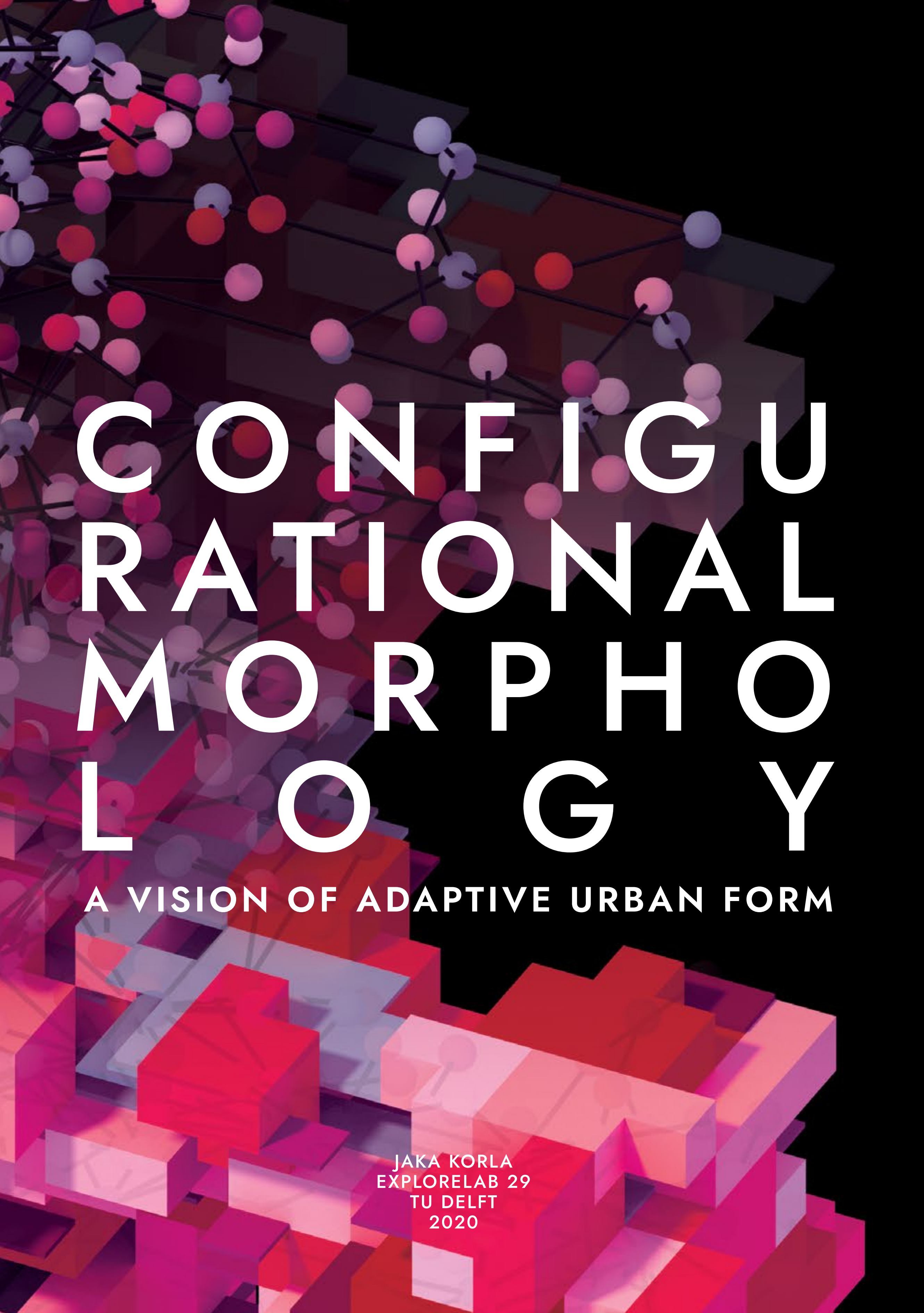

CONFIGURATIONAL MORPHOLOGY

A VISION OF ADAPTIVE URBAN FORM

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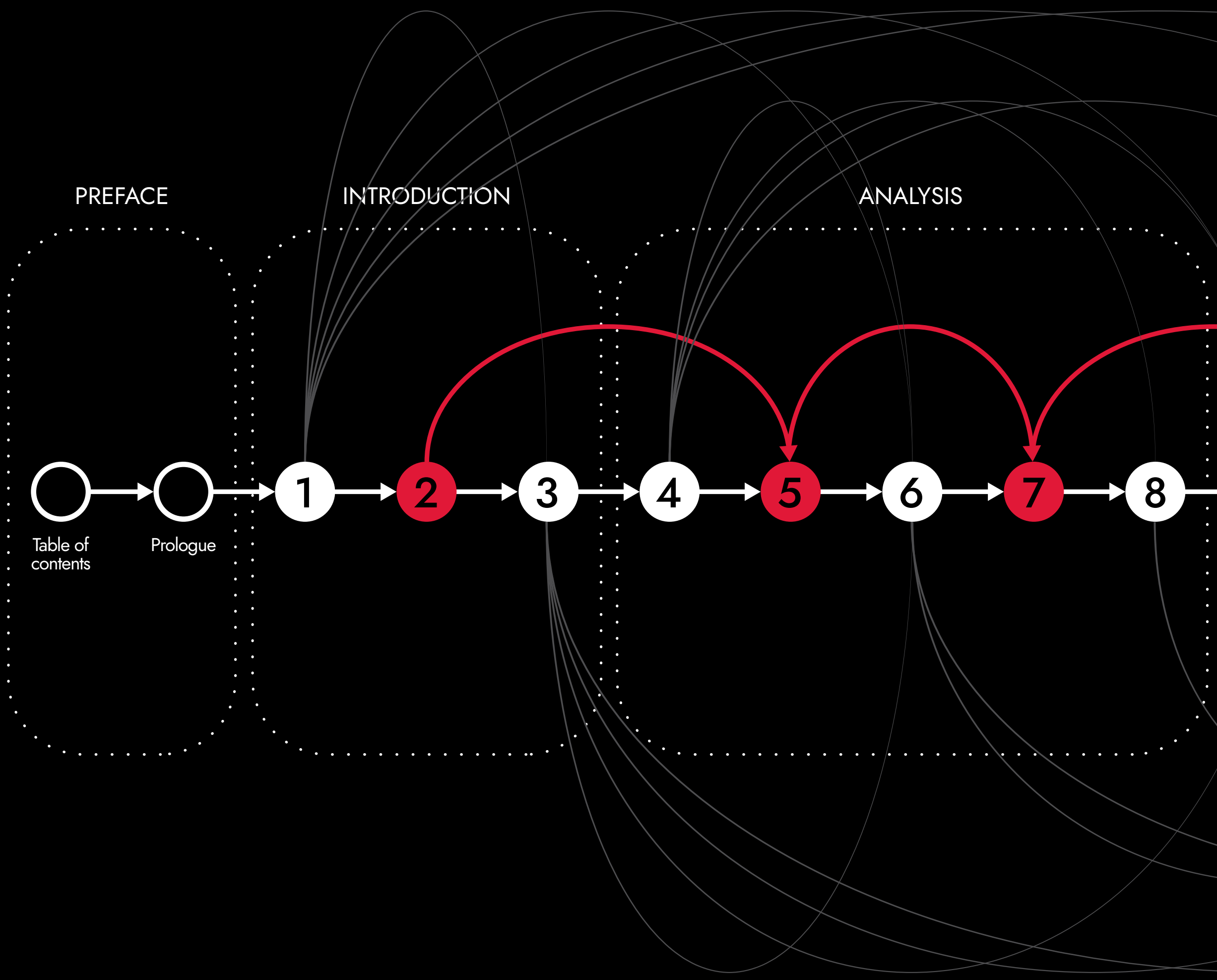


PREFACE
INTRODUCTION
ANALYSIS
Table of contents
Prologue
1
2
3
4
5
6
7
8

5 ON TYPOLOGY

What is typology, why is it useful, what are its main issues and how can it change to become a productive analytical and design tool for configurational design?

P. 86

6 CONFIGURATIONAL TYPOLOGY

A systematic catalogue of configurational urban types at the building/block scale based on predominant existing urban forms and their underlying spatial configurations, stripped of their formal limitations.

P. 95

7 ON DIAGRAMS

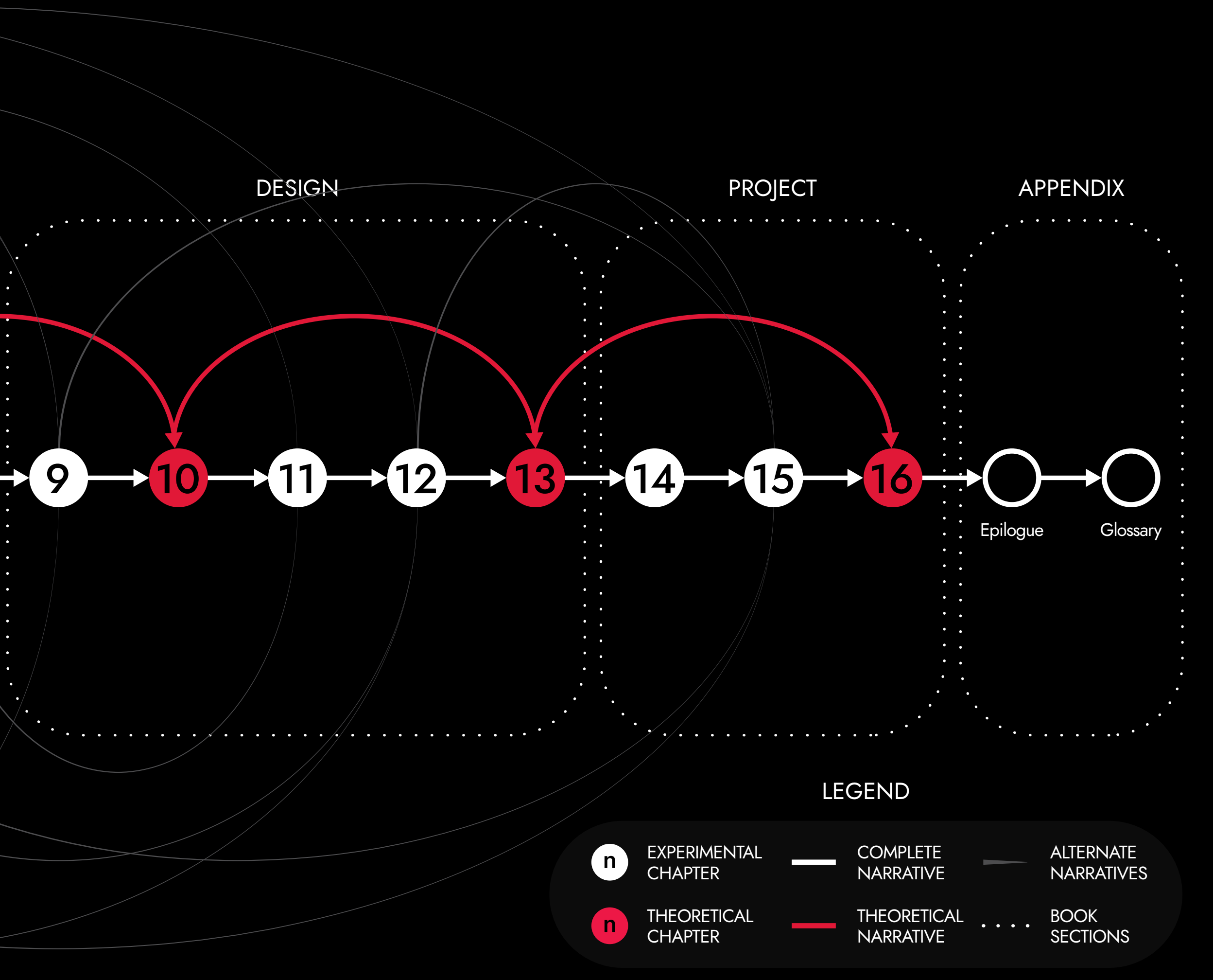
What is a diagram, what role does it play in the design process and how can it aid in creating designs which are adaptive and flexible? How can it be utilised as a mediator metween the human designer and computer?

P. 130

8 DIAGRAM AS A MEDIUM

Looking into the precedents, problems and potentials of diagrams as a configurational design tool and a proposal for an integrated configurational digital design interface.

P. 139



13 ON THE ARCHITECT

What is the role of the architect designer in the configurational-computational design approach and what is his relationship to the underlying generative algorithms? Who is the real designer?

P. 290

14 PROJECT CONFIGURATION

Deriving from the generated body of research, a project brief intended as a base for the development of a proof-of-concept architectural design on a site in Rotterdam, Netherlands.

P. 299

15 PROJECT DESIGN

The design project developed through the configurational computational approach and intended as a proof of its viability for the general architecture practice.

P. 333

16 ON INFLUENCE

What impact does the configurational design approach have on the discipline of architecture, its practice, as well as the broader society and the world?

P. 434

WHAT IF?

This book is about the spaces we live in. Our **cities**, towns and villages, their buildings and streets. The sprawling suburban cookie-cutter houses, introverted glazed-off commercial towers, everpresent slabs of anonymous apartments. Endlessly repetitive urban fabric proliferating all around the globe regardless of context, climate or culture producing the generic city. But what if this is not the only way?

What if we could replace repetitive towers, slabs and houses with **adaptive** forms growing organically out of local conditions, creating cities of tremendous spatial **diversity** and complexity, where a different spatial experience hides behind every corner? Could we imagine cities in which buildings and the urban fabric could again become generators of **identity** emerging out of contemporary culture, local climate and context? What if we could replace inert generic geometries with responsive **sustainable** forms of improved energy and climate **performance** capable of aiding in our battle to lower global emissions and stop global warming? What if urban **density** does not need to contradict openness and nature but can instead encourage both through increased **porosity** and vertical multiplication of the urban ground plane? What if this made possible cities in which living on the 20th floor does not mean a lack of a private sunlit terrace or proximity to a lively communal square? What if **hyper-density** could leverage its increased economic viability to improve accessibility to **affordable** housing, currently sorely lacking in many parts of the world? What if the patterns of streets, squares and buildings responded to the ways we interact and live together to once again foster the growth of meaningful living **communities** increasingly disappearing in our digital network society? What if the shape of the urban fabric would in itself encourage **equality** by reducing or eliminating inferior units today epitomized by sun-less north-facing apartments and ensuring equal **living quality** standards for everyone? What if buildings themselves were more than static containers for dwelling and working, instead operating as dynamic **ecologies** generating not only interior but also exterior urban space, producing food and energy, all while functionally adapting to our society in constant flux?

What if we as architects had the power to create such cities? **What if?**

INTROD

UCTION

1

Why is the contemporary urban fabric so generic and why is that an issue?

THE GENERIC URBAN FABRIC

Drawbacks of standardization in urban form

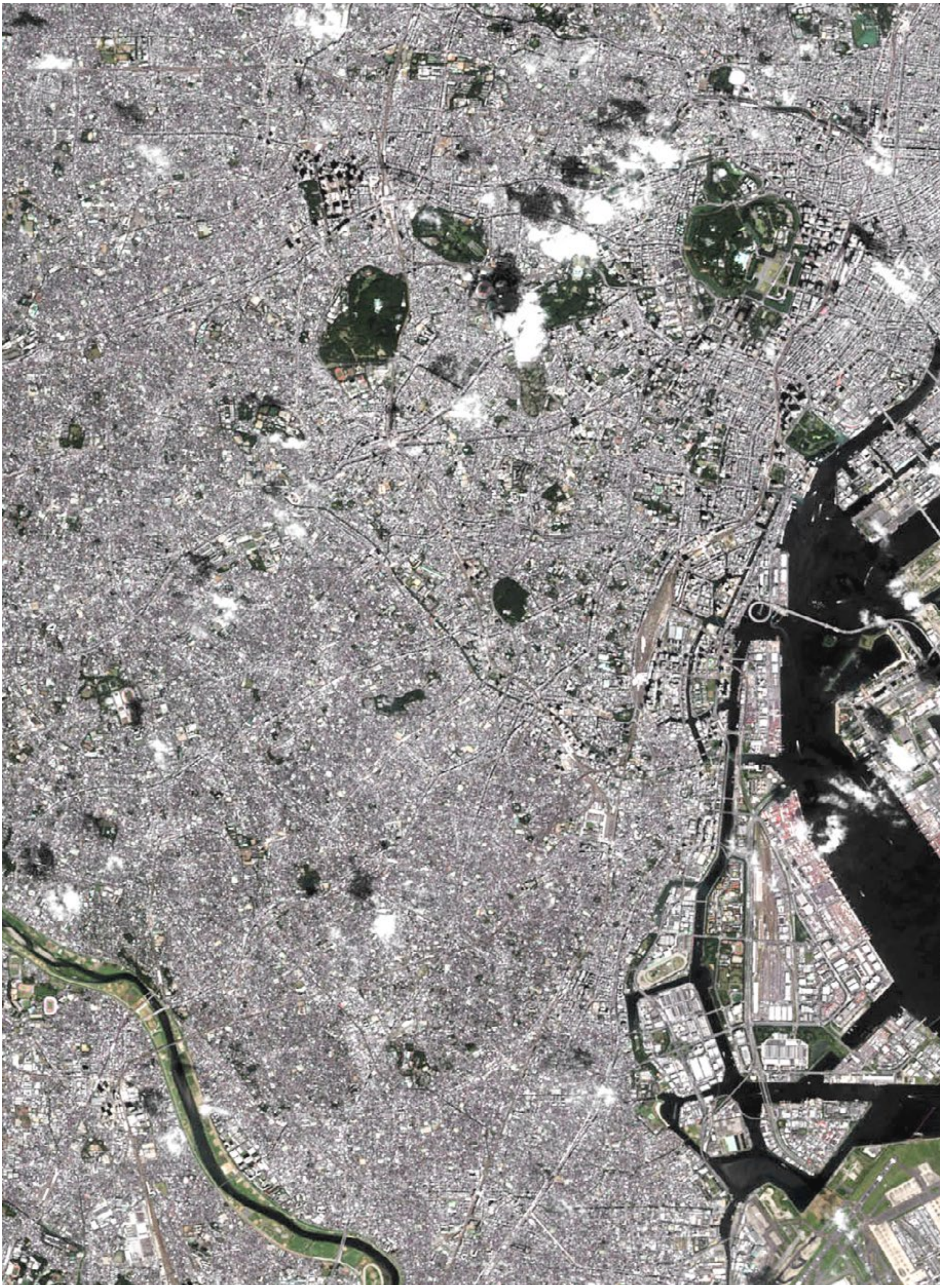
During the last few decades, cities have undoubtedly become the primary human habitat. Already home to more than half of the world's population, they continue to relentlessly grow as a result of global **urbanization** with Asia and more recently Africa as its main epicentres where seemingly every day new metropolises emerge.[1]

This expansion puts enormous pressure on existing types of **urban fabric**, already stretched to the limit of their performance, to be ever more efficient in terms of sustainability, spatial quality and density to adequately accommodate this growth. Among the most important factors determining this performance are the buildings from which a city is made; its **urban form**. Although usually used to describe the urban grain at the scale of a city, urban form is defined as the physical characteristics making up built-up areas including their shape, size, density and configuration.[2] As such, the term urban form can be used to describe the individual buildings and their groupings which act as fundamental building blocks from which a city is composed through a continuous process of aggregation.

In existing cities worldwide this form is predominantly defined by a small number of historically established **urban types**, some with cultural roots such as the dutch rowhouse, while others like the tower are purely an expression of the unending quest for efficiency and profit. The main types constructing the modern (especially western) city are the detached house, semi-detached house, rowhouse, courtyard townhouse, slab and tower. Although admittedly some regions and cities are due to various reasons more strongly associated with certain types, it is telling that in practically any city in the world irrespective of culture, climate or context most if not all of the predominant types can be found. These types are the source of **the generic city**.

This genericness eventually leads to reduced performance as a consequence of the inability to adapt to local conditions and varying requirements, in turn creating underperforming urban form at a time when efficiency and sustainability of cities are of paramount importance.
On top of this, the urban types themselves have shown to be fundamentally inadequate to effectively respond to the pressures of contemporary cities; ecologically **unsustainable** detached houses due to urban sprawl, socially unsustainable slabs and towers limiting interaction, economically unsustainable traditional types such as row houses through a lack of density.

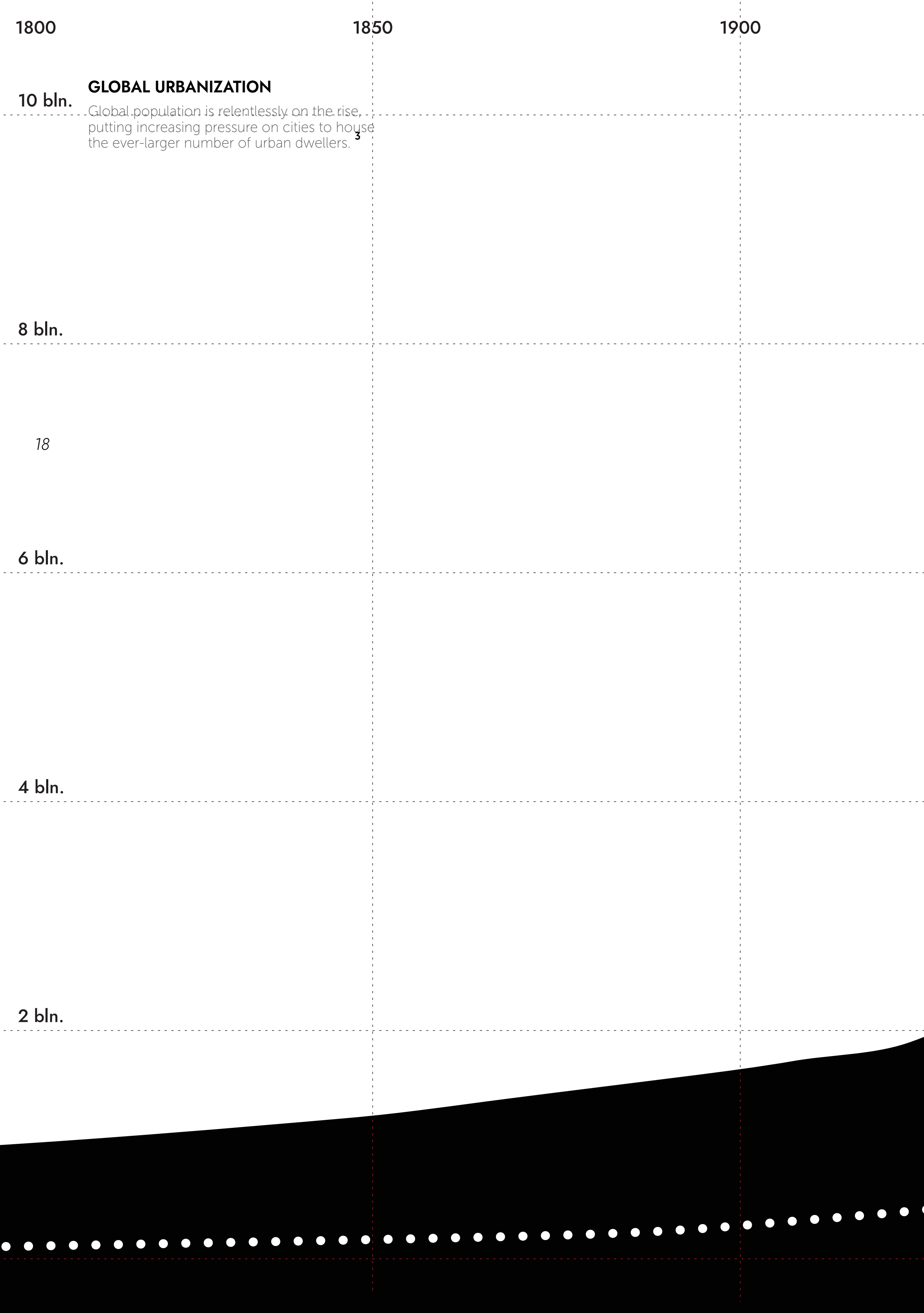
In our search for efficiency and profit, we have spread the generic city everywhere, while trading quality for quantity in the process. Today there is a pressing need to find alternatives and the question is how to create adaptive urban form capable of responding to the environmental, social and economic context in which it is placed.

