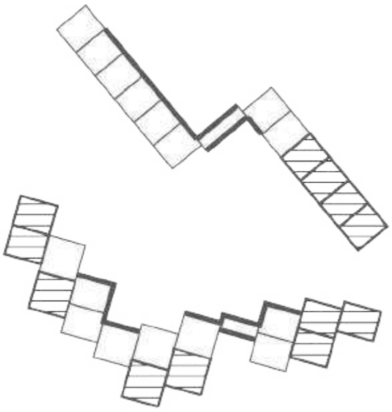
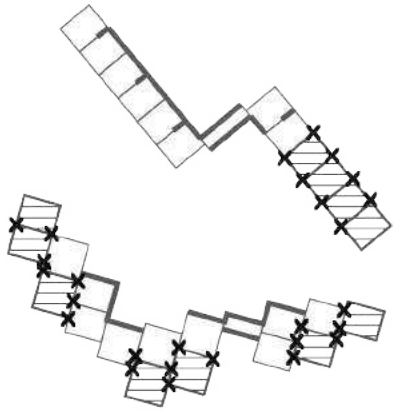
Step select (additional explanation)



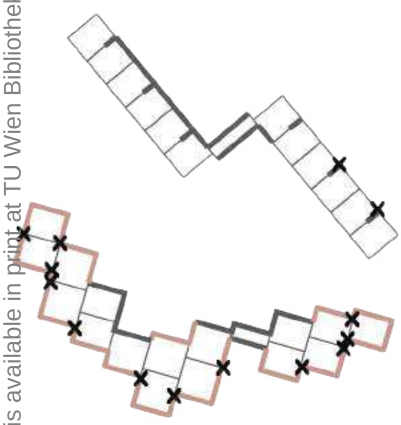
1.Main corridor path



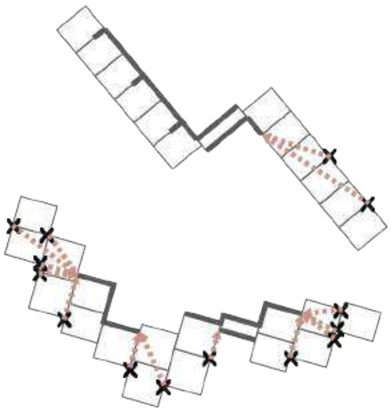
2.Find the remaining blocks, that are not connecting with main corridor path



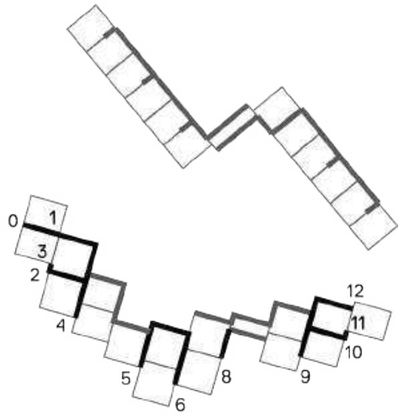
3.Find intersection points on remaining blocks



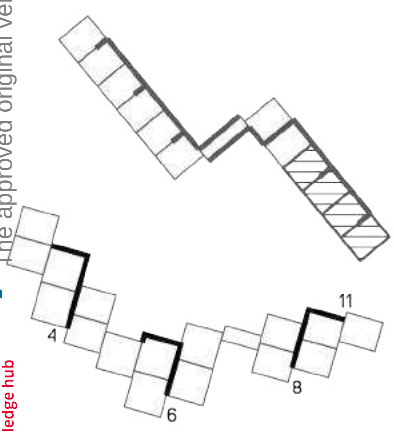
4.Select intersection points, that also on private side curve



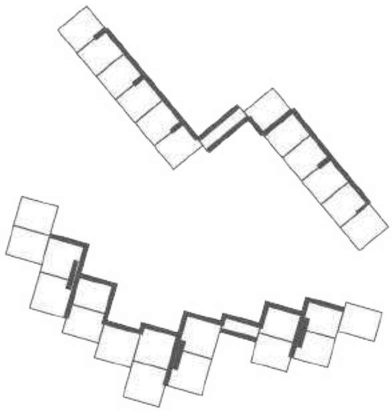
5.Find shortes distance between those intersection points and main corridor path



6.Transform those line segement into the shortes path on assumption blocks.



Select the shortes combination, hat connect with every blocks



8. Select the middle line segement from secondary path and offset them as staircase curve

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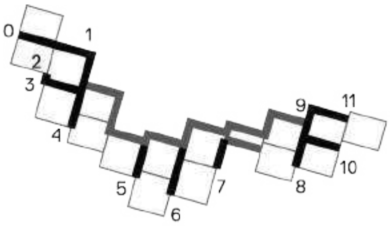
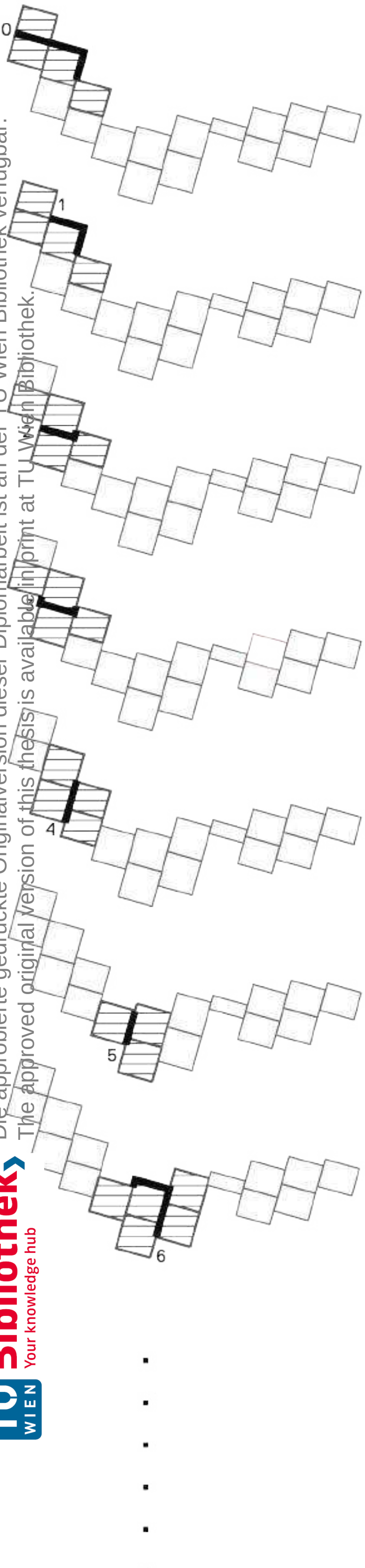
Step select (additional explanation)

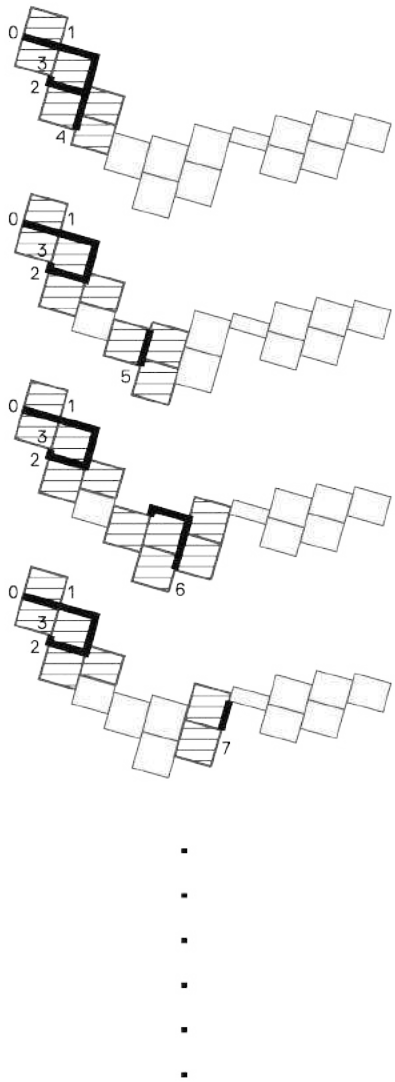


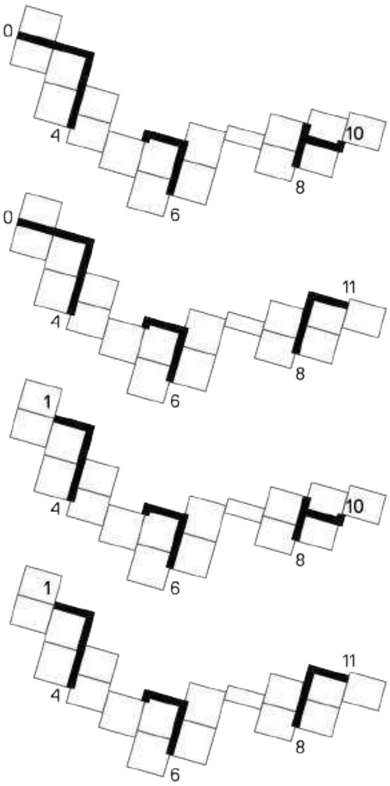
check the connecting blocks
of each path

C_5^{11}=462=(0,1,2,3,4),(0,1,3,4,5),......(7,8,9,10,11)

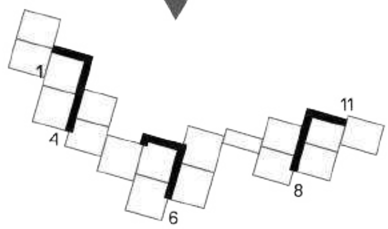
select every path set in combination C_5^{11} and find
the combination that connect with every
remaining blocks,then select the shortes combination







combination that connect with
every blocks



shortes combination

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4.2.3 Determine

This next step is of highly important, as it is a significant process for generating room layout. The room layout function distinguishes different areas in the room layout according to the circulation path curve. This step determines the combination of the output from step 1 and step 2. Since the assumption housing blocks need to be generated from step 1 and the circulation path curve from step 2, the circulation path curve will be used to select the subdivided units from assumption housing blocks. Then the subdivided units will be combined as a polygon. As chapter 2.2.3 already described, the number of rooms can be applied as an input parameter to estimate number of floors from a 3D model.

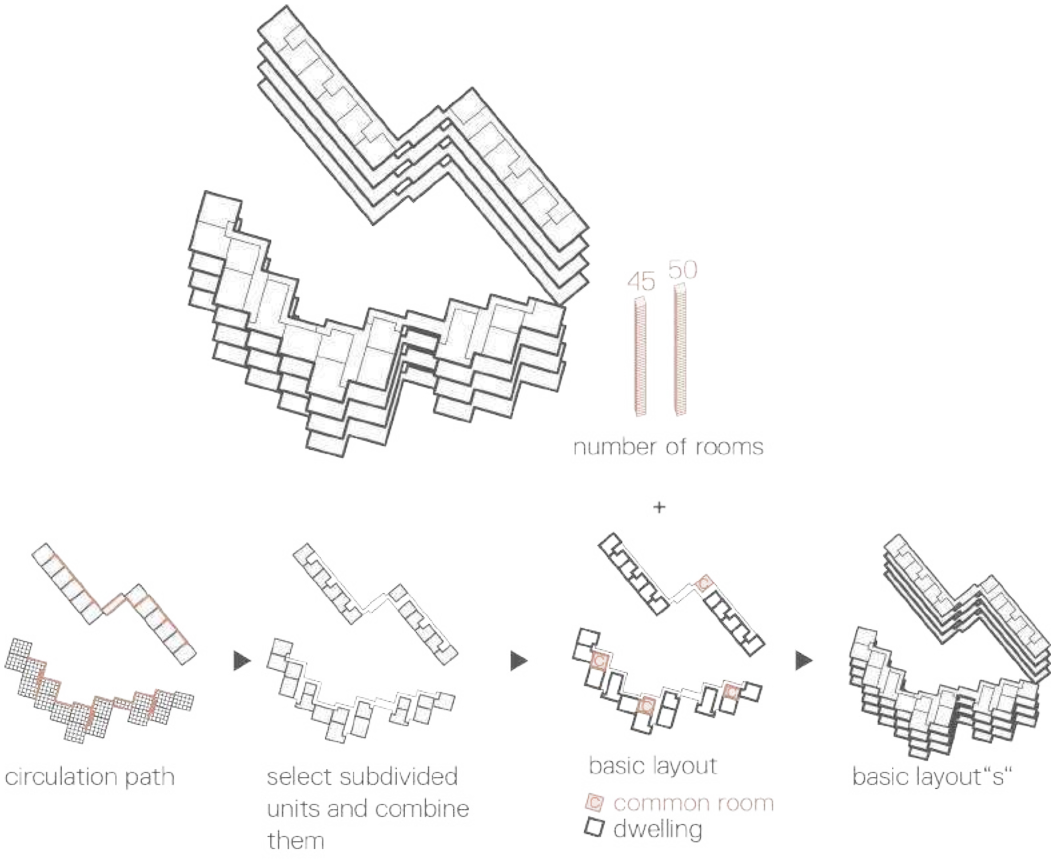

Fig. 63 Step determine

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4.2.4 Extrude

There are several methods to create a 3D model in Rhino-Grasshopper. A algorithm design is needed since each area in the basic layout are combined from the line segment of the subdivided unit. Therefore they can be classified according to their geometric properties to meet the design's demand. The line segments are defined from each flat polygon that is laying on the edge of building polygon as a façade line segment, the line segment lies both on flat polygon and circulation polygon as the entrance line segment, the line segment lies between flats as structure line segments....etc. Moreover, the selected line segments can be extracted in the Z-direction and used to create a polygon in the Z-direction, which represents the face of each construction element.