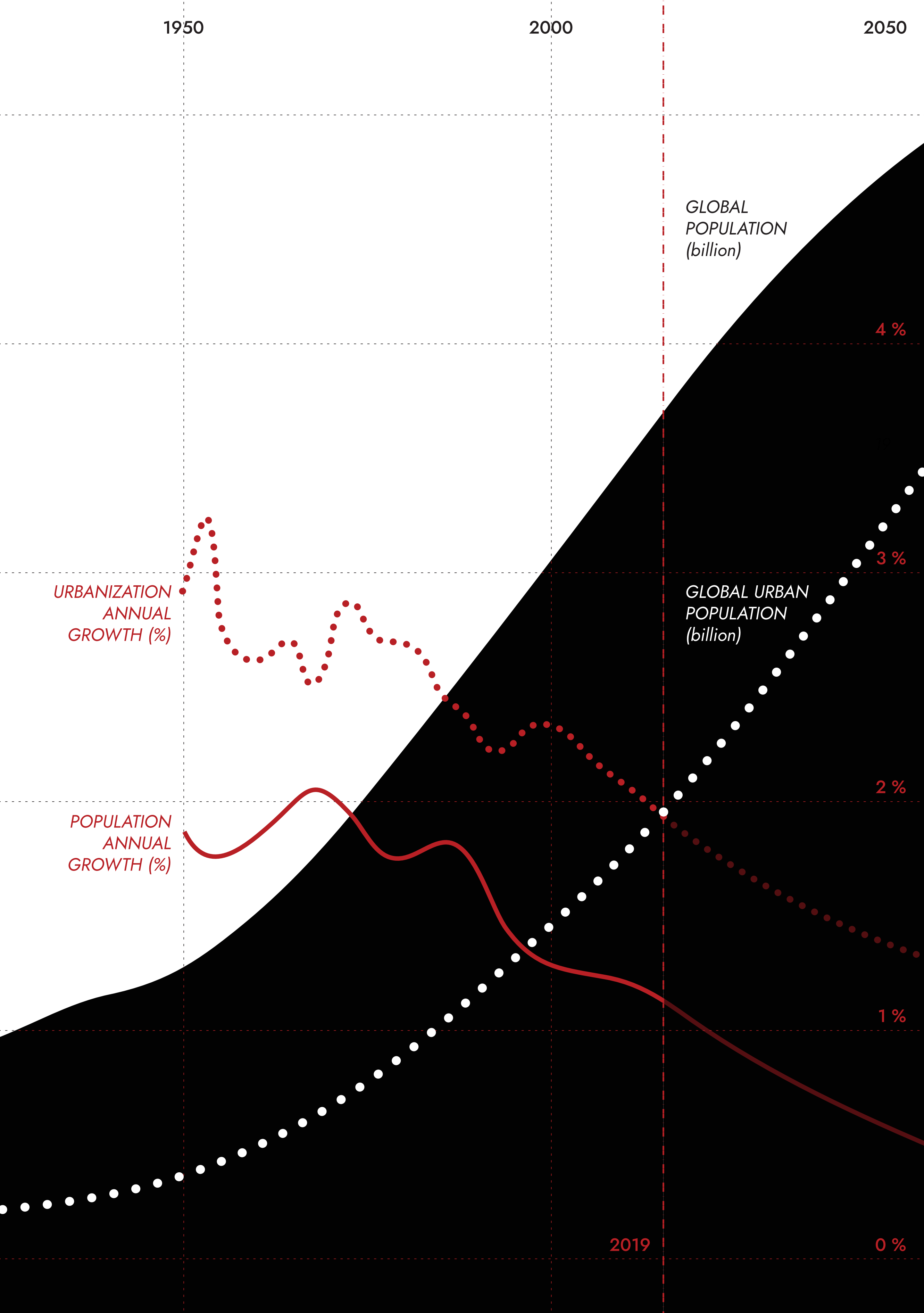


Tokyo, the largest metro area in the world with 38.140.000 inhabitants

GLOBAL URBANIZATION

Global population is relentlessly on the rise, putting increasing pressure on cities to house the ever-larger number of urban dwellers.[3]




1950
2000
2050
GLOBAL POPULATION (billion)
4 %
3 %
2 %
1 %
0 %
URBANIZATION ANNUAL GROWTH (%)
GLOBAL URBAN POPULATION (billion)
POPULATION ANNUAL GROWTH (%)
2019

URBAN BUIDLING BLOCKS

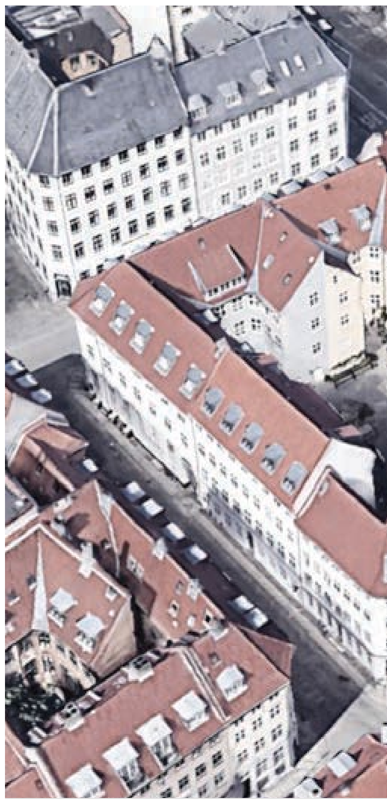
Left, a satellite view of the urban fabric of Almere, a newly planned city in the Netherlands. Right, a zoom-in into the additive process of its construction and growth.

URBAN FORM is defined as the physical characteristics that make up built-up areas, including the shape, size, density and configuration of settlements.[2] Whilst it can be considered at different scales including regional, urban, neighbourhood, block and street, in this research the focus is on the scales of a building and an urban block. These are chosen because it is at these scales that cities grow through a process of continuous aggregation of individual buildings into an urban fabric. The performance of this fabric in terms of spatial quality and sustainability also predominantly depends on its morphological characteristics at the aforementioned focus scales. The building and the urban block are the fundamental building blocks of cities.

Detached house; Los Angeles

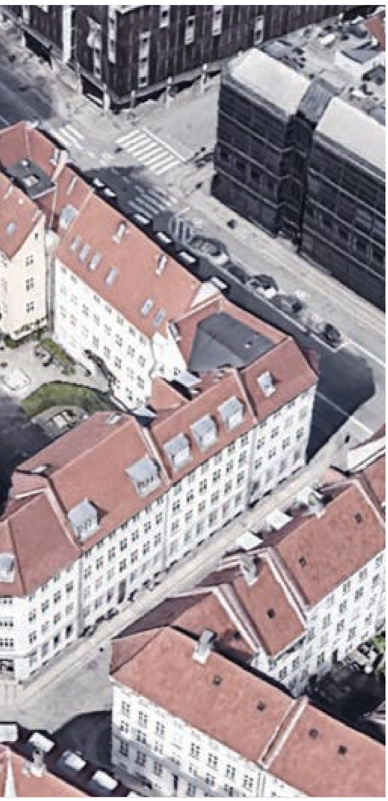
Row house; Rotterdam

Semi-detached house; London



Courtyard townhouse; Copenhagen

Slab; Moscow

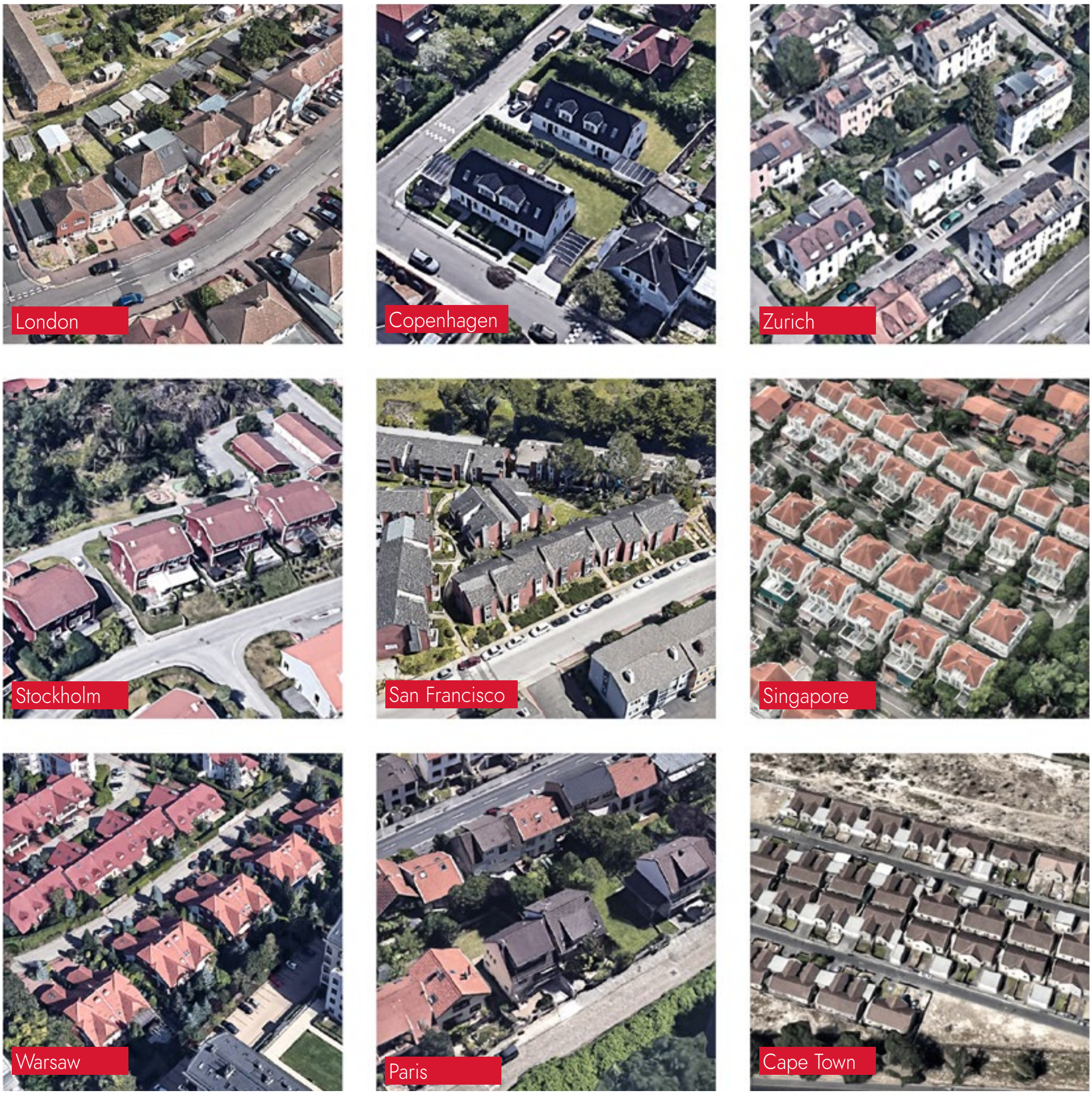


Tower; Rotterdam

Left to right: Los Angeles, Amsterdam, Hong Kong

EXISTING TYPES of urban form are increasingly found to be insufficient when deployed within our cities and dealing with their dynamic forces. Be it the environmental unsustainability of detached houses due to urban sprawl, the economic unsustainability of traditional types such as row houses as a function of insufficient density or the social unsustainability of introverted high-density developments such as slabs and towers, these existing ways of creating built fabric are not responsive enough to the complex conditions found in a contemporary metropolis, instead perpetuating a generic and suboptimal urban fabric all across the globe.

Generic detached houses



Generic semi-detached houses

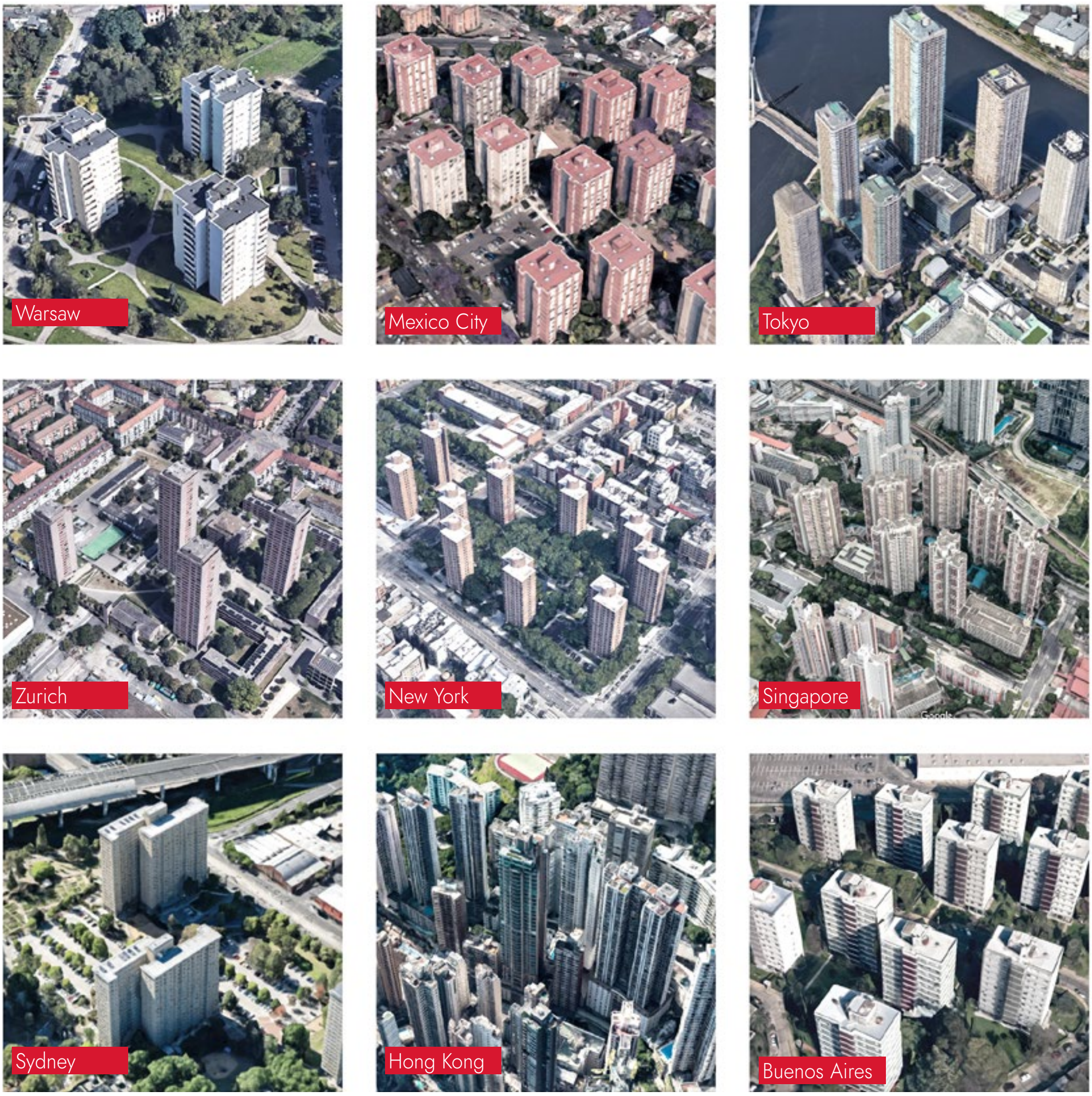
Generic row houses

THE GENERIC CITY

Overview of the expansive global spread of the generic city through the basic urban types constituting it.

Generic courtyard townhouses

Generic slabs



Generic towers























2

ON... DESIGNING

What are the issues with the current design process and what benefits could an alternate configurational approach bring to contemporary cities?

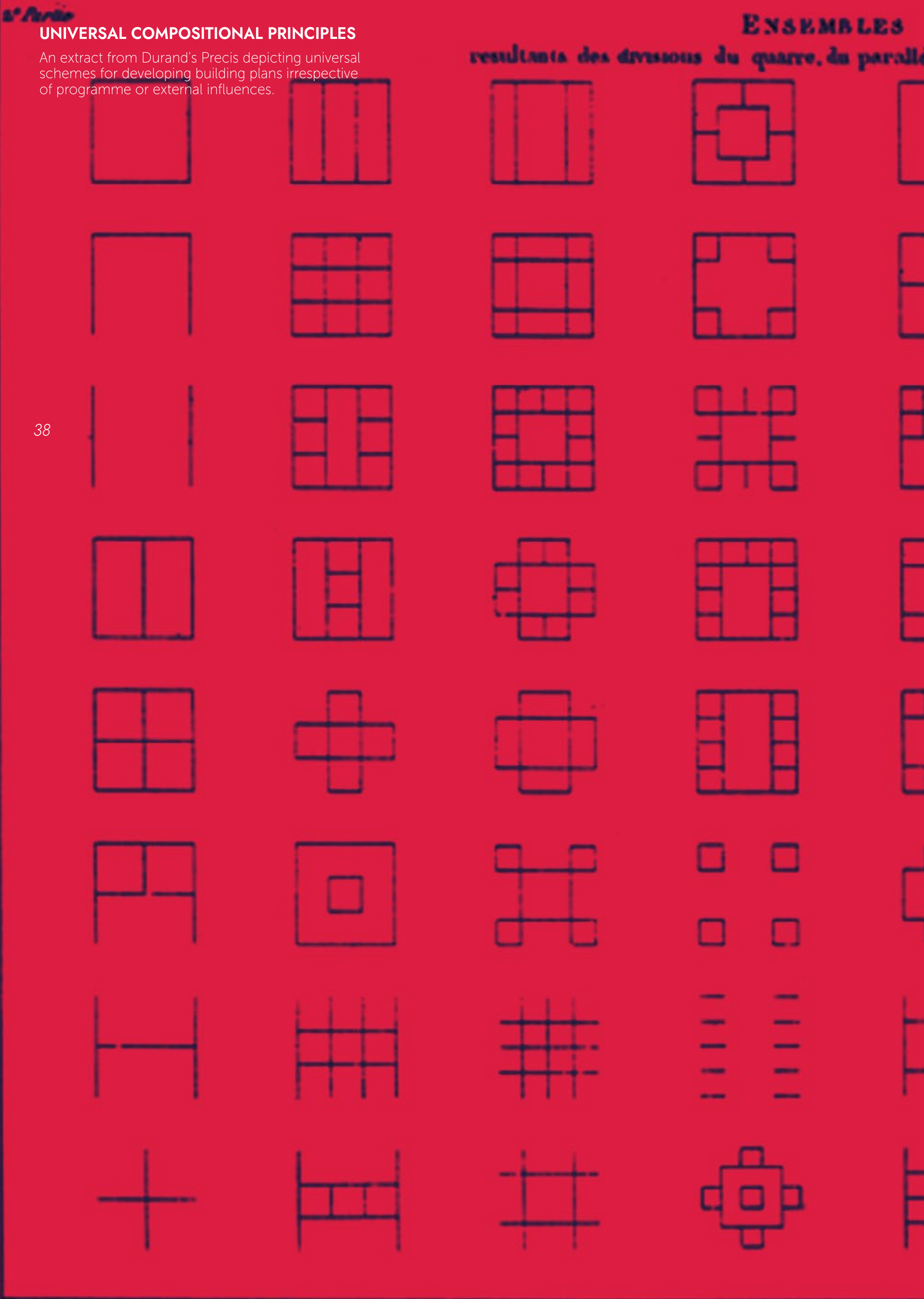
Evolution of **urban form** is a crucial part of the accelerating process of global **urbanization** and our search for the diverse, inclusive and sustainable city of the future. This search for new forms of habitation has always been and will remain one of the greatest challenges facing architecture in the coming decades as pointed out by **Mumford** already in the 1960s: ***"The paramount urban problem today is to invent an adequate urban container which will do for our complex and many-sided culture what the original Stone Age container did for the far simpler cooperations and communications of earlier societies"***.[4] While this is a struggle encountered by every generation of architects, today the issue is more pressing than ever considering the shape of our cities is essentially unchanged since the start of the 20th century despite a hundred years of increasingly rapid development and accompanying **societal change**.

What we are capable of creating as architects is directly influenced by the way we design; our **design process**. The predominant form-based approach in architecture today is rapidly proving to be insufficient for inspiring the production of new urban forms adapted to the contemporary city, a changing society and the increasing ecological crisis, instead perpetuating the spread of rigid, standardized and often underperforming **genericness**. Today, the generic city is everywhere. Manifested in sprawling shopping malls, swathes of isolated glass towers, everpresent slabs resembling walls of soulless apartments and endless expanses of repetitive suburban houses, it represents the materialization of globalization as well as being the reflection of a design approach inclined towards sameness and repetition.[5] At the level of urban form, the generic city is mostly composed from established **urban types** constructing the majority of existing built fabric. Detached houses, slabs and towers are multiplied everywhere around the world irrespective of context, culture or climate, creating an urban fabric which, as a result of its unresponsiveness, underperforms and does not live up to its potential. Searching for reasons why this is so, a large amount of blame can be attributed to the fact that within the architecture, engineering and construction industry (AEC) the predominant mode of production remains **Fordist mass-production**, as well as to the ever-increasing pressures of the **market economy** driven by efficiency and profits.[6] Global capitalism effectively drives the spread of the generic city.

Although the way urban fabric is created admittedly depends on many external factors beyond the power of architects, there remains a complementary set of influences within our own **design approach** reinforcing this unending production of genericness. Firstly, throughout history, be it classicism or modernism, architectural design was predominantly based on simple **universal principles** of composition such as proportion, mass, scale and symmetry, which represented the foundation on which all architectural form was created in a **top-down** formal manner.[6] Whilst such rigid use of principles and "ideals" is less common today, the tendency for top-down imposition of forms, systematic simplification and reduction of **complexity** remains strongly present. This is most evident in project presentations where seemingly every project and its shape can be neatly reduced to a single concept sketch explaining the entire scheme. In an age in which ideas are universally shared and recycled, such a reductive approach can only work for so long before leading to generic buildings and spaces. Secondly, especially at the scale of urban form, (typological) design via precedents has been used as a method intended to both simplify design through the reuse of existing models as well as allow for innovation by their

FORDIST MASS-PRODUCTION

Example of fordist mass-production of urban fabric in China creating generic and soulless expanses of semi-detached houses.



UNIVERSAL COMPOSITIONAL PRINCIPLES

An extract from Durand's Precis depicting universal schemes for developing building plans irrespective of programme or external influences.

adaptation. Although this can yield productive results when used appropriately, it also introduces potentially limiting **preconceptions** and biases into designers minds, leading to direct formal reproduction and thus genericness.[8] Together, these influences have combined to create an environment in which meaningful formal innovation is made increasingly difficult, as visible in the lack of progress in recent decades.

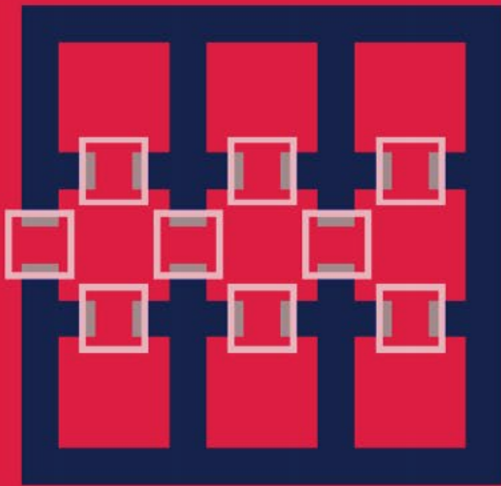
While form is undoubtedly the primary spatial aspect with which an architect operates, architecturally, space can be examined at different **levels of abstraction**, each describing a specific system of organization. As described by **John Habraken**, coincidentally on the example of an urban type, any space can be viewed in many ways, three of which usually predominate; **stylistic, formal and configurational**. In this context, style describes ornament as well as the placing and proportions of windows and doors, for example, form describes the physical system of walls and ceilings that define space and give a building its shape, while **configuration** defines the network of spaces contained within, their relationships and interconnections.[9] In the existing design process, architects spend the vast majority of time consciously operating on the level of form; this becomes even more pronounced when working at larger scales related to urban form such as the scale of a large building or even an urban block. It is precisely this preoccupation with formal aspects of architecture that can become an obstacle for inventiveness and creativity as a result of our internalised preconceptions which are in turn an inevitable result of past experiences, established precedents and personal ideologies. Paradoxically, our intense focus on form directly limits our capacity to reinvent it.

In hopes of countering this, a **configurational approach** to architecture argues for the shift of conscious design to a higher level of spatial abstraction; **spatial configurations**. This abstraction temporarily disconnects the architect from formal aspects by shifting his focus to the configuration of space, while simultaneously allowing a multiplicity of forms to autonomously emerge as a result of external influences acting on the designed configuration. In other words, abstraction via configuration can be thought of as a device for removing preconceptions and helping the designer to think previously unthinkable forms. Beyond mere abstraction, such spatial patterns underlying built form already constitute the elementary building blocks of cities according to **Alexander**: ***"Every place is given its character by patterns of events that are locked in with geometric patterns in space. Each building and town is ultimately made out of these patterns in space, and out of nothing else; they are the atoms and molecules from which a building or a town is made"***.[11] Importantly, the proposed change to configuration does not imply the total abolition of conscious formal design which will always remain a crucial aspect of an architect's work, but merely a reshuffling of priorities after which configuration becomes the primary **design driver** through which form is created.

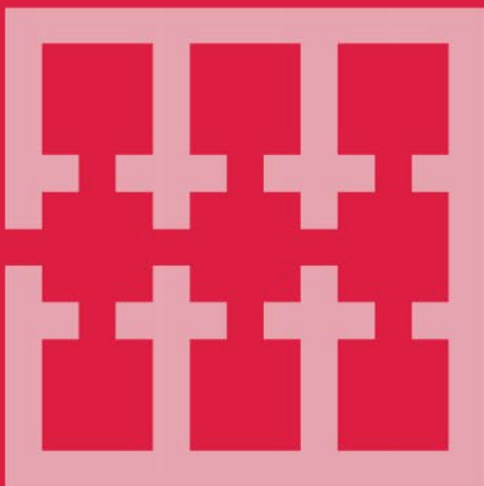
Besides making the production of novel forms possible, the primary advantage of a configurational approach is its adaptive and responsive potential. Because a configuration only defines spaces and their interconnections it has enormous combinatorial possibilities allowing for a near-infinite amount of physical arrangements. Such **adaptivity**, combined with a lack of predefined form, enables the organic emergence of form in direct response to internal requirements and external influences, as well the highly complex interactions between them. In this way, configurations are able to merge top-down design with

WAYS OF LOOKING AT SPACE

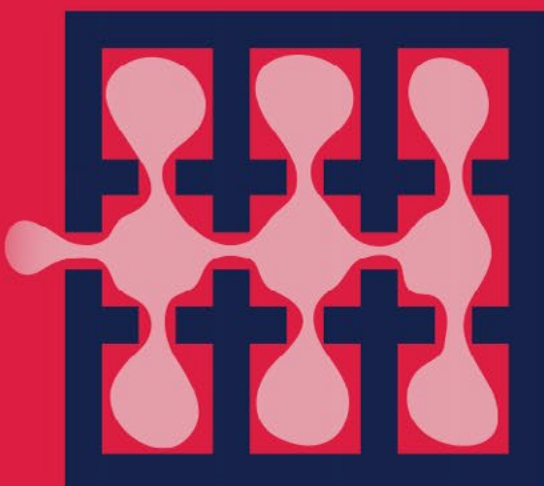
As Habraken describes, space can be examined and described in different ways; as detail, as form, as configuration



Stylistic system
Detail



Physical structure
Built form



Spatial organiation
Configuration

a **bottom-up** response to local conditions, which, in addition to making adaptation possible, could also facilitate their use as participatory tools capable of mediating multiple stakeholders. As a natural consequence, this adaptivity could lead to greatly increased **diversity** by way of specificity and potentially **improved performance**, be it spatial, social, economic or environmental.[12] Furthermore, by virtue of its higher order of abstraction, such an approach would also simplify and empower precedent-based design. No longer burdened by concerns of reproduction, architects could extract patterns from existing buildings and reapply them in new situations and contexts by means of a holistic process that is both **analytical** and **generative** and enables the evolution of new urban form from existing configurations.[13] Lastly, the shift from form to configuration as the primary design driver brings with it a renewed focus on **socio-spatial patterns** which more often than not directly correlate with the configuration of space. As Bill Hillier observes in A Social Logic of Space: ***"The social stuff of buildings, we may say, is the configurational stuff, in the sense that buildings are configurations of space designed to order in space at least some aspects of existing social relationships"***.[15] As a result, by working with configurations, an architect can consciously act on and shape the socio-spatial patterns underlying his building, making them in tune with the needs of contemporary society, which could in itself possibly turn into a source of new spatial compositions and urban form.

By way of formal abstraction and its focus on spatial relationships, a configurational approach to architecture attempts to free designers from existing self-imposed limitations to encourage new formal innovation, while simultaneously creating a new design method rooted in principles of adaptivity and diversity. By doing this, configurational design could put an end to reductive simplification, allowing us to productively channel the complexity of contemporary cities to create diverse urban forms responsive to our present-day needs for social, economic and environmental sustainability, in the process creating our the city of the future. Nevertheless, many questions remain about how configurational design could be systematized and operationalised for real-world application, as well as its benefits and drawbacks within a practical context.

SITE-SPECIFIC URBAN FORM

Configuration can lead to adaptive designs organically growing out of local conditions resulting in better performance and spatial qualities

3

What are the precedents of configuration as a design approach in architecture?

A CONFIGURATIONAL APPROACH

Exploring precedents of configurational design

Use of **configurational** principles in the production of our built environment is not a novel proposition, as they have been directly or indirectly applied in numerous theoretical and practical settings in the past.

The most widespread and simultaneously the most obscure application of configurational thinking is its role in **vernacular architecture**, where spatial relationships and response to local conditions have always taken precedent before form, which in turn organically grows as a consequence of both. Cases of this can be found all around the globe in historical city centres, Mediterranean towns and African villages among the most prominent examples.[16] In the discipline of architecture, conscious focus on configurations first emerged in the 1960s most notably in the work of Team 10 and **Aldo van Eyck** as part of their reappraisal of the vernacular. As exemplified by van Eyck's essay Steps Towards a Configurative Discipline, in their work, configuration was specifically linked to questions of dwelling, meaning and identity as opposed to being used as a design methodology.[17] This kind of comprehensive approach was later developed by **Cristopher Alexander** as part of this book A Pattern Language published in 1977. Here, configurations are represented by spatial "patterns"; fragments derived from existing cities at various scales, with explicit rules for connecting them into new urban tissue.[11] While this resulted in a set of systematic methods capable of generating new form, its lack of generality as a result of the fixed catalogue of predominantly vernacular patterns prevented it from ever surpassing its value as a theoretical project and becoming a genuine design method. Finally, in 1996 **Bill Hillier** attempted to provide such a general framework of configurational design in his book Space is the Machine; A Configurational Theory of Architecture. In his work configurations become explicit, themselves systematized and materialized as topological graphs enabling them to become objects of design.[13] Through this systematization, his theory gains general applicability and potential for practical application; this has led to the development of Space Syntax, which, while an effective tool for examining configurational aspects of cities, remains purely analytical thus leaving the generative potential of a configurational approach unexplored.

In philosophy, the possibilities of a configurations for generating form were theorised by **Manuel de Landa** who connects them to natural processes of morphogenesis potentially enabling organic emergence of form based on its physical surroundings.[12] Furthermore, throughout his work, de Landa emphasises the compatibility of configurational thinking with fields of mathematics, physics, biology and computer science, opening the door for its enhancement with ideas of automation, natural processes of growth, environmental responsiveness and more, all of which could help in one day making configurational thinking a practical design approach.

Examples of vernacular architectura; Left: Marrakech Medina, Top right: village in Japan, Bottom right: village in Andalucia, Spain

VERNACULAR architecture has always been one of the primary areas in which configurational design principles have had precedence before form and image. Guided by specifics of site, functional requirements and climatic conditions among other factors, vernacular buildings are adaptive and responsive urban form par exellance. The people building such structures, unburdened by superficial aesthetics and style, unconsciously operate through configurational patterns defined by the aforementioned influences. This has often resulted in locally adapted buildings and settlements with an organic sense of order; famous examples include old japanese villages, mediterranean towns and Medinas - old middle-eastern city centers. Additionally, the organic and site-specific growth of such settlements often results in a diverse and beautiful urban spaces, a direct result of the complexity from which these aggregations emerge. The configurational rules embedded in the local population, passed down through generations and perpetually evolving alongside society are the bedrock on which these vernacular wonders were built.

Aerial view of Kowloon Walled City, Hong Kong [10]

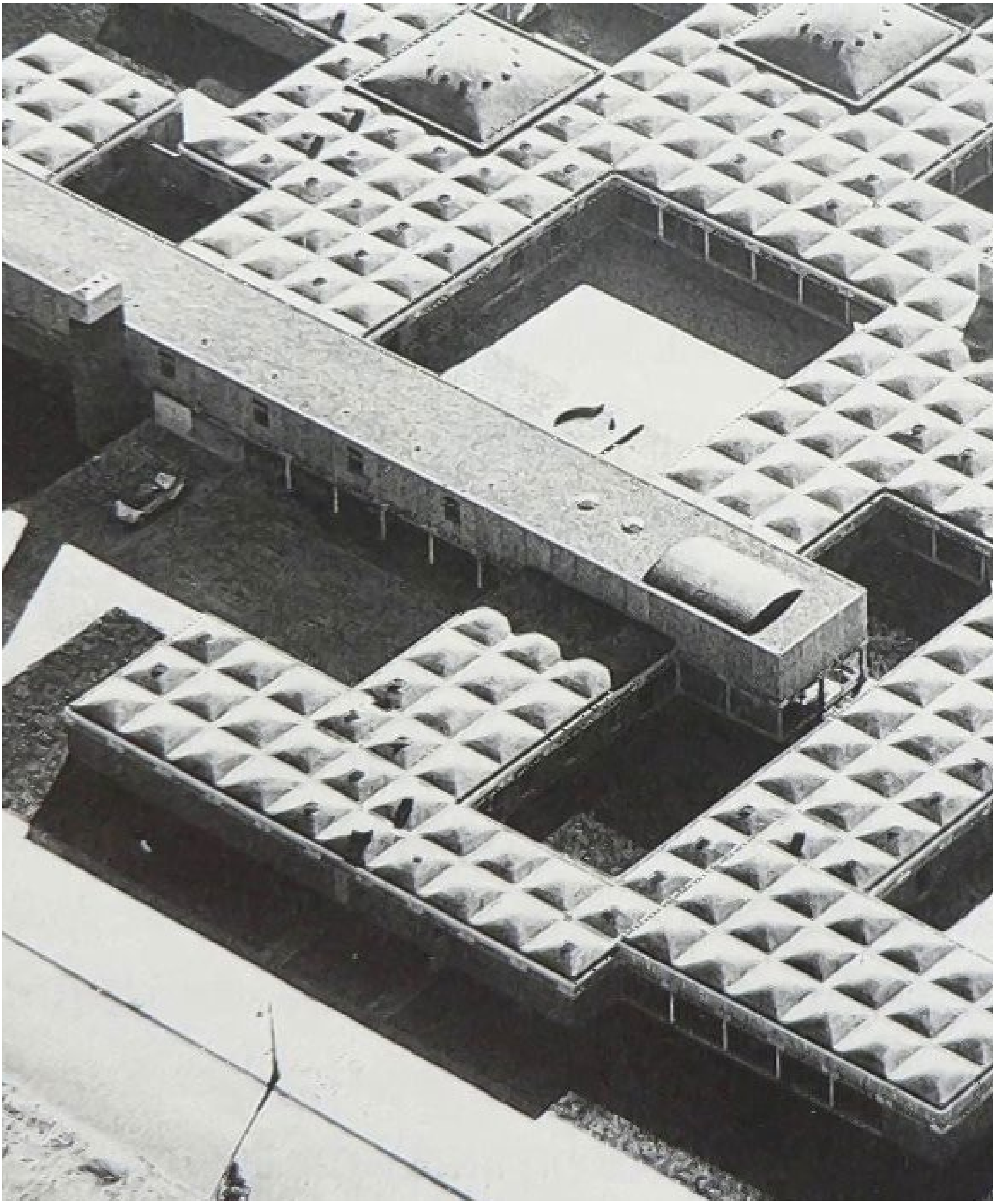
KOWLOON WALLED CITY presents a great example of hyper-urban vernacular architecture with all its benefits and drawbacks. Kowloon was a self-regulating urban village created through the vertical aggregation of houses, shops and workshops directly responding to the social patterns of its inhabitants as well as extarnal pressure of sky-high land prices driving its incredible densification.[10] Such extreme land-use achieved through an informal building approach naturally results in issues such as diminished spatial quality, inadequate sunlight provision, privacy and more. Nevertheless, Kowloon successfully showcases the immense power of configurational bottom-up design. Unskilled citizens with no coherent plan of construction had managed to create a complex urban form which, in spite of its problems, successfully negotiated the local conditions to provide them with a living space for many years until its eventual demolition.

FORUM

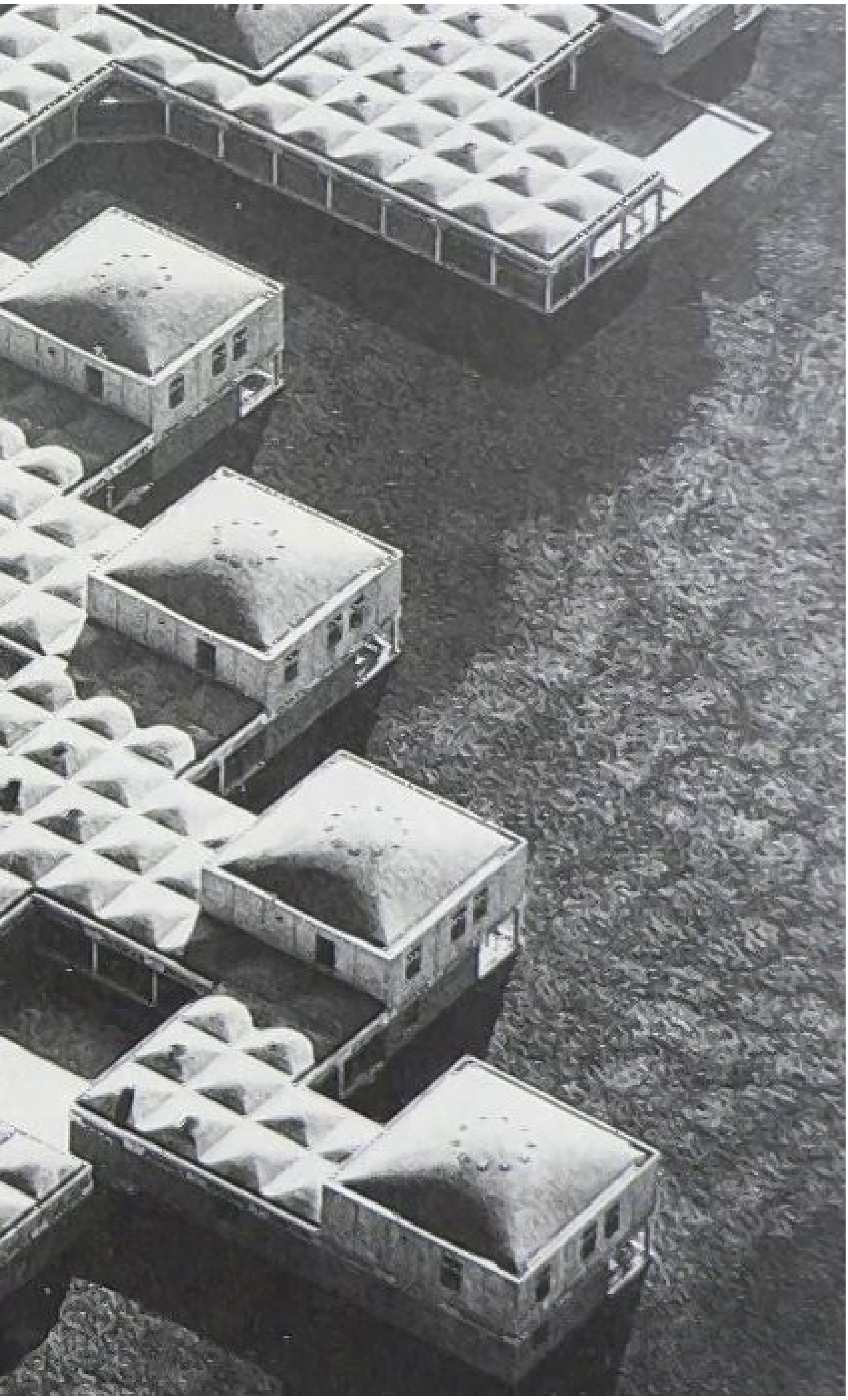
4 1960/61

It is now possible to invent dwelling types which do not lose their specific identity when multiplied, but, on the contrary, actually acquire extended identity and varied meaning once they are configurated into a significant group.