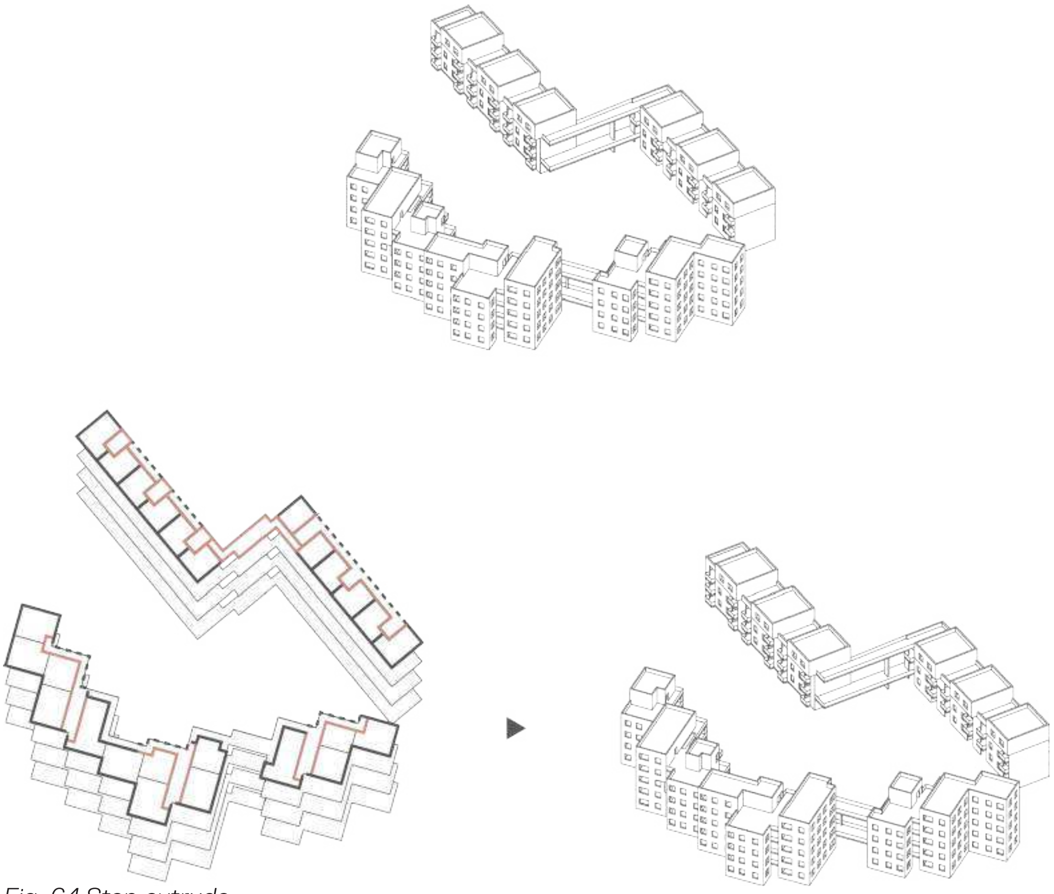

Fig. 64 Step extrude

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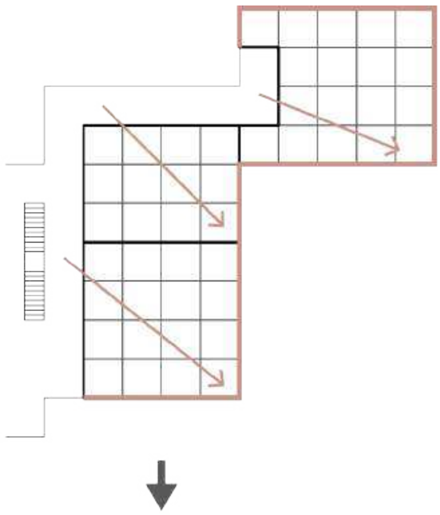
Room layout

The extra step room layout is also an extension of the layout generator. It's aim is to generate the room layout from the subdivided units, building outline and flow line within the apartment. First of all, the area of an apartment will be divided into four areas; light, dark, active and inactive through the building outline and flow line. After that, the room program will be determined according to the relationship of those areas.

1. Subdivide units
2. Building outline
3. Flow line

↓

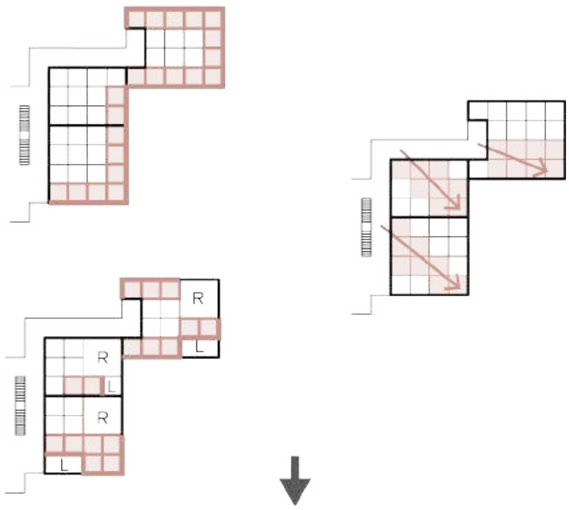


1. Light area: area near building outline
2. Dark area: area despite light area
3. Active area: area selected by flow line
4. Unactive area: area despite active area

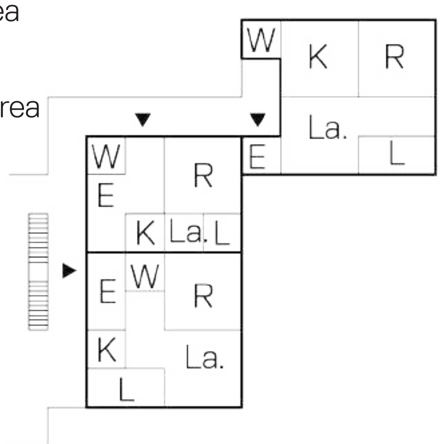
↓

1. Room: light area and the dark area are connected
2 Loggia: area connecting building outline

↓



3. Wet area: dark area without flow line
4. Entrance: the overlapping of the active area and dark area
5. Kitchen: light area without the flow line
6. Living area: overlapping of the active area and the light area



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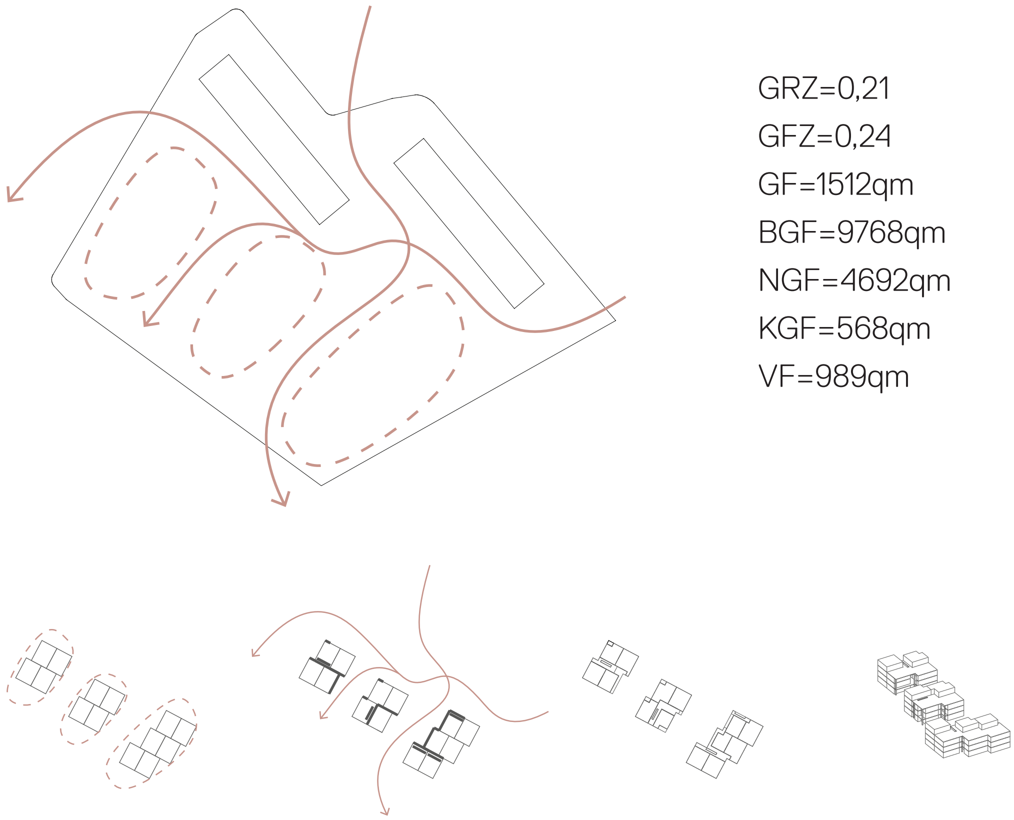
4.3 Comparison and Evaluation

For the algorithmic design process of layout generator, the flow line curve and approximate assumption outline for the new building area has to be provided by the user as the initial input data. After that, the user can apply the number of apartments and the number of mix-used rooms as a parameter according to their requirements. With these determined process and rules required to use the layout generator, those curves could also be transformed into an exact 3D model as outputs. Then the key figures can be extracted from the 3D model. This way the design methods can be applied in different architecture projects by showing the designer a way to plan effectively and reasonably. The advantage of the layout generator is that the approximate floor plans and building coefficients can be determined easily with simple geometric lines. This feature will be demonstrated in this section with the comparison of the different input curves. After the base analysis, the different inputs and parameters can be gotten. Most importantly, this also includes the assumption building curve and the spatial flow curve. Afterwards, a list of three layout plans will be created according to the different assumption building curves and spatial flow curve. Besides that, the other parameters, such as building structure, the number of rooms remain unchanged.



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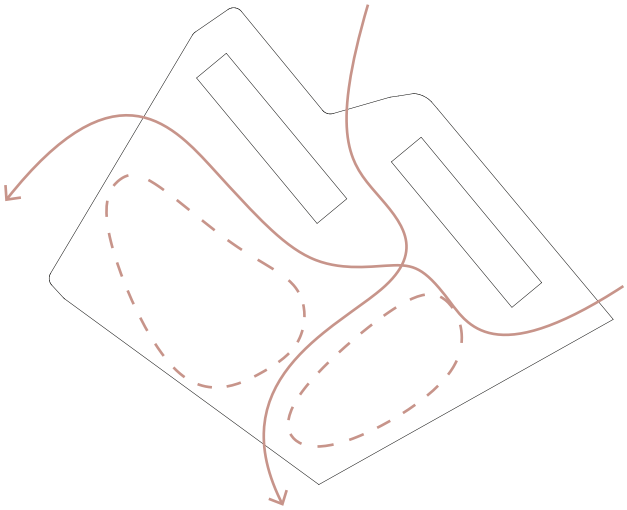

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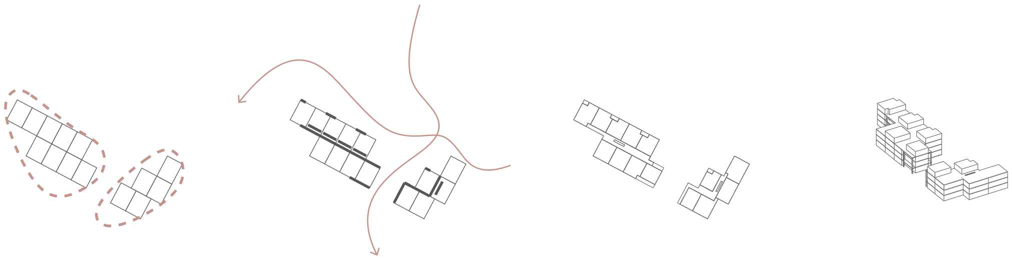