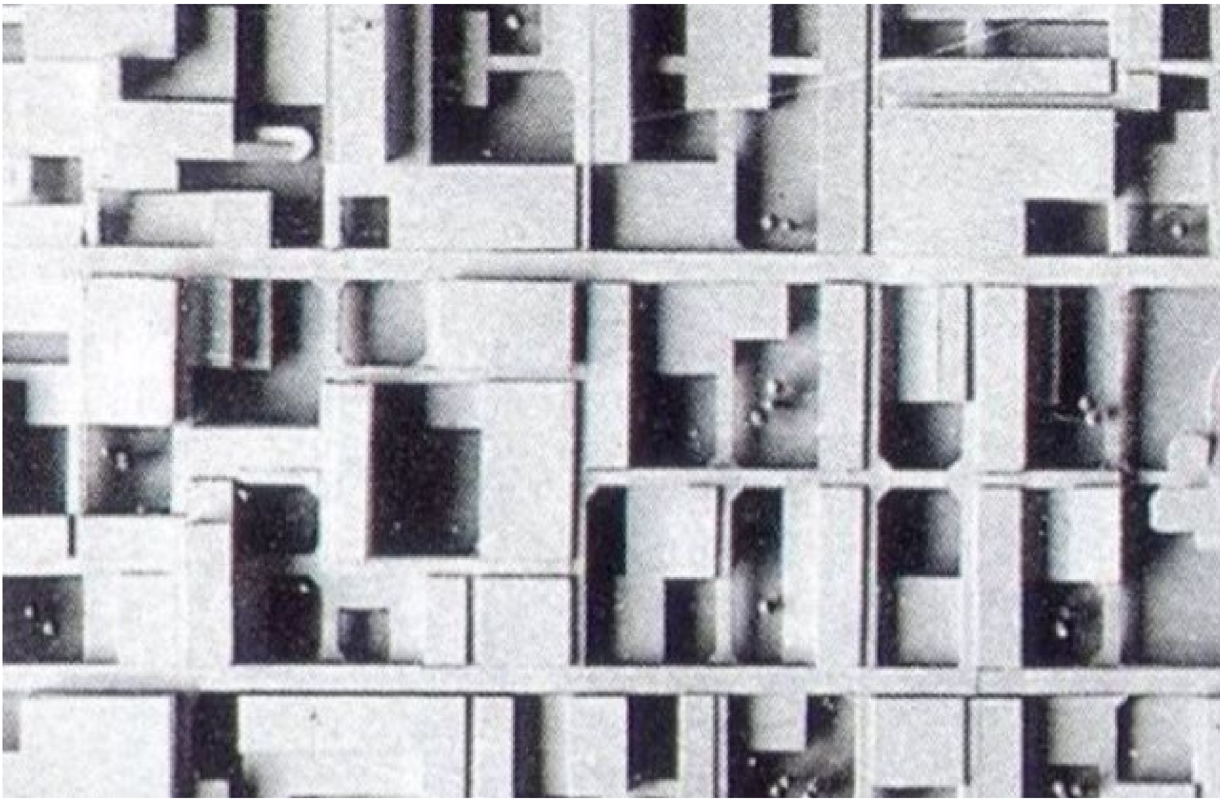
- Aldo van Eyck, Steps Towards A Configurative Discipline, Forum, 1962 [17]

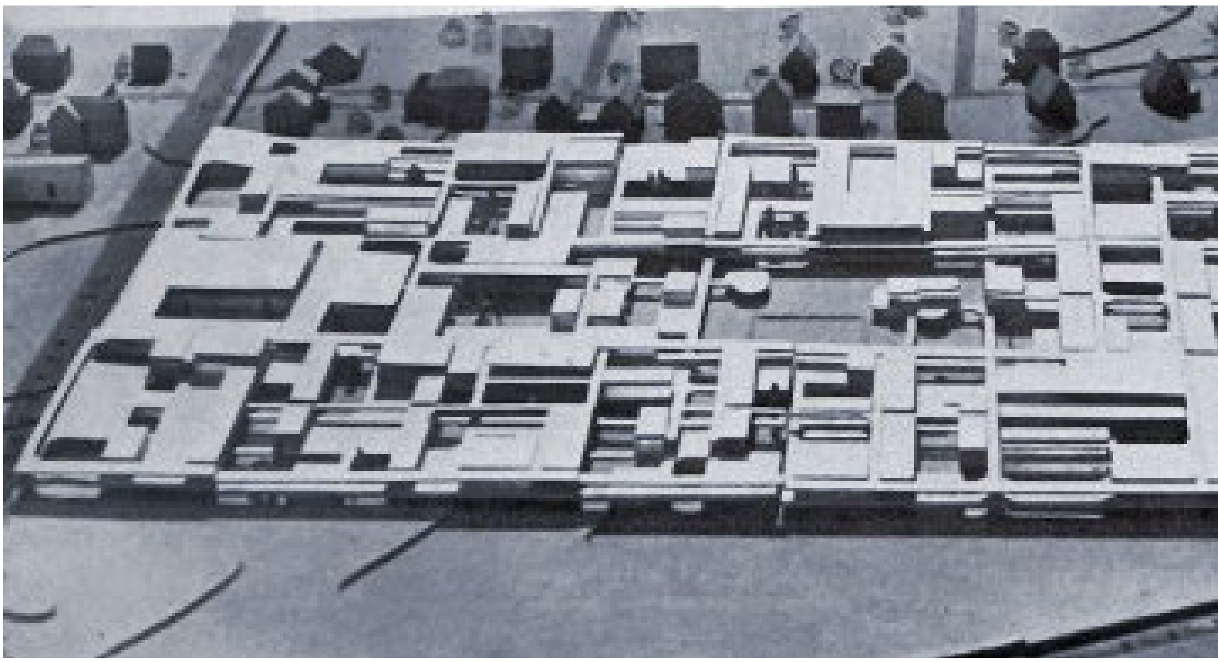


Amsterdam Orphanage; Aldo van Eyck; 1955

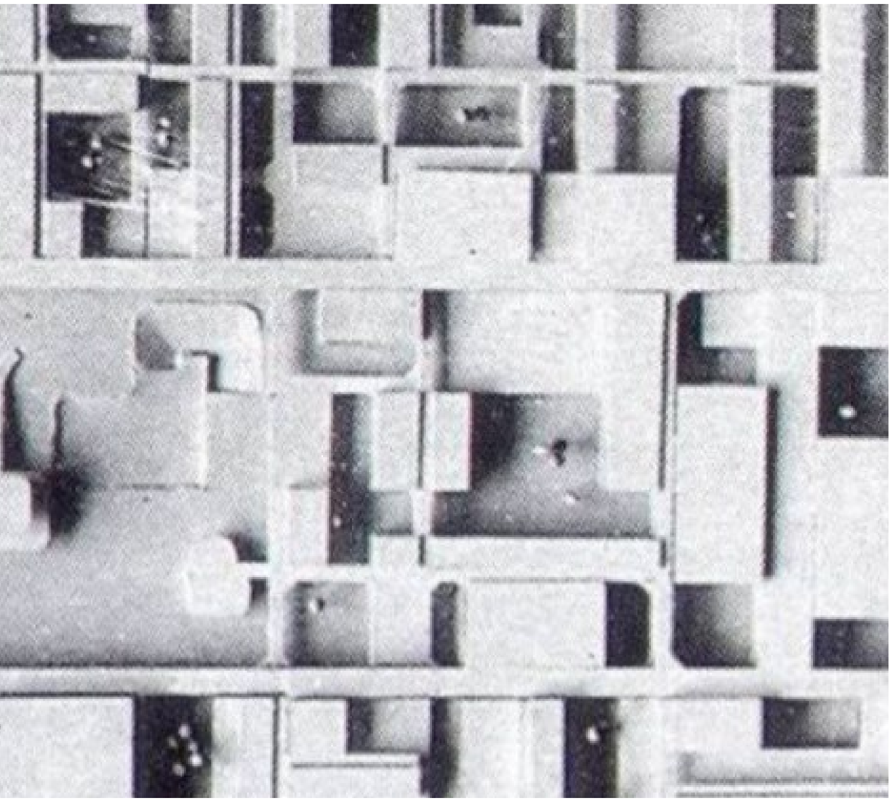


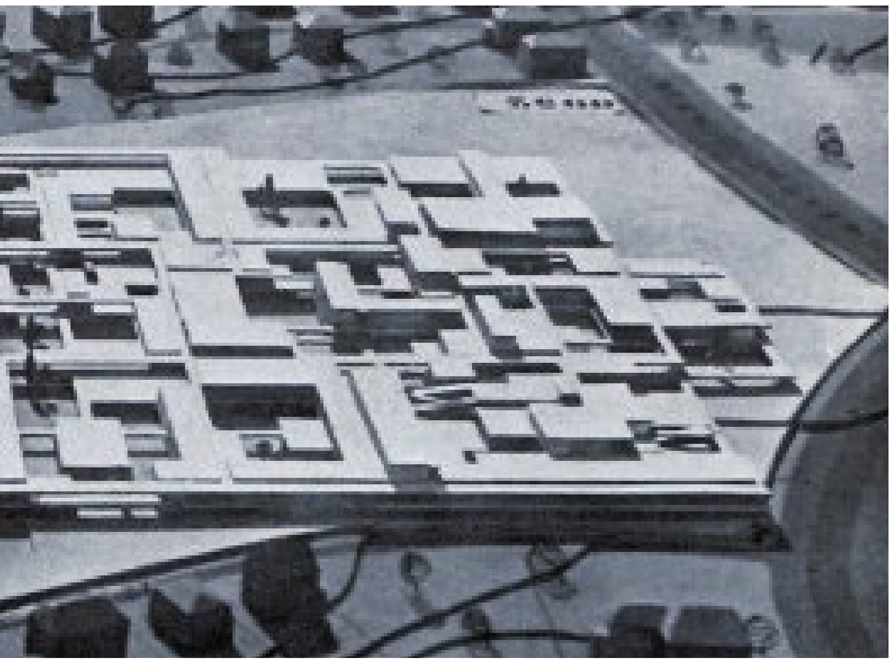
ALDO VAN EYCK was one of the first architects to consciously adress the issue of configurations within disciplinary architecture. As visible from his text Steps Towards a Configuratve Discipline published in Forum in 1962 [17], van Eyck's interests lied mostly in the relationship between spatial configurations and urban identity, how we as humans construct meaning and identify with a place. While this is only one rather narrow view of configurations, it represented an important step towards alternative views of archtiectural space not based on tectonics, composition or style. Despite this, in the work of van Eyck configurational thinking never evolved into a design methodology but was latently present as part of his structuralist approach as best evident in his built works. such as the famous Amsterdam orphanage.





Mat-building Freie Universitat Berlin; Candilis, Josic & Woods; 1963 [64]





STRUCTURALISM was an important architectural movement in the second half of the 20th century of which, though Team X, Aldo van Eyck was a part of. Simplified, the program of structuralism was to prioritise relationships over objects and uncover the hidden structures that underlie all the things that humans do, think, perceive, and feel. This reading of Structuralism which focuses on underlying patterns/structures shows many parallels with configurational design despite Structuralism's lack of conscious focus on topology and general systematism.
A radical example of such thinking is the concept of Mat-buildings proposed by Candilis, Josic and Woods of Team X. Instead of designing individual buildings and focusing on their formal aspects they proposed an anti-icon; a single flexible multi-level megastructure bridging the gap between building and city with spatial characteristics of the city in which it is placed. Instead of form, the configuration of spaces, streets and squares takes precedence in the design opening the door for evolution and vertical extrapolation of the urban fabric currently static and limited to the ground plane.

A Pattern Language

Towns · Buildings · Construction

Christopher Alexander

Sara Ishikawa · Murray Silverstein

WITH

Max Jacobson · Ingrid Fiksdahl-King

Shlomo Angel

Every place is given its character by patterns of events that are locked in with geometric patterns in space. Each building and town is ultimately made out of these patterns in space, and out of nothing else; they are the atoms and molecules from which a building or a town is made.

- Christopher Alexander, A Pattern Language, 1977 [11]

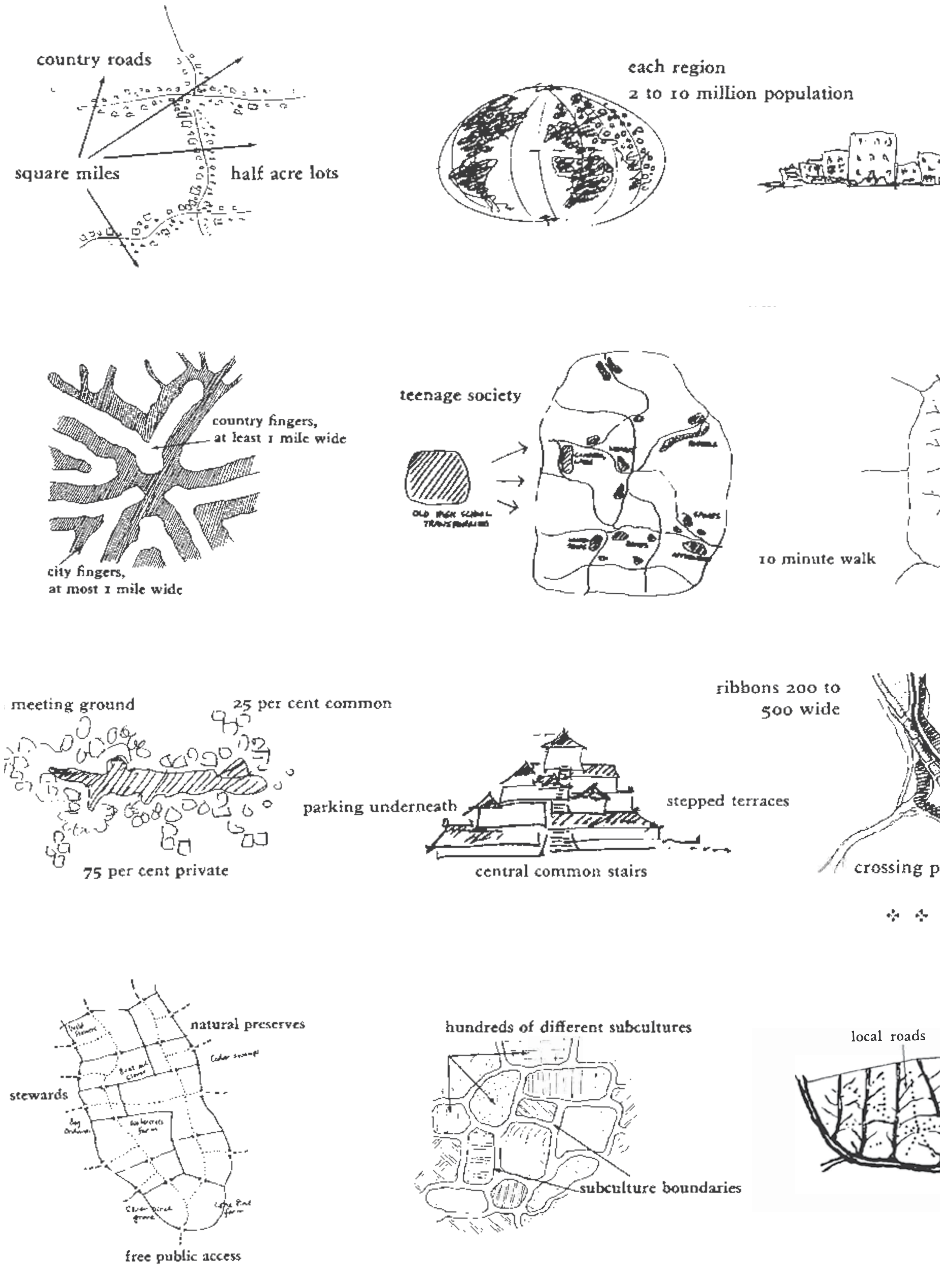
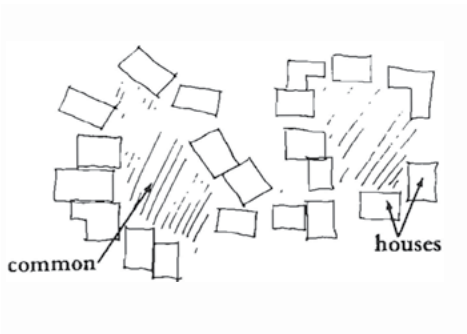
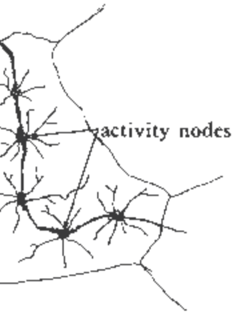
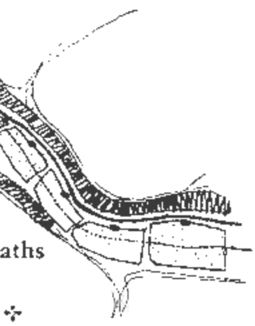
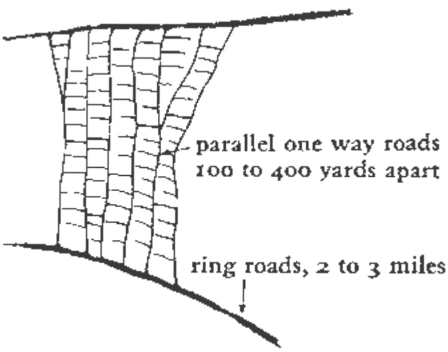


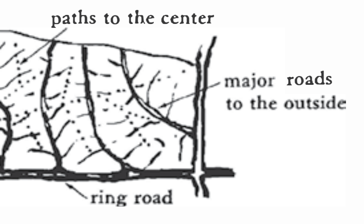
Diagram illustrations of patterns; C. Alexander, A Pattern Language, 1977. [11]

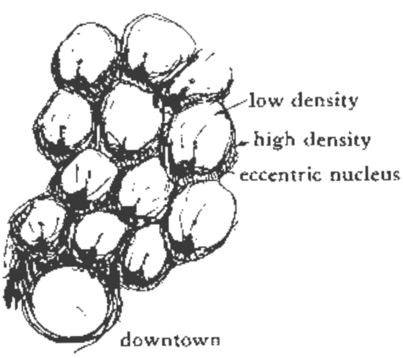




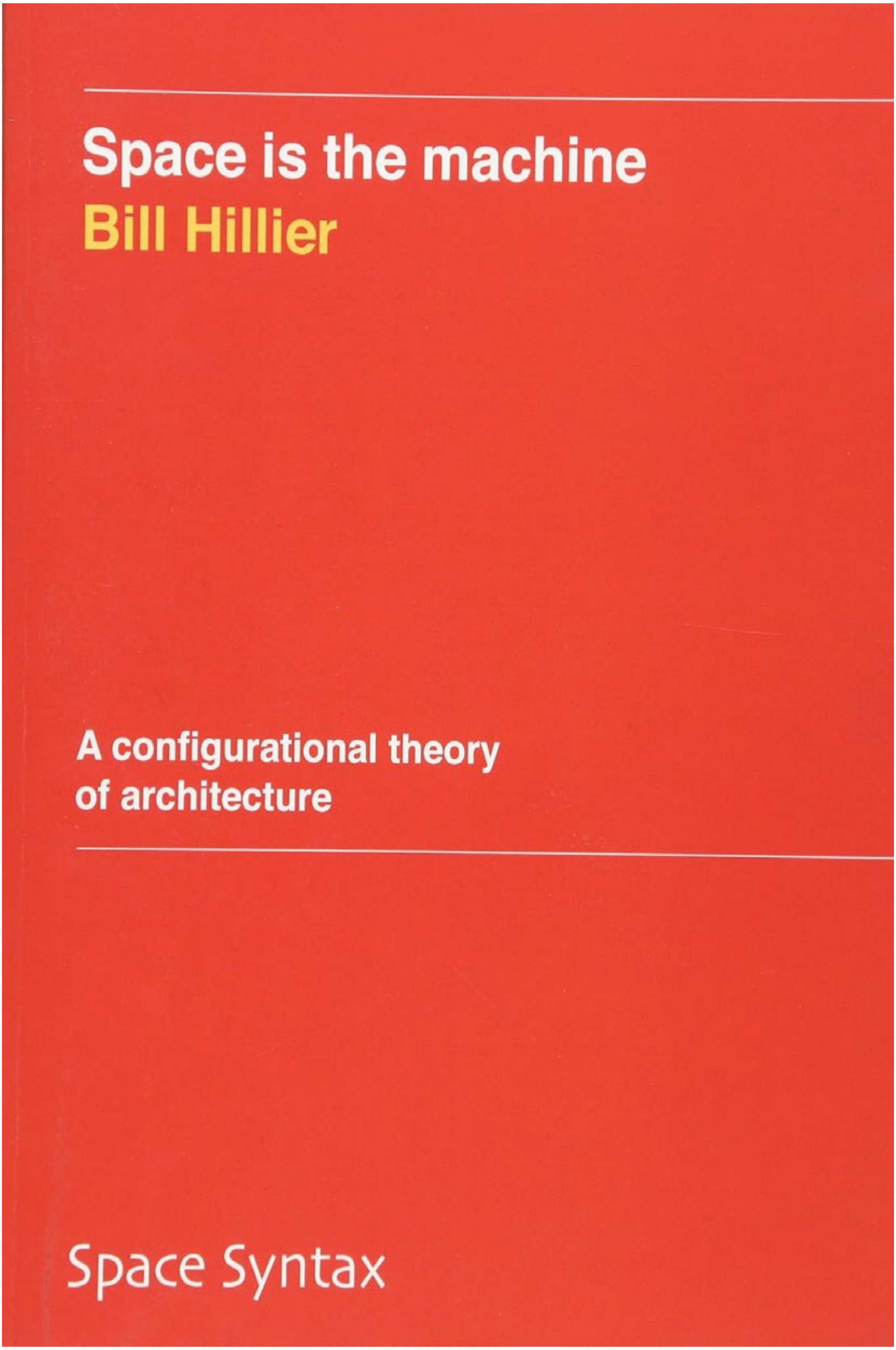








CHRISTOPHER ALEXANDER is the first person to attempt to create a comprehensive theory of design based loosely around configurational principles. First in Notes on the Synthesis of Form and later in A Pattern Language, Alexander outlines a structured design approach based on combining spatial patterns of various scales to create new architectural space. Although indeed a systematic approach it was limited by a defined and fixed catalogue of patterns unable to (not intended to?) evolve, while the patterns themselves were extracted mainly from vernacular architecture and as such increasingly inadequate for contemporary use. These drawbacks were the main reason Alexander's method did not gain traction in architectural practice in spite of its tremendous theoretical influence that lasts to this day.

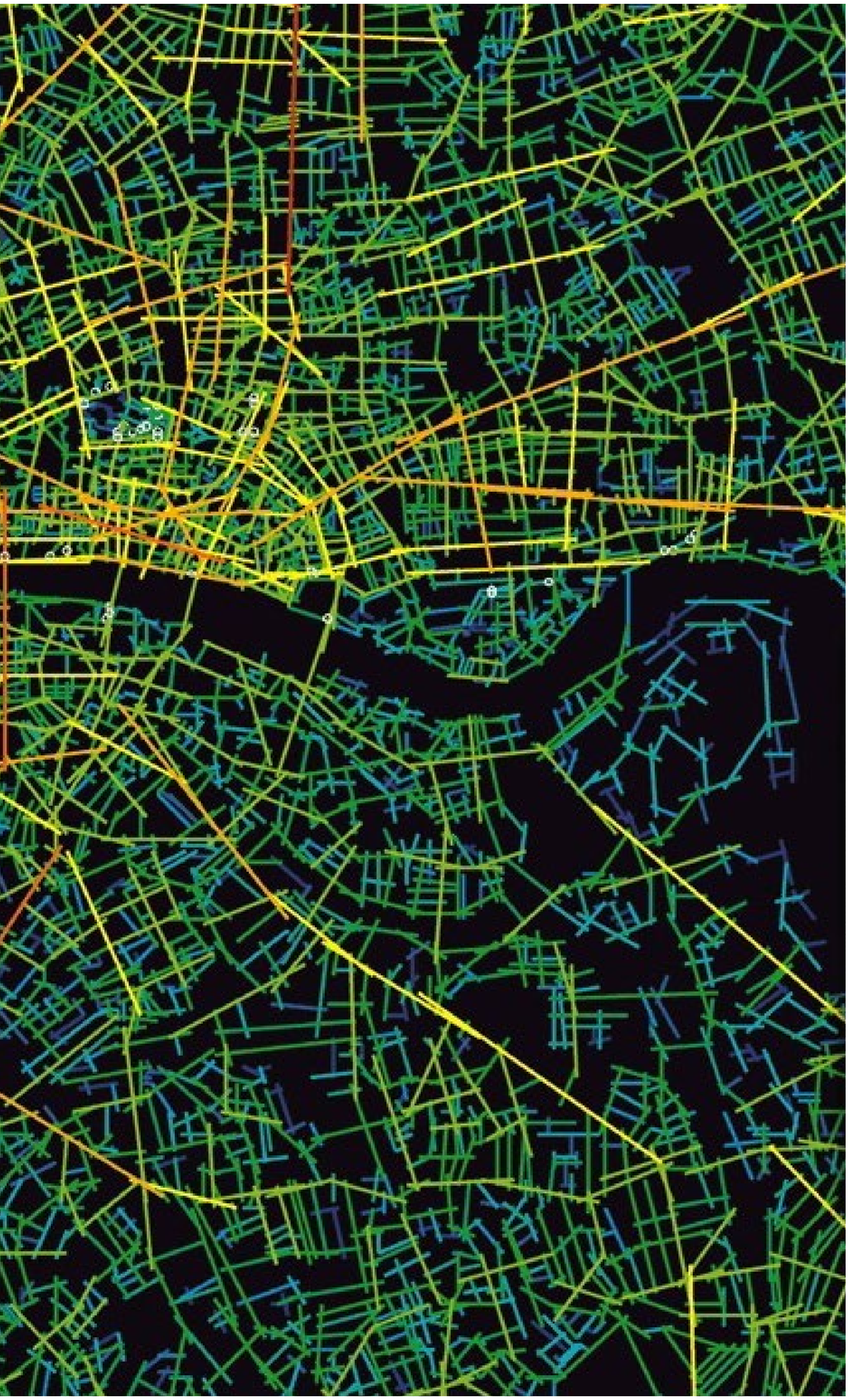


Space is the machine
Bill Hillier
A configurational theory
of architecture
Space Syntax

The social stuff of buildings, we may say, is the configurational stuff, in the sense that buildings are configurations of space designed to order in space at least some aspects of existing social relationships.