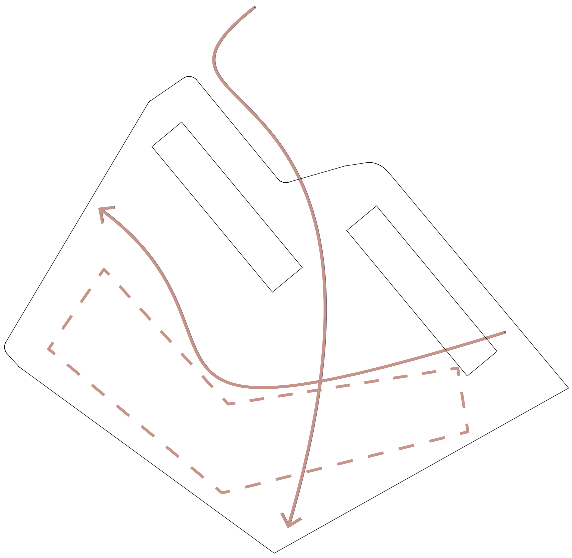

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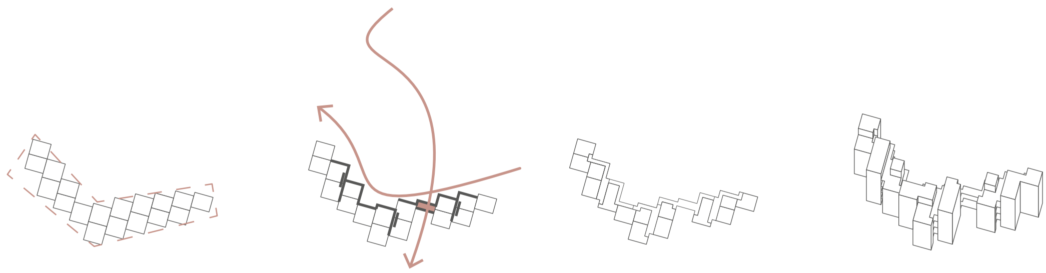

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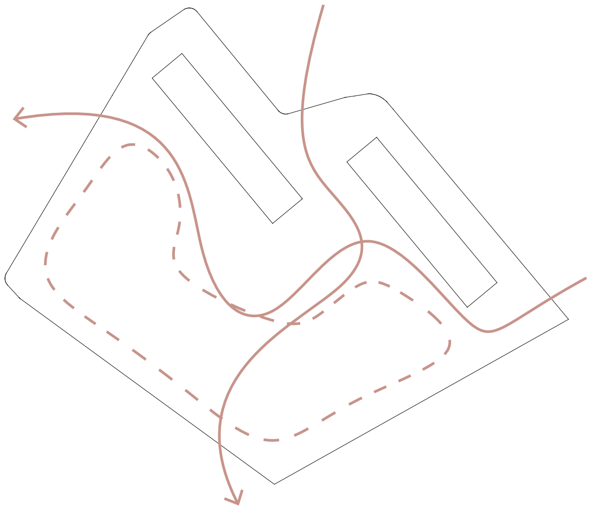

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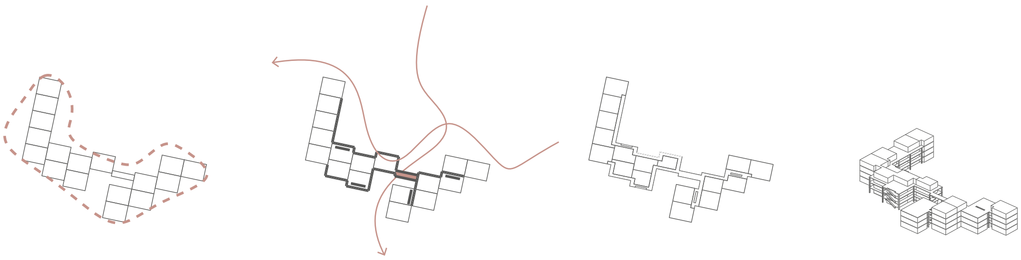

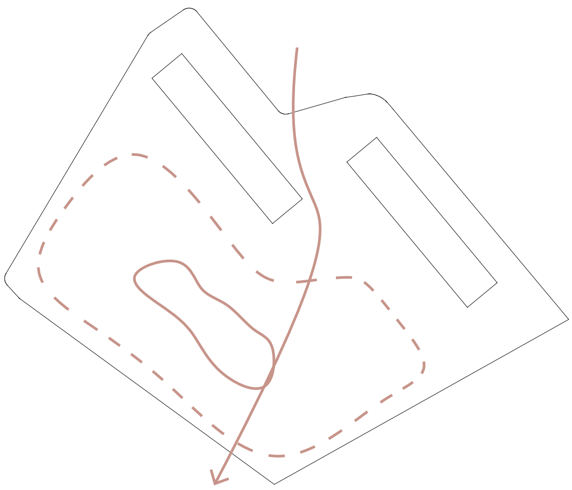

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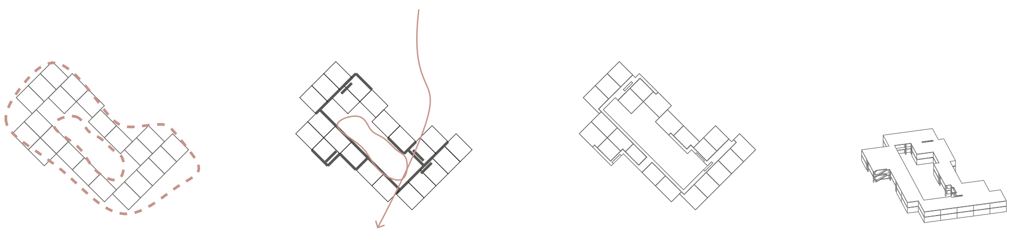