- Bill HIllier, Space is the Machine, 1984 [13]

Space Syntax street centrality analysis in central London



BILL HILLIER is the father of configurational thinking in architecture. In 1994 he published Space is the Machine where he describes the first and to this day the only comprehensive design theory and methodology based on configurations. Hillier argues for a rigorous and objective design theory capable being both analytical as well as synthetic, enabling designers to rely on one methodology throughout the whole design process. For Hillier the strength of configurations is in their capability to make visible and extract socio-spatial patterns in our cities thus reasserting the importance of built space to respond and evolve with our living patterns. Hillier's research and theories of configuration have led him to develop Space Syntax, an urban analysis tool used primarily for inspecting configurations of street patterns and their corresponding social implications.[14] Whilst this has proven a valuable analytical tool, its generative potential is limited to a support role in a traditional top-down design process. As such, it remains to be seen how the powerful configurational design theory Hillier outlined can be channeled in a holistic design process capable of creating better performing and adaptive architectural and urban spaces.

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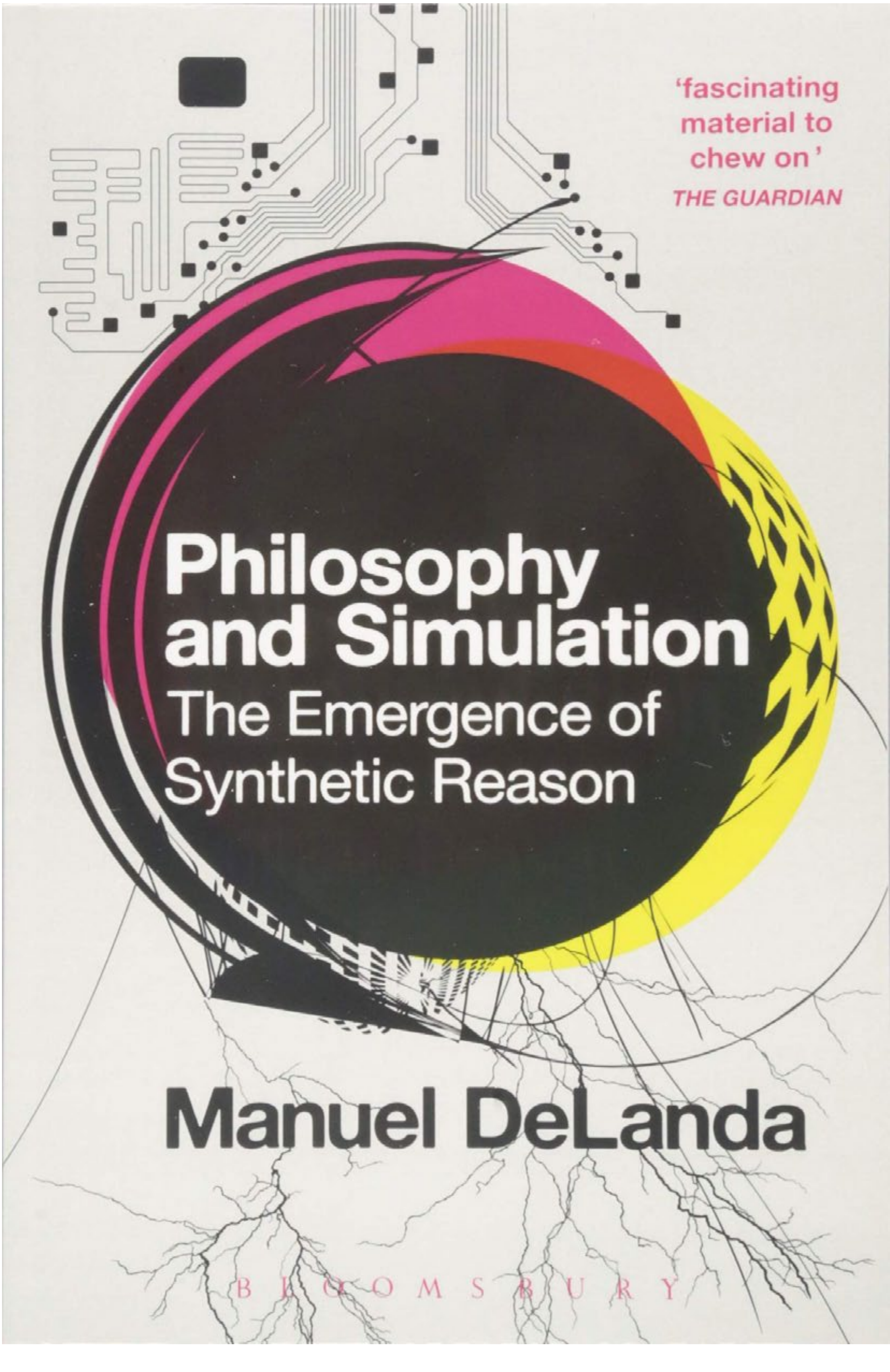
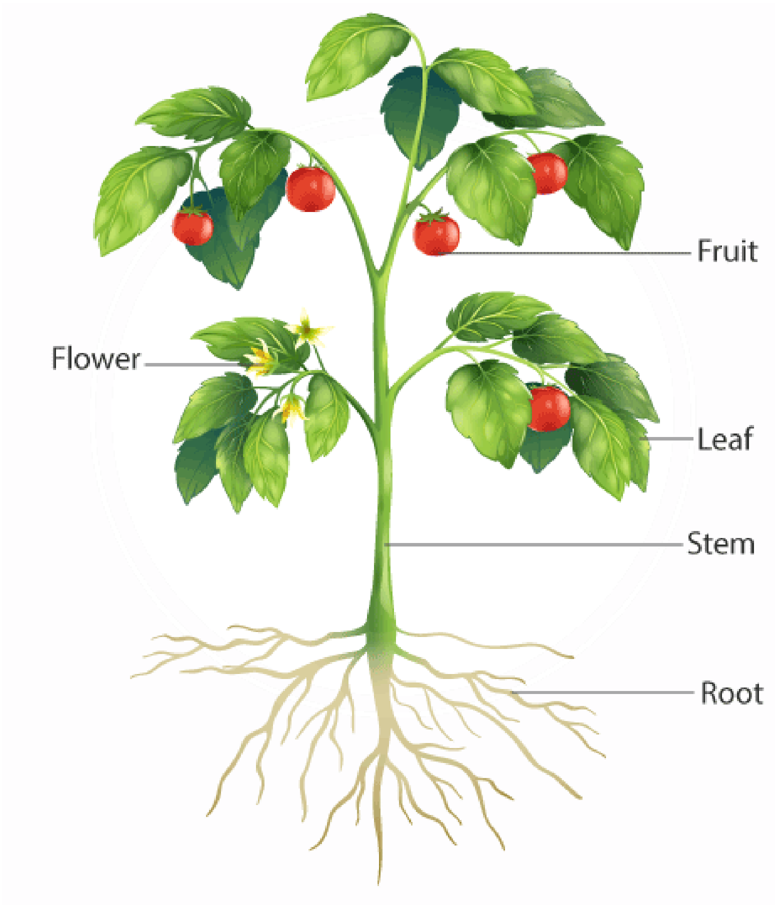

'fascinating
material to
chew on'
THE GUARDIAN
Philosophy
and Simulation
The Emergence of
Synthetic Reason
Manuel DeLanda
BLOOMSBURY

Topological form guides a process which results in many different physical forms, including spheres and cubes, each with different geometric properties. In other words, one and the same topological form can guide the morphogenesis of a variety of geometrical forms.

- Manuel de Landa, Philosophy and simulation, 2002 [12]

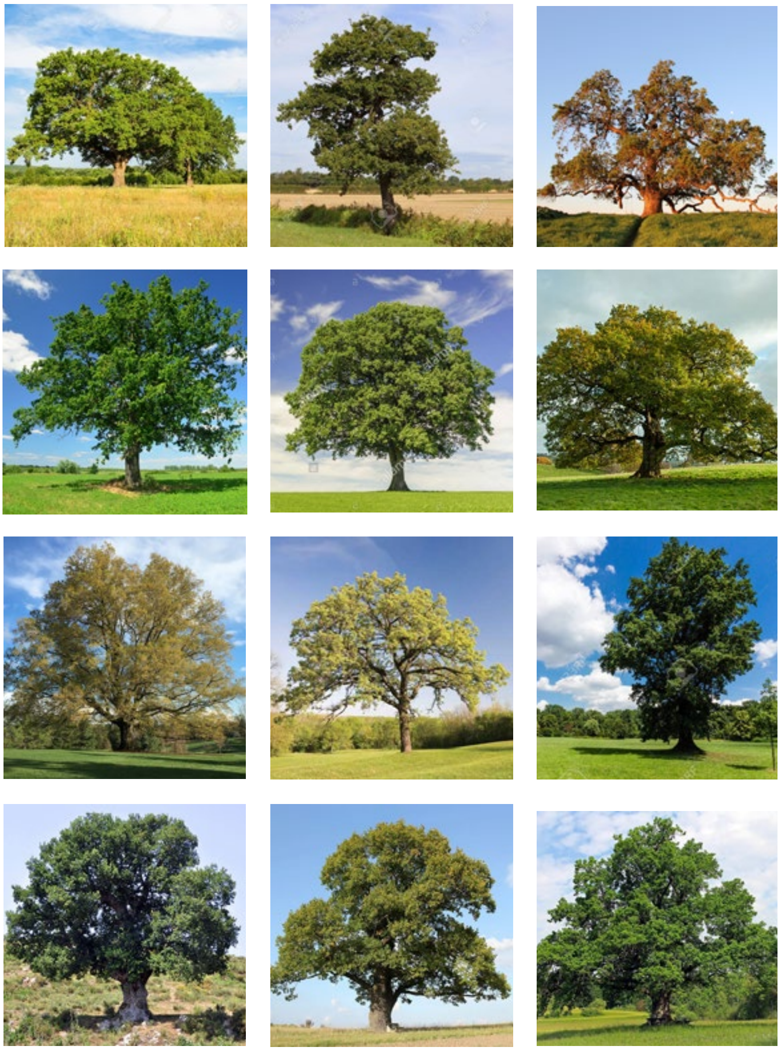


TOPOLOGICAL thinking is derived from mathematics and in a design context describes a process in which a designer as opposed to creating a finished model in a top-down manner instead defines a broad (topological) solution space within which many possible designs exist and are allowed to emerge bottom-up in response to local conditions. Instead of fixed objects and forms, topological designs only describe parts and their interconnections whilst leaving their final formal/spatial articulation undefined. This principle is best exemplified in natural genotypes acting as general morphogenetic rules from which a multiplicity of varying organisms can develop.

INTENSIVE thinking assumes that sp
ically pregnant and is able to generate
physics, more specifically thermodyna
intensity or concentration of morphog
the morphogenetic process loosely co
space, together producing site-specifi

MANUEL DE LANDA

Three fundamental fields of the morphogenetic design theory as proposed by De Landa: Topology, Intensity, Populations[12]

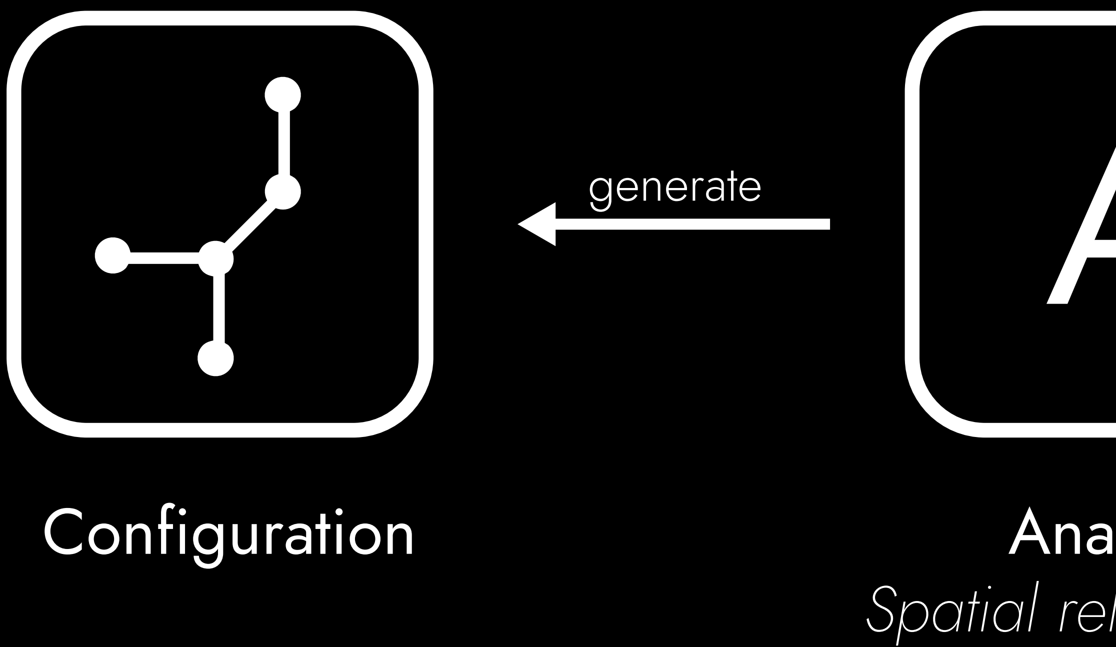


ace is not inert but morphogenet-
 form on its own. Derived from
amics, it states that differences of
gens (sunlight / rain /...) actively drive
onstrained by a topological solution
c forms.

POPULATION thinking implies that for any design problem there exist multiple - a population of - competing designs each excelling in a different way compared to the others. It is precisely this difference that enables natural selection and evolution, leading to perpetual improvement over time. In a design context it implies a paradigm shift from striving for a single universal design towards a multiplicity of locally adapted and optimized designs.

A N A L

LYSIS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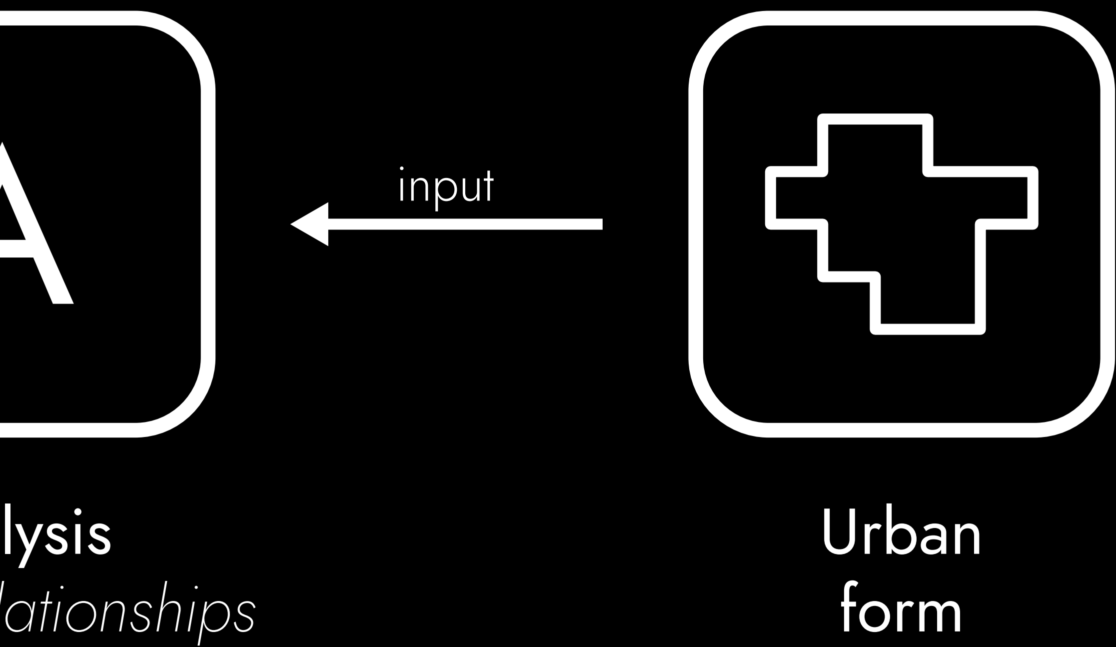
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4

How can space be systematically abstracted and represented through configuration?

FROM FORM TO CONFIGURATION

Abstracting existing urban form through spatial networks

For configurations to become operative in the architectural design process, the way they abstract physical space must be precisely and systematically defined. The possibilities for such a general definition are explored via precedents in the fields of applied mathematics and architecture, finally leading to the formulation of a **Spatial Network**; the proposed elementary medium for the configurational design of architecture.

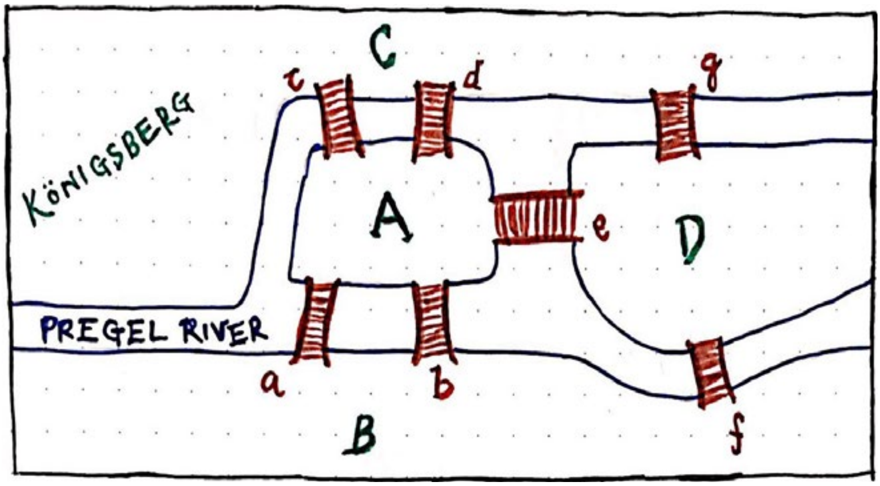
Inspired by Bill Hillier's theory of configuration, the project appropriates his use of **topology** as the primary mechanism for the systematic abstraction of form through its underlying spatial relationships. Appropriately topology, also a branch of applied mathematics studying geometrical properties and spatial relations unaffected by the continuous change of shape or size, can be concisely represented by mathematical **adjacency graphs** in which nodes represent distinct spaces while links the connections between them. Due to their logical and unambiguous structure, aforementioned graphs can provide an efficient base for abstracting existing form to configurations.[15] Nevertheless, due to the complexity and layered nature of space abstracting it purely by means of its topology would result in gross oversimplification. A possible solution to this may be contained in a tool many architects already routinely use in the process of design; the **bubble diagram** often used do depict functionality and connectivity. This enables the expansion of the topological adjacency graph with additional information encoded in different node and connection types. Such an information structure is also called a **Spatial Network**; a graph in which the vertices or edges are spatial elements associated with geometric objects, used where the underlying space is relevant and where the graph's topology alone does not contain all the information.[16]

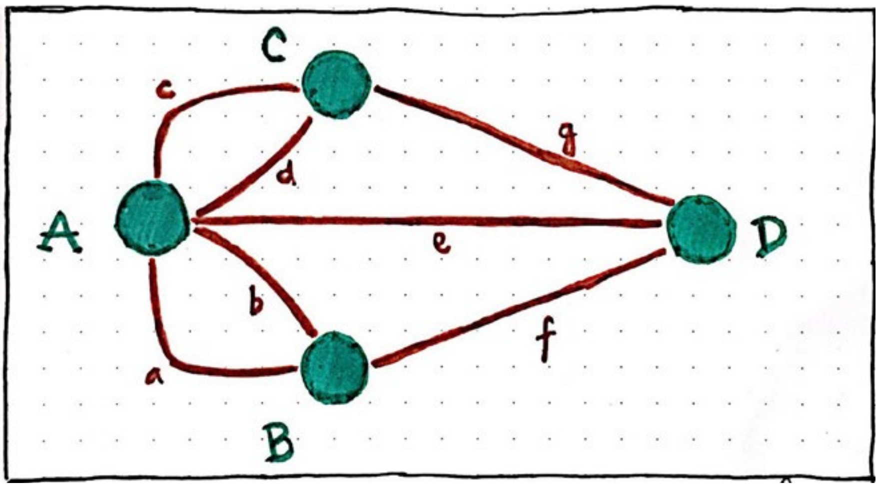
To define the possible types of elements that can constitute a spatial network, a classification of space is developed uncovering the most important traits pertaining to urban form and architecture. In addition to quantitatively measurable parameters of spatial quality like proportions of space or the amount of sunlight, which can be assigned as attributes of individual spaces, the classification proposes three main categories through which space should be defined; interior-or-exterior, programme-circulation and degree of privacy. Combined, these can be used to describe the majority of relevant spaces and their nuances in a **configurational approach**. Lastly, a notational system is developed which enables the unambiguous representation of all defined spatial types, simplifying the use of the spatial network as a design tool.

Although the proposed Spatial Networks and their corresponding system of notation form a sufficient basis for configurational analysis and design in the scope of this project, for their universal architectural application to be possible they would need to be further refined especially with regards to classification and definition of individual spaces.