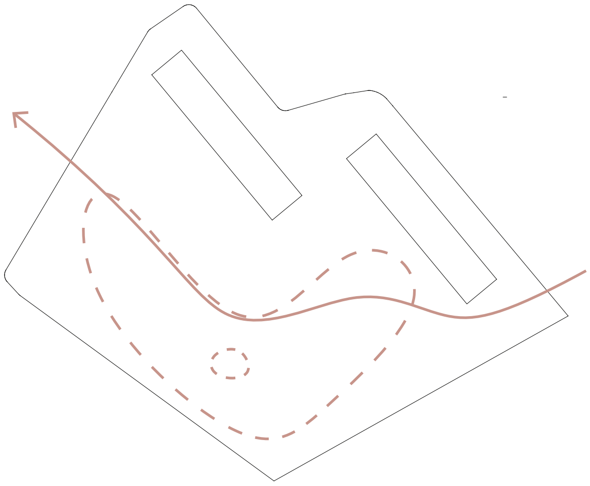

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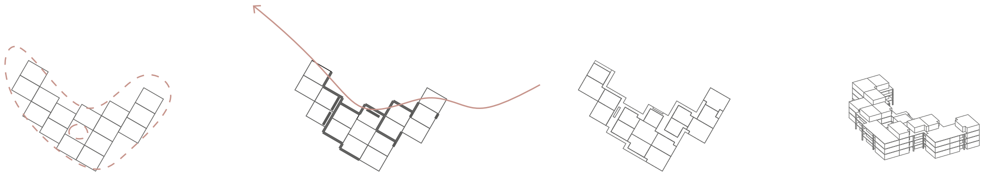

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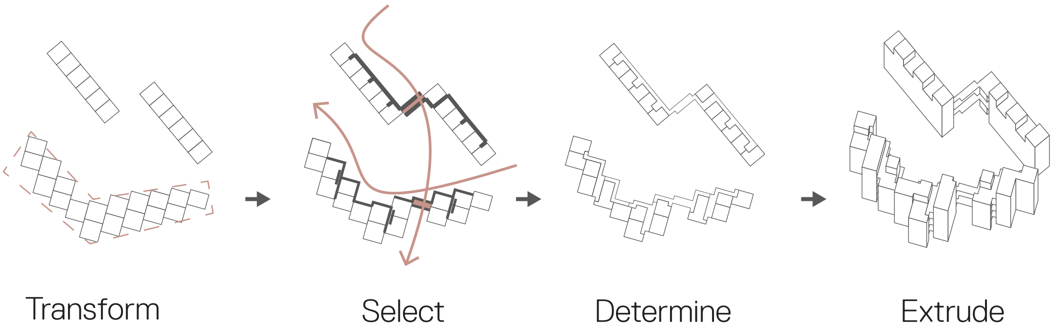
4.4 Output



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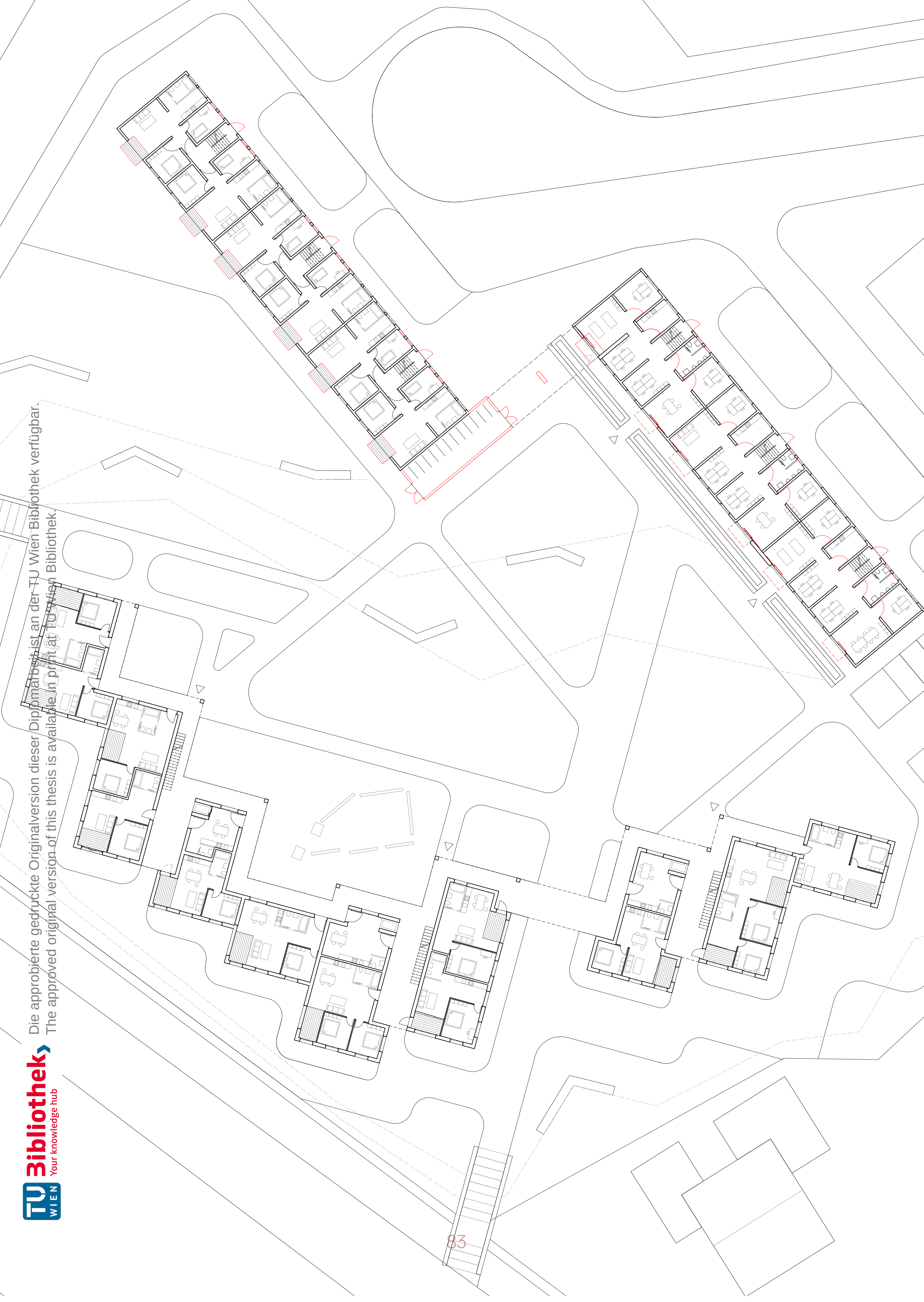