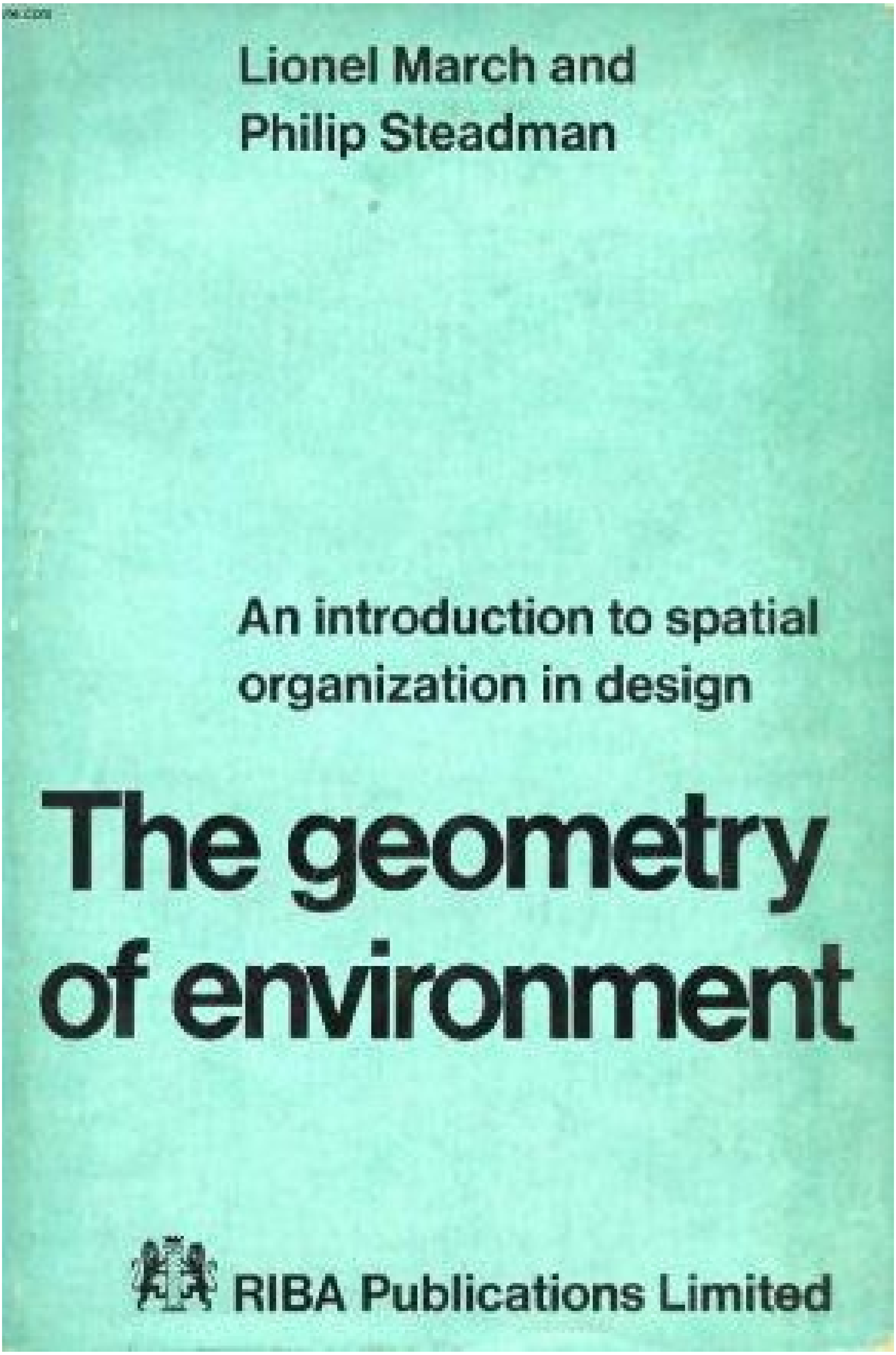

Die Fürstliche Hauptt Statt in Preussen
S. Niclas
Schlos thurn
Der Cragheim
Schlos
Schmit Pruck
Der Thum
Stut hoff

Opposite: drawing of central Konigsberg where the topological problem originated; Below: diagrams of topology conceptualisation.





TOPOLOGY is a mathematical field concerned with the properties of a geometric object that are preserved through continuous deformations such as stretching and twisting. The field's foundations were set by Leonhard Euler in 1736 who used the abstractive qualities of topological graphs to arrive to his negative solution of the Seven Bridges of Koenigsberg problem.[18] These same qualties make topology an efficient mechanism for systematically abstracting space and form into topological graphs.



Lionel March and
Philip Steadman

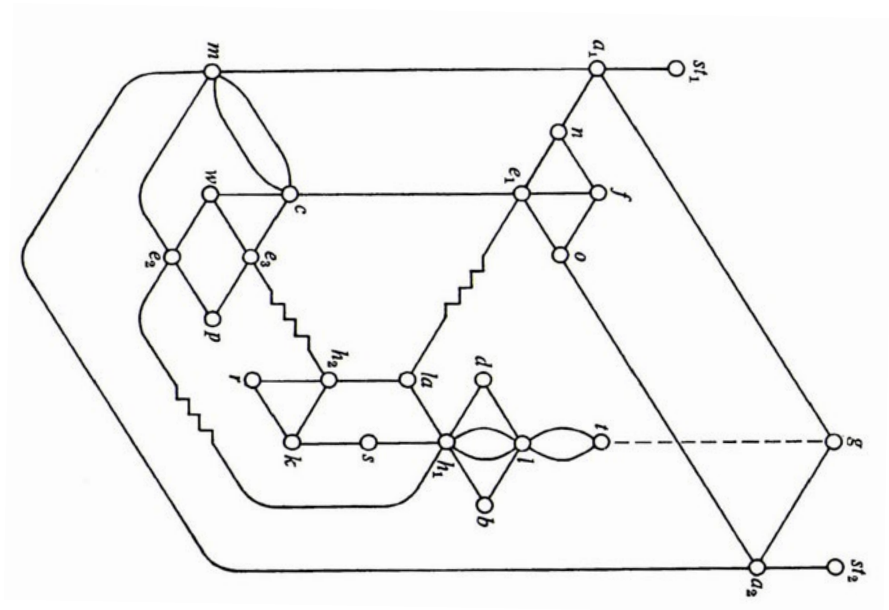
An introduction to spatial
organization in design

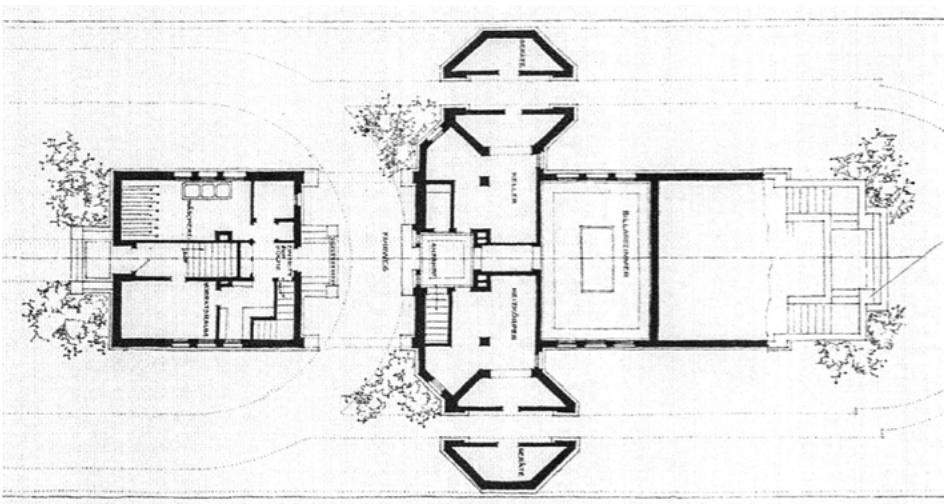
The geometry of environment

RIBA Publications Limited

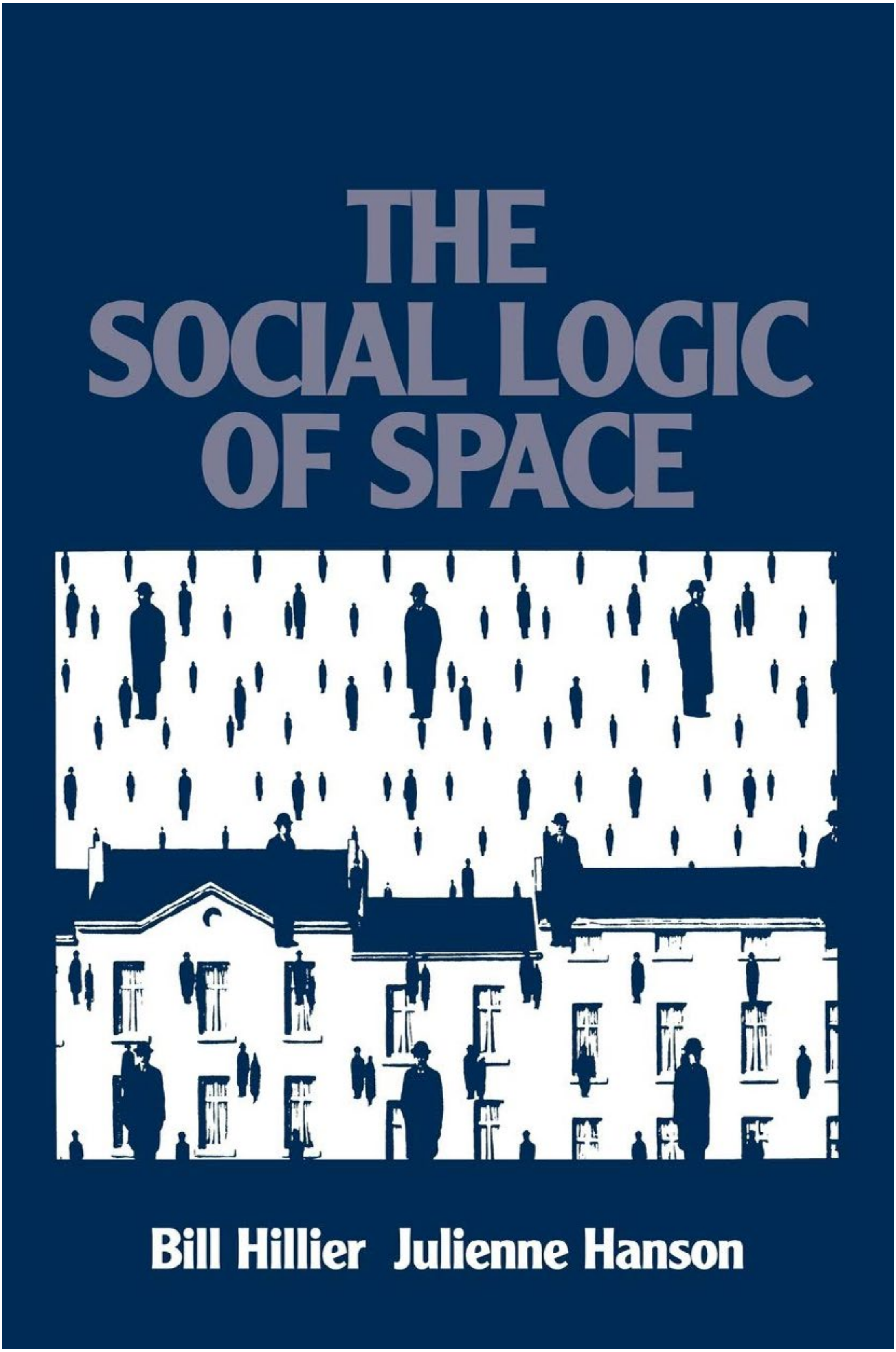
THE GEOMETRY OF ENVIRONMENT

Opposite: Geometry of Environment by March & Steadman [19]; Below: excerpt from the book abstracting Wright's Devin house plan to topological graph.



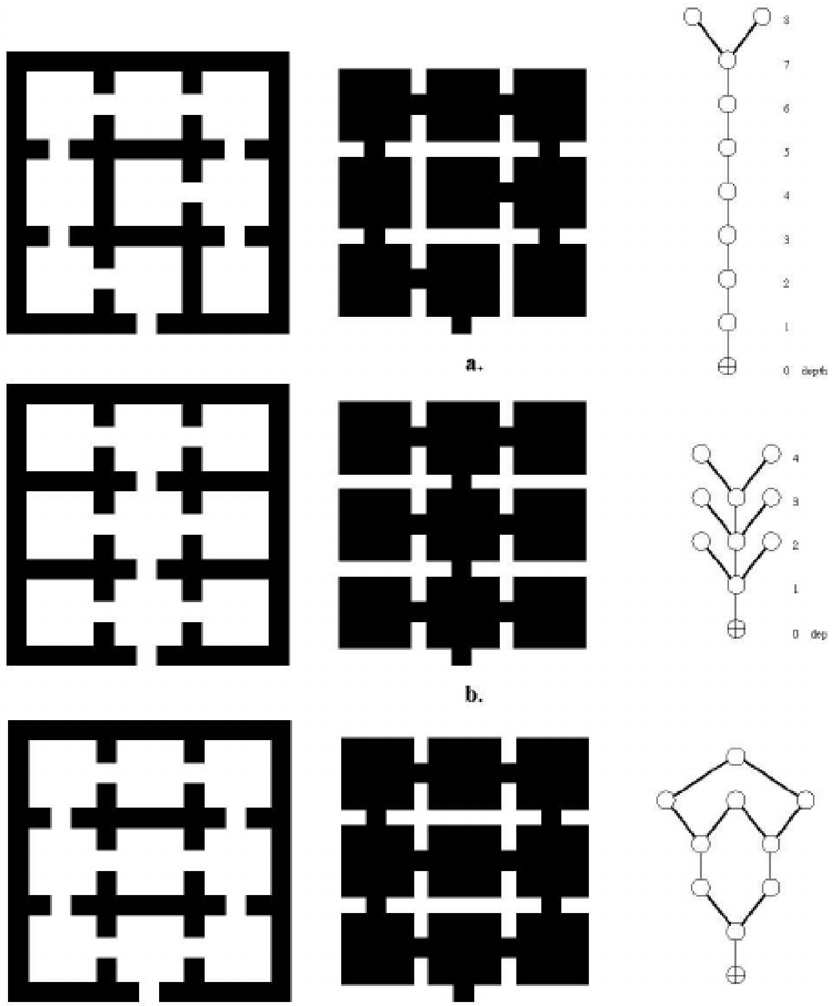


TOPOLOGY AS ABSTRACTION was first explored in 1974 by March and Steadmann as a mechanism for recording spatial conncectivity via adjacency graph drawings. Among other examples, they used this technique to abstract the plans of Frank Lloyd Wright's Devin house showing that compex spatial arrangements can indeed be recorded with topology pointing towards its potential as a design tool.


THE SOCIAL LOGIC OF SPACE
Bill Hillier Julienne Hanson

THE SOCIAL LOGIC OF SPACE

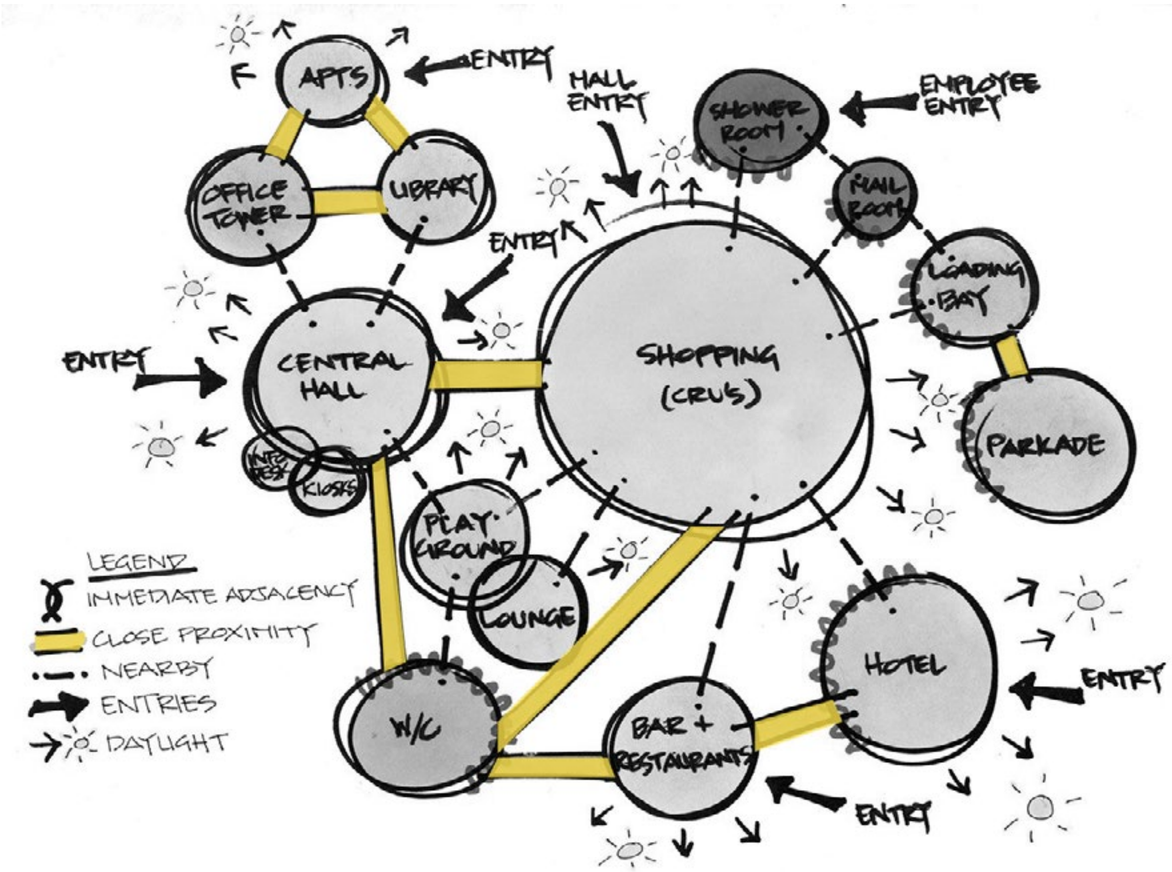
Opposite: The Social Logic of Space, 1984 by Hillier & Hanson [15]; Below: a diagram explaining systematic abstraction of space to topology.



TOPOLOGY IN ARCHITECTURE was first described by Hillier and Hanson in 1984 who, in addition to theorising its application, extensively used it as an analytical tool at multiple spatial scales ranging from a house to the neighbourhood. The extracted configurations directly represented the underlying socio-spatial patterns in space which later formed the theoretical basis for the development of Space Syntax, an urban analysis tool used to this day.

BUBBLE DIAGRAM

Opposite: Satellite photo of central Copenhagen; Below: Archtiectural bubble diagram depicting programme, its parameters and connectivity.

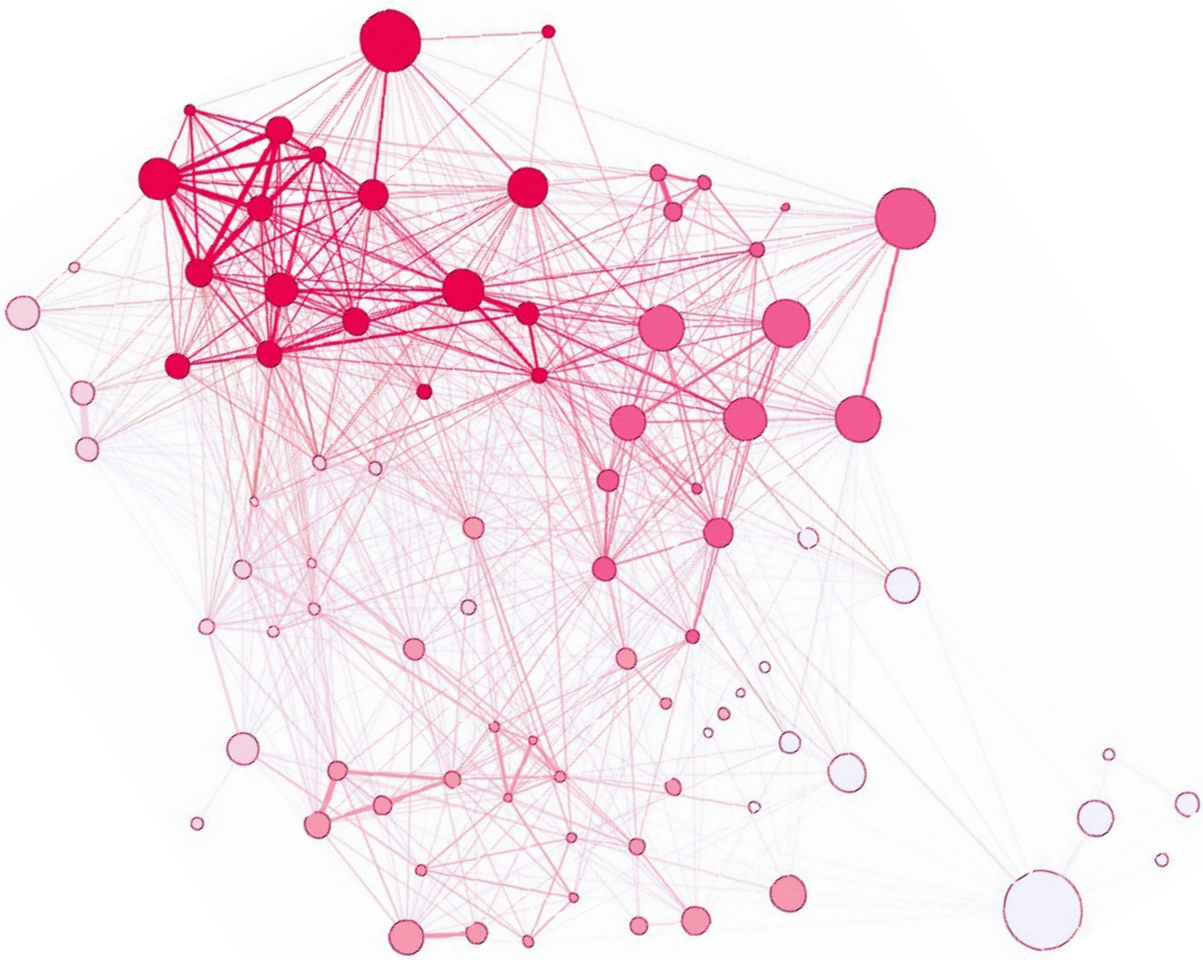


BEYOND TOPOLOGY

Although an efficient approach to forma abstraction, in itself topology can never tell the complete story, missing crucial details and spatial parameters. This is best apparent in bubble diagrams, a tool architects actively use as an aid in creating desired spatial organisations. Bubble diagrams, whilst similar to graphs through nodes and connection, always include additional parameters such as the type of connection, the size of the room, its entrances, requirements for sunlight and many more. These additional parameters enable the diagram to comprehensively describe space while maintaining the level of formal abstraction characteristic of topological graphs.