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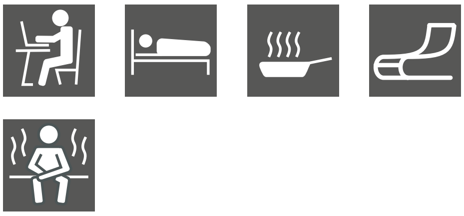
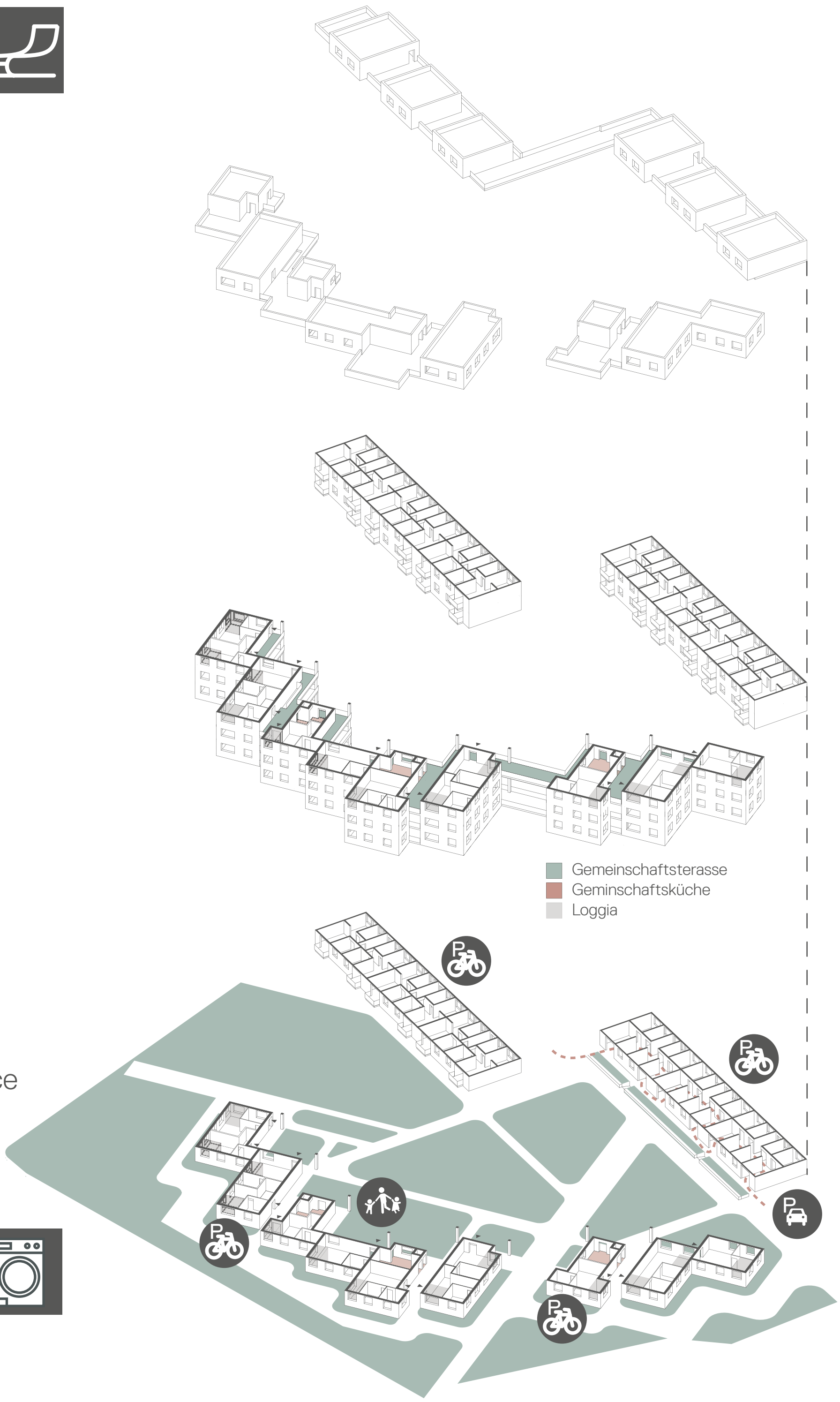
DG
Dachterrase
Gemüsegarten
Wellnessbereich
Gemeinschaftsküche
Loft Studio



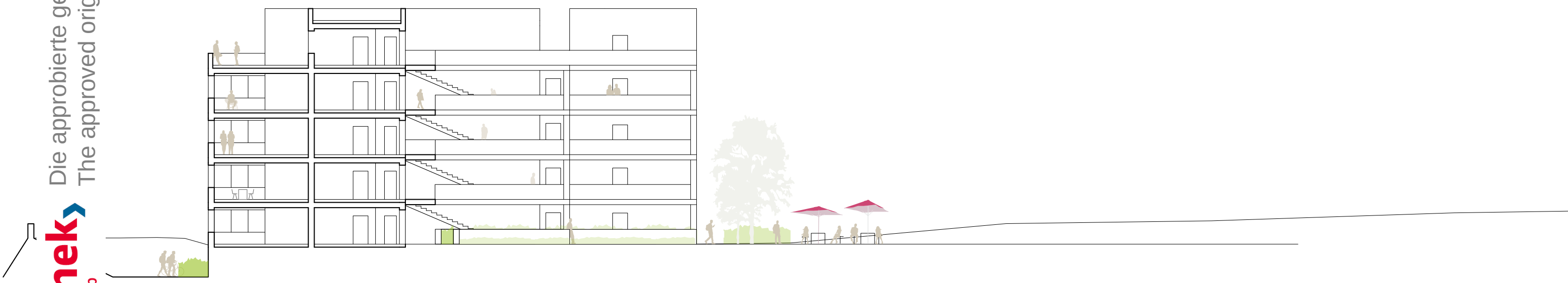
RG
Gemeinschaftsterasse
Gemeinschaftsküche

EG
Gästeapartement
Co-Working und Marker Space
Carsharing
Fahrradraum
Spielplatz



Ansicht Nordest

Ansicht Südwest 1:200



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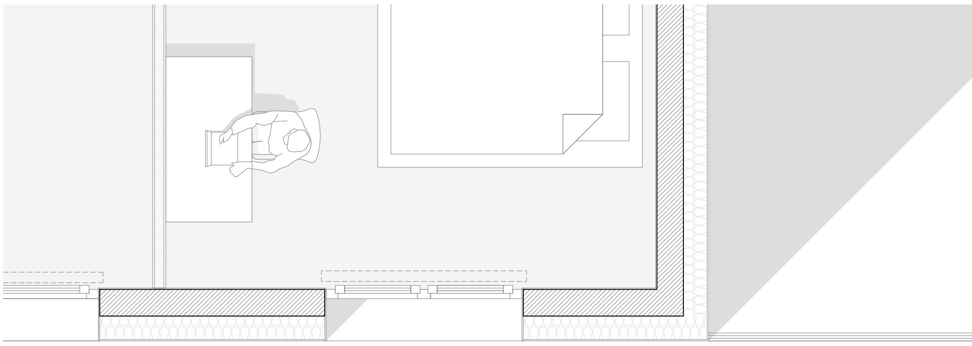
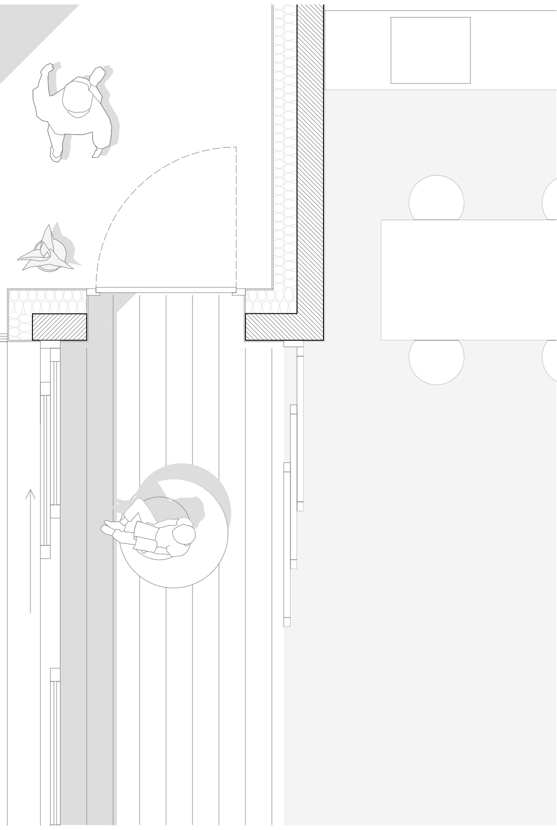




Fassaden

Ansicht Nordost
Außengangerschließung

Ansicht Südwest
Lochfassade

Wandaufbau
Einschalige Außenwand mit WDVS
Kalkputz
Wärmedämmung
Kalksandstein
Innenputz

Dachaufbau

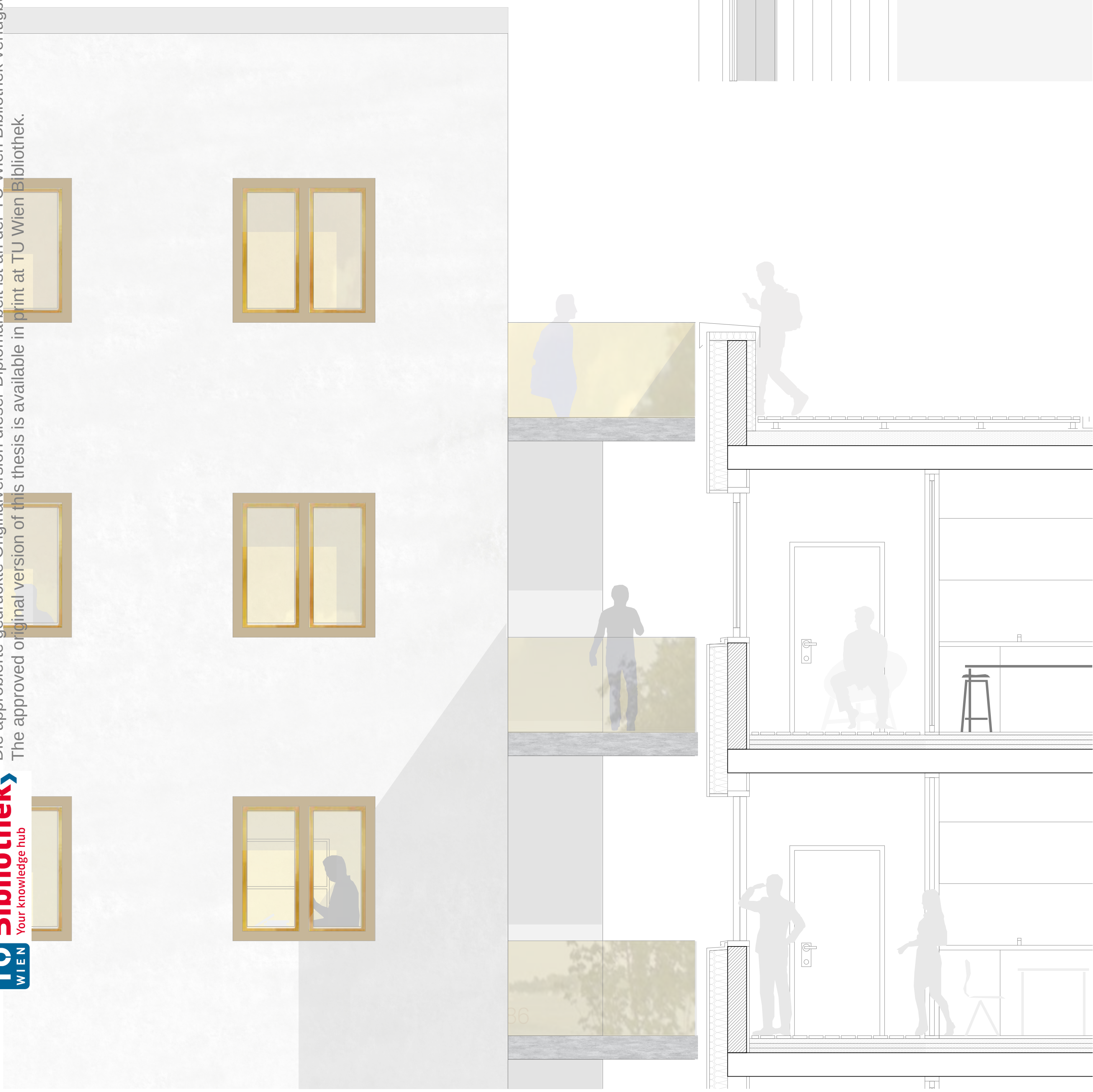
Photovoltaik
Kiesschüttung
Abdichtung
Wärmedämmung
Trenntschicht
Stahlbetondecke

Bodenaufbau

Dachterrasse
Holzdielen mit Gefällekonstruktion

Fußbodenheizung im Tackersystem
Bodenbelag
Heizrohor im Heizestrich
Dämmrolle
Sperrschicht gegen Feuchtigkeit
Unterbodenkonstruktion

Loggia/Wintergarden
Holzdielen
Heizohr im Heizstrich
Dämmrolle
Spreeschicht gegen Feuchtigkeit
Unterbodenkonstruktion



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