SPATIAL NETWORK

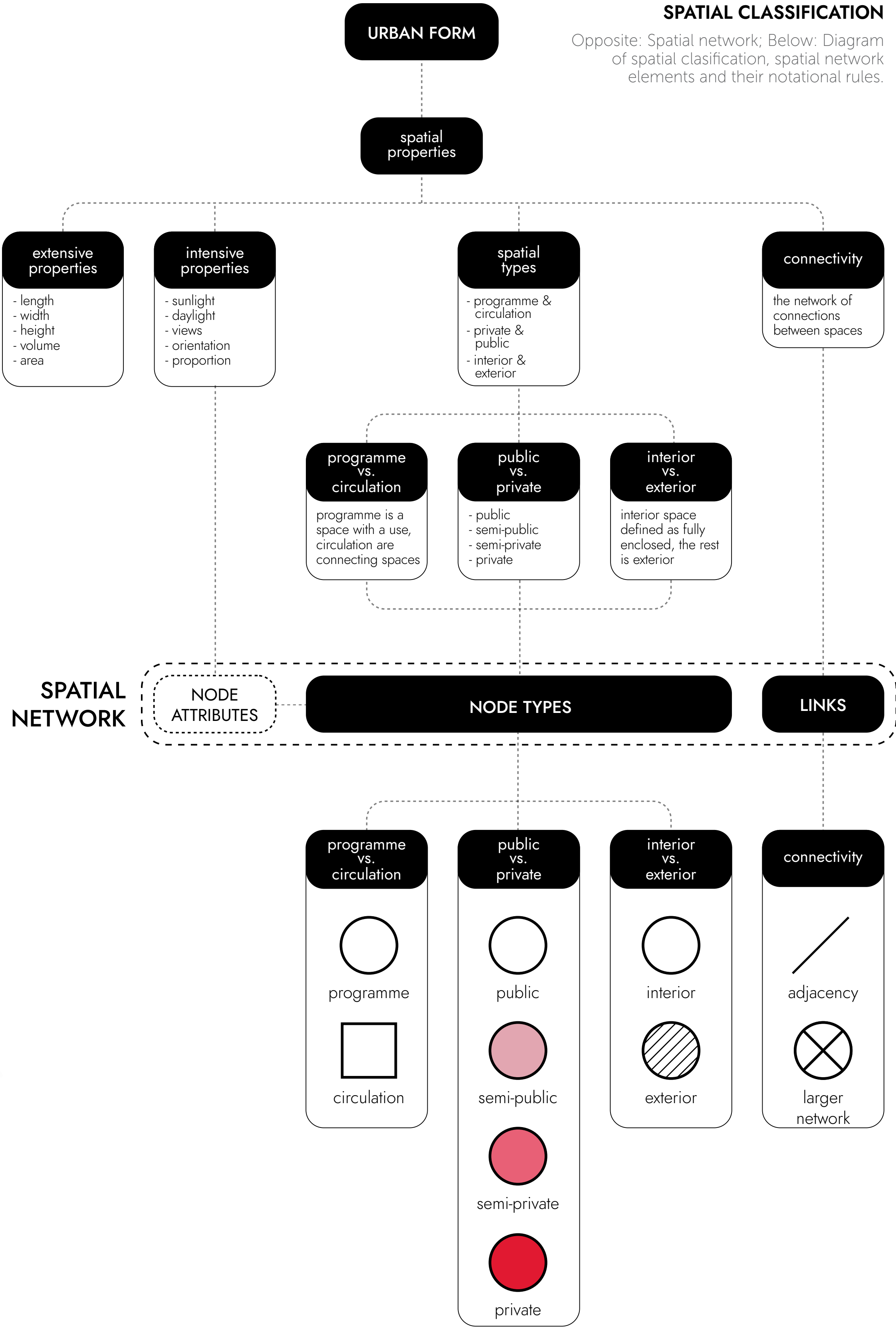
To expand the traditional topological adjacency graph with more spatial information it must be transformned into a spatial network; a graph in which the vertices or edges are spatial elements associated with geometric objects, used where the underlying space is relevant and where the graph's topology alone does not contain all the information.[20] To define the Spatial Network, space must first be deconstructed into to its relevant properties. First, spaces are represented by nodes of three different types representing properties not quantitatively measurable and independent of external conditions such as public-private or interior-exterior. Second, the basis of topology is connectivity, a property describing external connections of a space to other spaces as part of built space and represented as lines connecting nodes. Next, intensive properties represent quantitatively measurable parameters whose value is independent of the amount measured (common physical example is temperature, independent of volume or shape). These properties define spatial qualities and whilst not included in the analytical stage due to their dependence on external conditions they will be used in the design phase as node attributes. Lastly, extensive properties, the most obvious category describing quantitatively measurable parameters like distance whose value directly depends on the amount measured. These properties are often used to explicitly describe space or form and are therefore discarded from the Spatial Network diagram.



Spatial Network diagram drawing

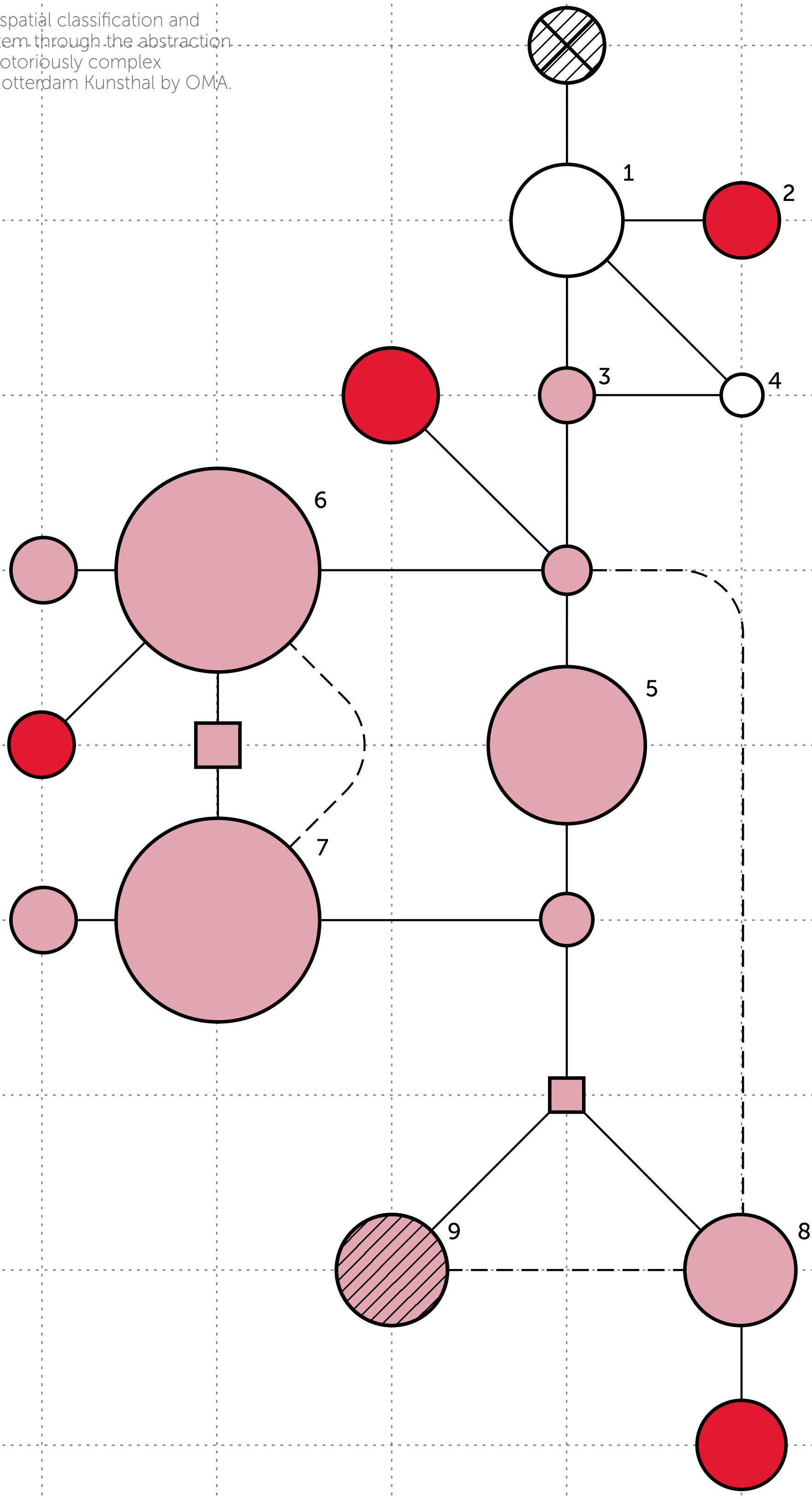
SPATIAL CLASSIFICATION

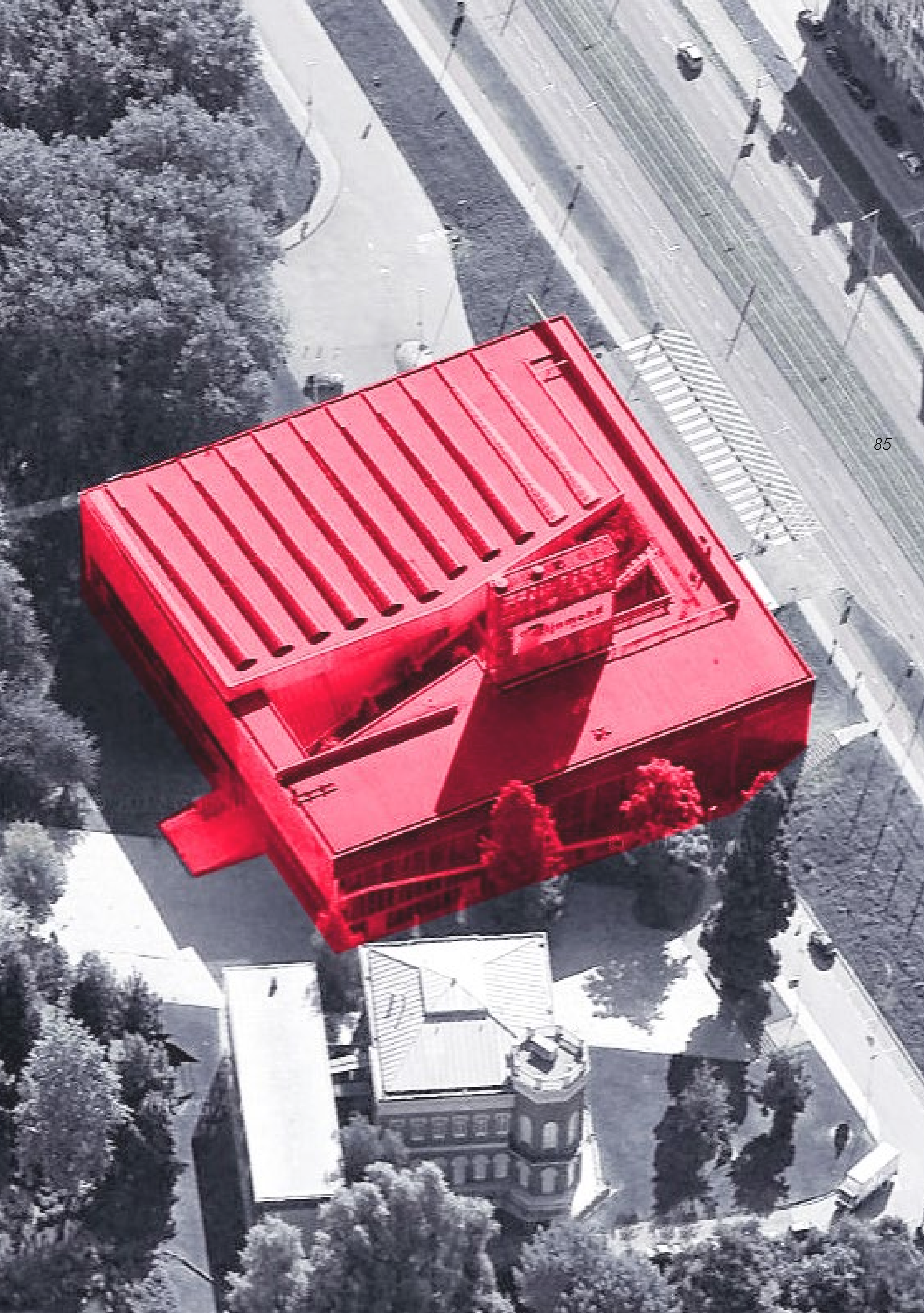
Opposite: Spatial network; Below: Diagram of spatial clasification, spatial network elements and their notational rules.

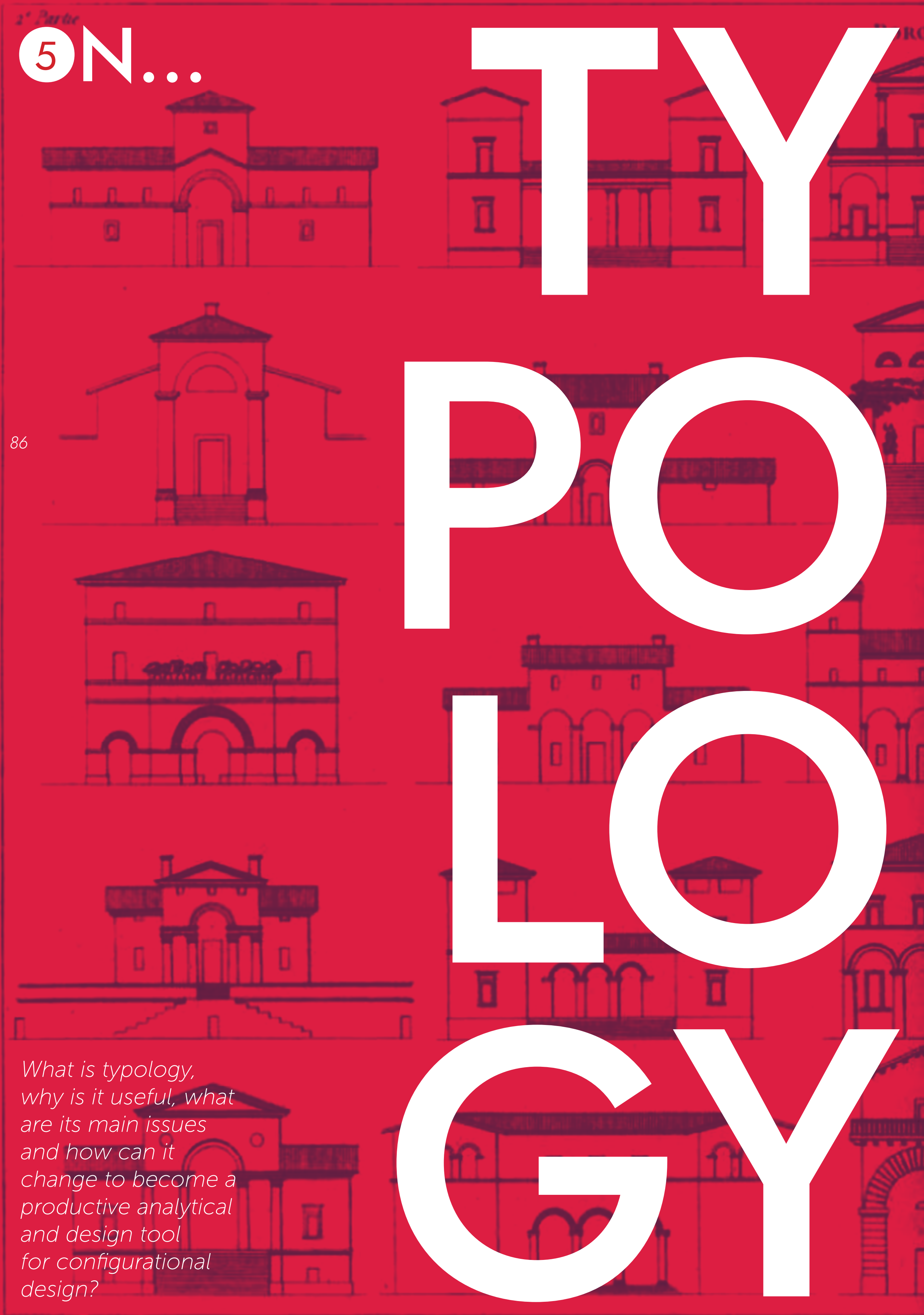


KUNSTHAL SPATIAL NETWORK

Testing of the spatial classification and notational system through the abstraction of a spatially notoriously complex building; the Rotterdam Kunsthal by OMA.







5 ON...

TYPOLOGY

What is typology, why is it useful, what are its main issues and how can it change to become a productive analytical and design tool for configurational design?

Although the capability of **configurational design** to enable production of new more responsive objects and forms is its most important implication, the method would gain substantially more legitimacy by also enabling their evolution from existing **socio-spatial patterns** in contemporary cities. For this to be possible, configurations must be applied analytically as a tool for the identification and extraction of complex spatial relationships in which established social structures are crystallized in built space.[21] It is precisely these assemblages which can act as the base for the production of new urban forms better adapted to the pressures of the modern city.

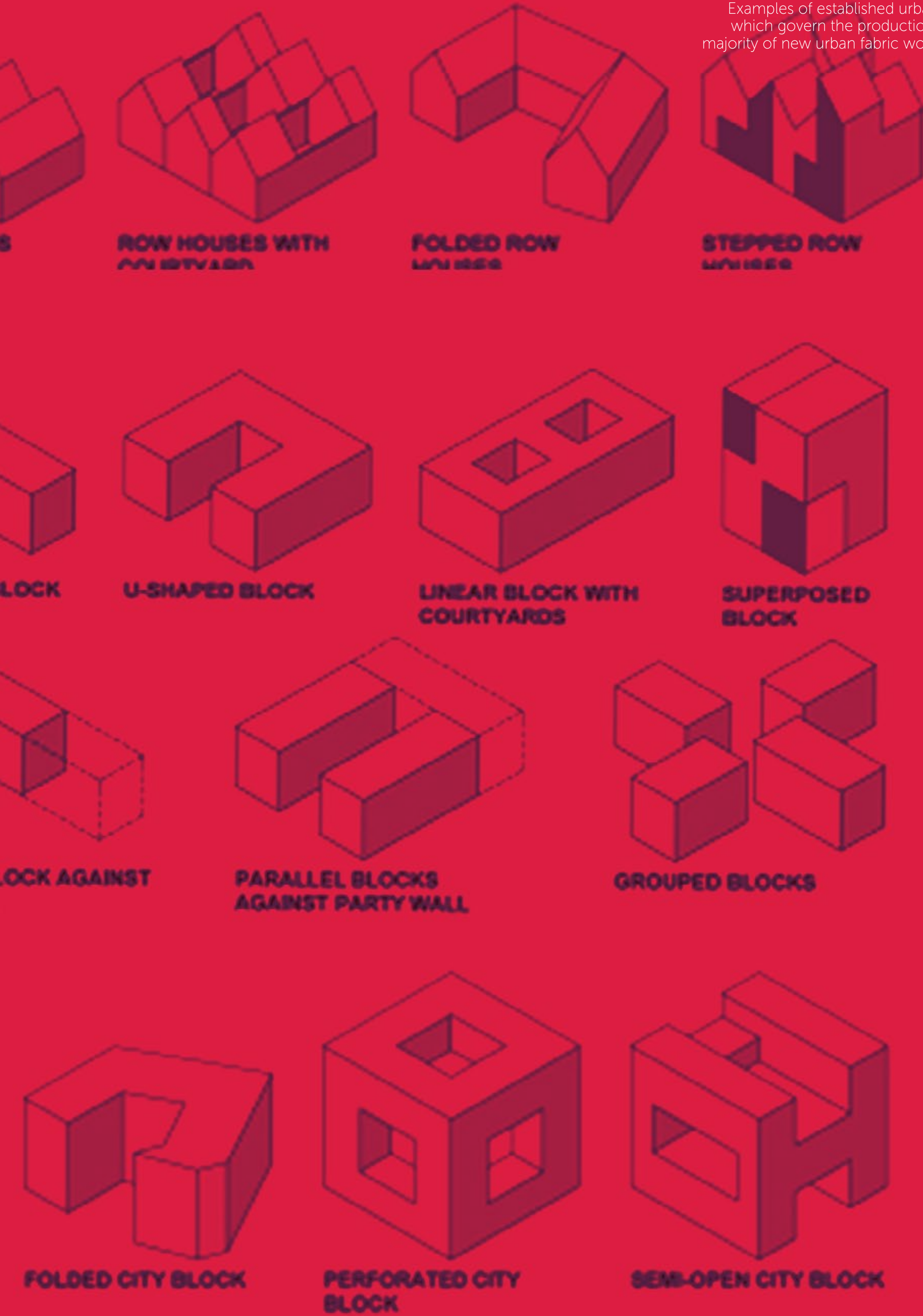
Configurations, albeit very adept at systematically mapping underlying socio-spatial patterns, are limited in analytical application due to the drastic lack of available comprehensive information on the built environment from which existing configurations could be "read" or extracted. Whilst this issue might eventually disappear with widespread adoption of BIM urban databases, even the hypothetical future existence of such a dataset brings difficulties of its own, namely the fact that the **complexity** and **diversity** of extracted configurations would far surpass the cognitive capabilities of a human designer and would thus inevitably require a degree of analytical simplification to be of any practical use to a human designer.

Both of the aforementioned issues could potentially be addressed with the implementation of a systematized typological approach to the analysis of existing. **Typology**, defined as analysis or classification based on types or categories, and **type**, defined as a distinguishable generalized instance representing a larger category, could together allow us to bypass exhaustive analysis in favour of an inquiry into a range of representative specimens which could together efficiently explain the complex entity that is a city. In the words of **Moneo**, ***"Type is fundamentally based on the possibility of grouping objects by certain inherent structural similarities. It might even be said that type means the act of thinking in groups"***.[22] This effectively enables the designer to only perform analysis on a limited subset of the population (of buildings), the results of which are generalizable and representative of the entire population via a method akin to statistical sampling.

Within a typological approach, types emerge through the act of grouping a series of (existing) objects by their mutual similarity, be it formal, stylistic, functional or configurational, while emphasising their common traits and suppressing divergent ones.[23] This **categorisation** by virtue of simplification results in generalised types serving a dual purpose; on one hand, the grouping provides an analytical and explanatory function, whereas on the other hand individual types become empowered with generative capabilities. Due to the generic nature of a type, it can be applied to any situation provided it is used as a starting point, a **prototype** that deforms and adapts to the circumstances. This way of understanding typology has been at its core from its inception in Architectural discourse in 1825 by **Quatremère de Quincy** who asserts: '***The word 'type' presents less the image of a thing to copy or imitate completely than the idea of an element which ought itself to serve as a rule for the model'***.[24] In other words, type is the essence (idea) of an object, which should merely guide the designer as he develops his specific solution (model). Understood this way, the type is abstract and conceptual instead of concrete and literal. The very concept of type implies the idea of change and transformation and is effectively the frame within which change operates.[22]

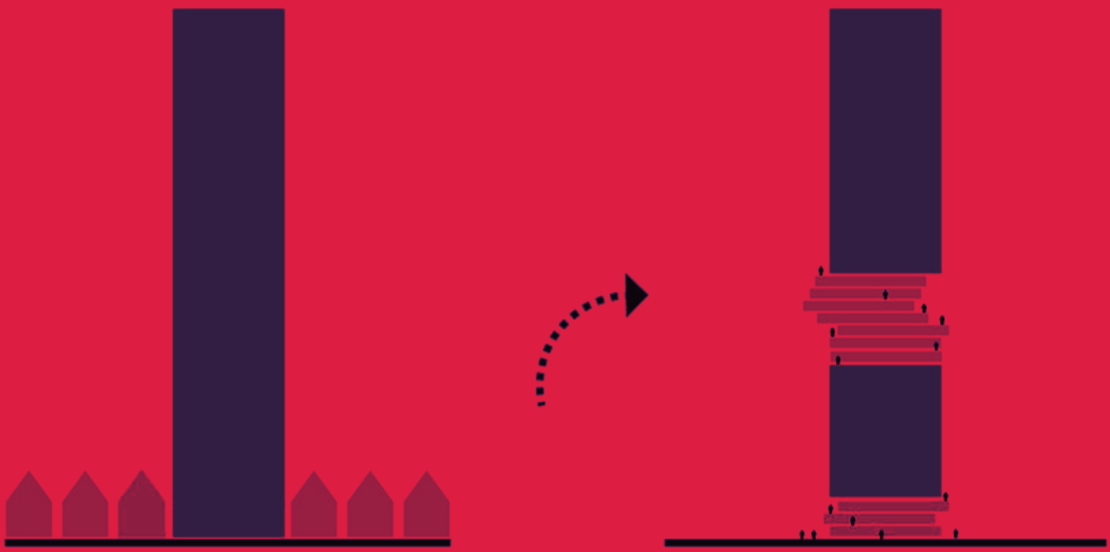
URBAN TYPES

Examples of established urban types which govern the production of the majority of new urban fabric worldwide.



OVERSIMPLIFIED DESIGN

An example where the tower typology has become so embedded in the production of architecture that it limits formal innovation and reduces it to small meaningless interventions.



MIXED USE

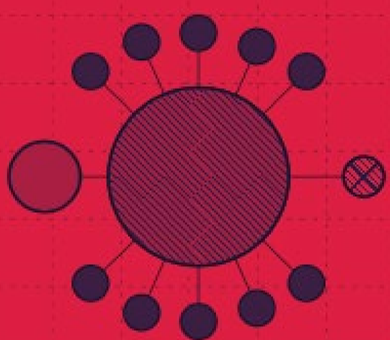
The tower is located in the center of this mix between tall and low. Its design reacts to the constraints and potential of the different programs housed within, including two office types, residental and public space. The influence of each specific program and height creates a silhouette that is both rational and sculptural.

Despite this openness to interpretation, in contemporary architecture 'type' is commonly **misunderstood** as buildings categorised by their formal resemblance as is the case in urban types such as detached houses, slabs and towers, to name only a few.[24] This reductionist understanding of type in combination with the increasing complexity of the contemporary city often leads to its misuse by designers inclined to fall back on well-known generalized examples for solving new specific problems; type as a recipe for a solution obtained by direct reproduction.[25] Although this approach undoubtedly enables fast, efficient and standardized solutions especially valued for their profitability within the global market economy, its drawbacks include lack of user control, reduction of variety and decreased performance as a result of inflexibility. It leads to "**typification**" of design, effectively discouraging the emergence of new formal structures [26], which has lead **Rem Koolhas** to accuse typology of being ***"a preemptive tactic that aborts history before it can happen"***, pointing towards its tendency to impede evolution, change and progress. As such, the powerful presence of the formal type in the mind of the designer oftentimes actively suppresses his ability for the invention of new alternative solutions.

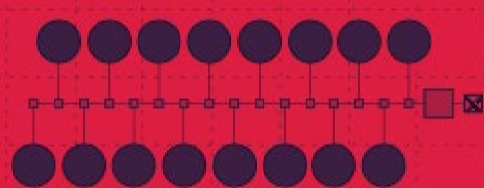
It is clear from this context that typology needs to be rethought if it is to maintain relevance as a legitimate design approach in architecture. To release established types from their formal connotations while retaining the socio-spatial structures they embody, a configurational approach proposes their abstraction into configurations capable of recording and visualising those relationships using spatial **topology** whilst discarding their characteristic forms along the way. No longer represented by axonometric drawings, plans or sections, types represented by abstract configurational diagrams discourage the formal reasoning which often underlies the application of types today and encourage their conceptual application as a set of perpetually **unstable** and **mutating relationships** in a state of constant evolution, each allowing the possibility of innumerable formal arrangements.[27] In other words, type is transformed from a formal precedent imitated via repetition and reproduction to an abstract topological structure with no inherent formal expression which can be utilised in a process of evolution and proliferation.[26]

Applied in practice this could produce a comprehensive **configurational typology**; a collection of type **diagrams** representing the elementary building blocks of a certain urban area, which not only describe its spatial (topological) characteristics but through them the social dimension of which physical space is a result. As such, types are transformed from fixed formal prescriptions to dynamic sets of relationships capable of adapting to different actors, pressures and situations, potentially allowing them to transcend their analytical origins to be used as design drivers within a renewed typological approach leading to new formal compositions adapted not only to the site and environment but also to the society they are made to serve.[8]

MONASTERY

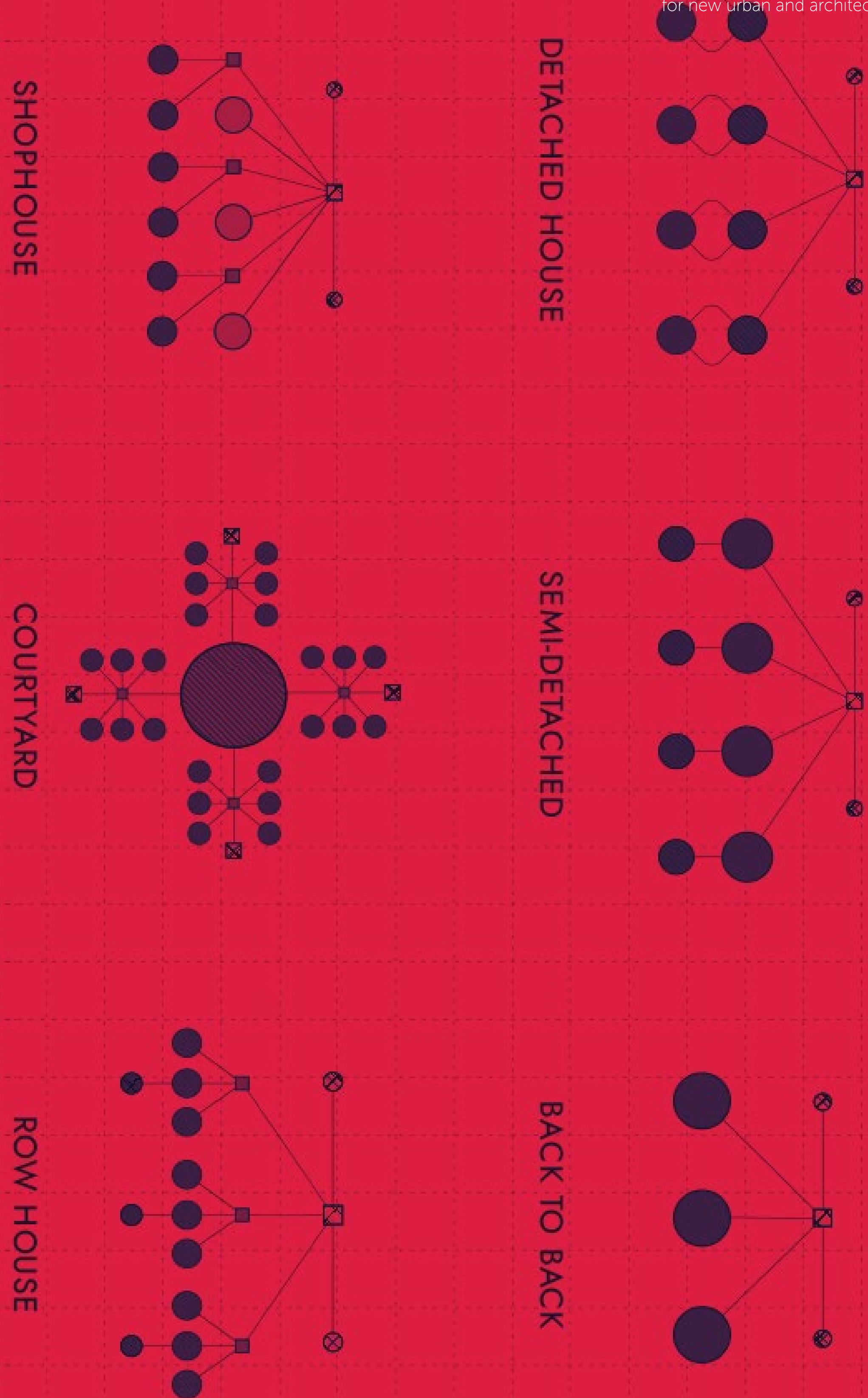


TOWER



CONFIGURATIONAL TYPES

Examples of possible configurational types capable of acting as generative design drivers for new urban and architectural form.



How can configuration be used to analyse the urban form of existing cities?

CONFIGURATIONAL TYPOLOGY

Translating urban types from form to configuration

The potential of **configurations** as analytical tools for extracting existing **socio-spatial relationships** was examined through their systematic application to the existing urban fabric in different contexts and at various scales.

As a first analytical attempt, spatial networks were used to analyse two contrasting locations; a traditional rowhouse courtyard block located on the outskirts of Rotterdam, The Netherlands and a modernist high-density slab housing estate in the suburbs of Ljubljana, Slovenia. In each case, the analysis was performed at four distinct scales aimed towards a comprehensive description of a part of urban fabric; unit, building, block and street. Despite the drastic differences in morphology of the locations and building types, spatial networks performed similarly in both cases producing clear and legible **configurations** at the unit and building scales, while confronting issues of a lack of data, a (too) high degree of complexity and difficulty with the delimitation of spaces at higher scales of a block and street.

Inasmuch as a lack of data and complexity are issues that could be minimised through the digitalisation of such analysis, the issues of delimitation are of a more fundamental conceptual nature and reflect similar difficulties encountered by **Space Syntax**. The central question here becomes by what criteria do we define a space, what separates one space from another and how spatial overlaps are accounted for. These are crucial questions a configurational approach should answer if it is to become universally applicable as an analytical tool.

In response to the issues encountered in the primary analysis, specifically the lack of information and reduced performance on higher scales, the analysis was continued and expanded on the principal scale of the research project; the building scale. Focusing on **generic** and predominantly residential **urban fabric**, the analysis was conducted via the systematic transformation of exiting generic urban types and certain iconic architectural buildings to their configurational counterparts with the use of spatial networks capable of recording the number, and types of spaces as well as their interconnections. In this process, the formal traits of established types are discarded opening them to new potential interpretations, some of which immediately become visible through the comparison of formally radically different objects with the same underlying patterns; a detached house and Habitat 67 by Moshe Safdie.

The resulting catalogue produces a **Configurational typology**; a series of spatial networks that can effectively describe the predominant socio-spatial patterns present in contemporary western cities and the buildings that constitute them. Furthermore, due to the **adaptive** nature of configurations, the spatial network types can be further modified, combined and cross-bred to generate new configurations capable of generating hybrid urban forms better adapted to the pressures of contemporary cities

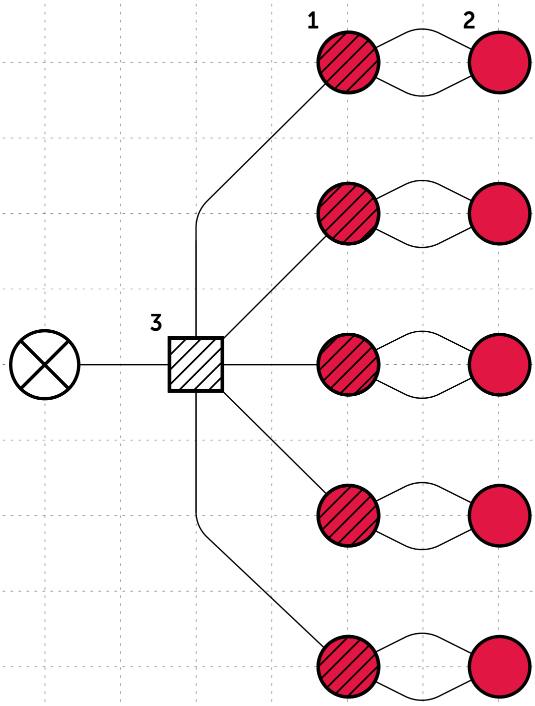
DETACHED HOUSE

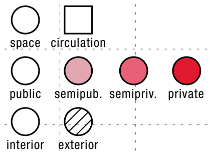
Info:

A free-standing, single-family dwelling unit that does not share a common wall with any other structure. Usually surrounded by a garden on all sides.

Space list:

1. Garden
2. Unit
3. Street





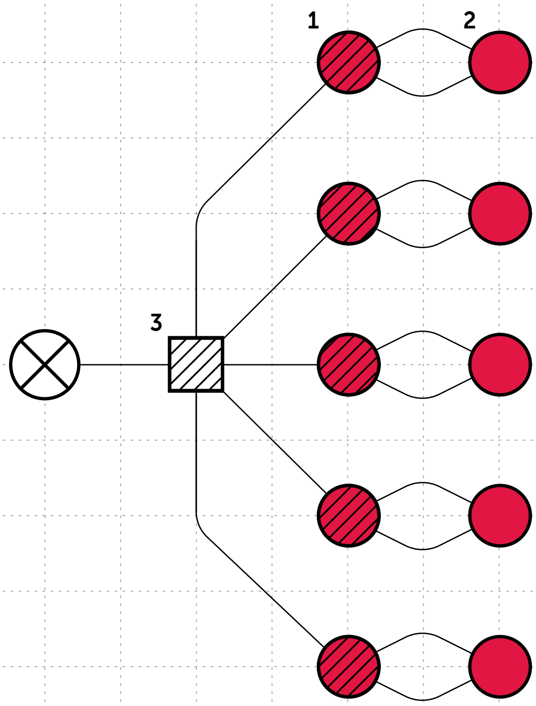
SEMI-DETACHED HOUSE

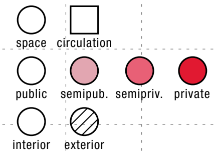
Info:

A semi-detached house is a single family dwelling house that shares one common wall with the next house. Usually surrounded by a garden on three sides.

Space list:

1. Garden
2. Unit
3. Street





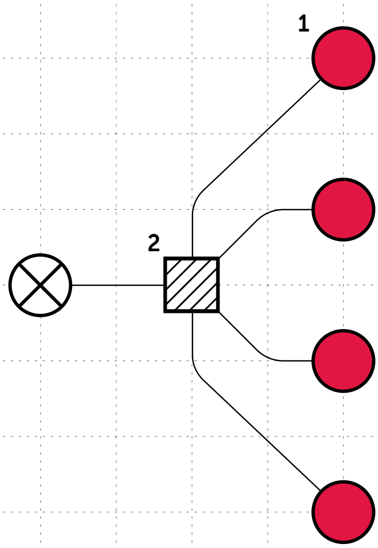
BACK-TO-BACK HOUSE

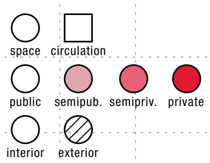
Info:

A back to back house is a single family dwelling house that shares three common wall with the surrounding houses. As such it is not able to have any outdoor space

Space list:

1. Unit
2. Street






DISABLED

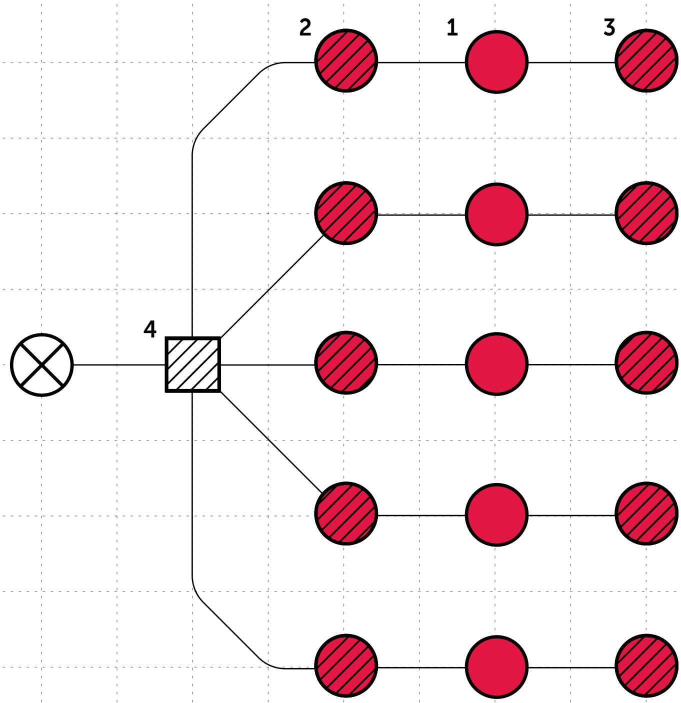
ROWHOUSE

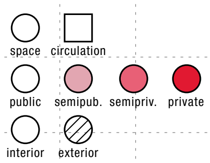
Info:

Single-family dwelling units attached to one another by common walls, generally with a common facade. With or without a front garden/porch.

Space list:

1. Unit
2. Front garden
3. Main back garden
4. Street





103

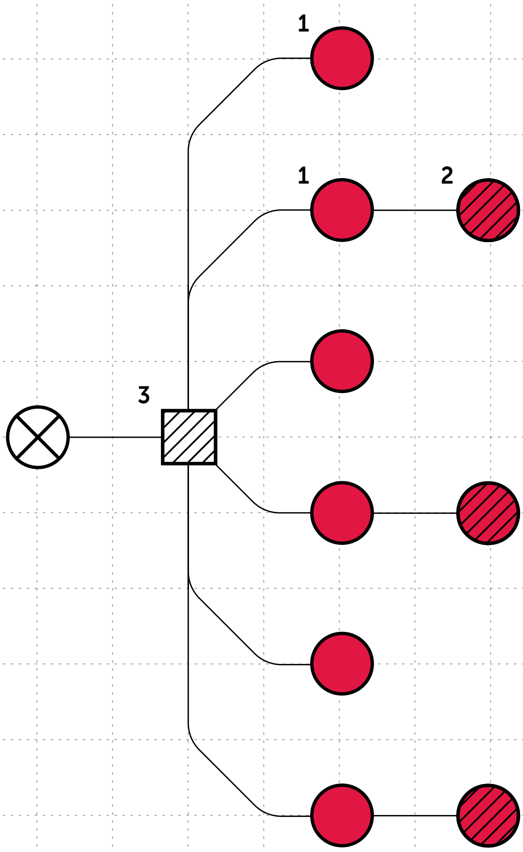
STACKED ROWHOUSE

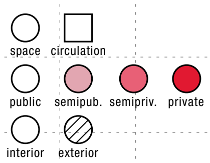
Info:

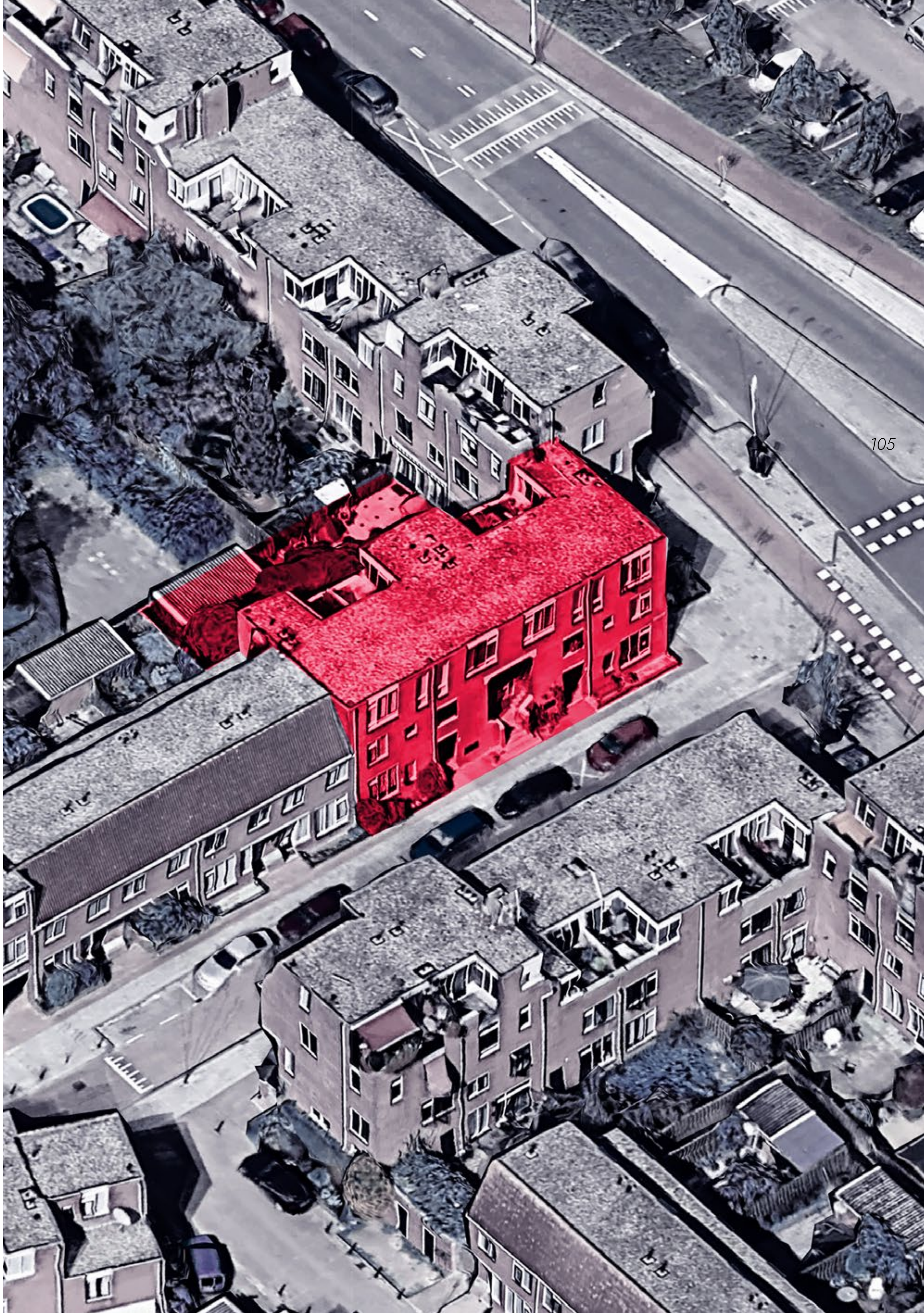
Stacked row houses share a sidewall like traditional ones but are also stacked vertically with 2 or 3 units on top of each other. The lower unit typically has an outside terrace, while the upper unit sometimes features a rooftop terrace or balcony. Every unit has its own front door.

Space list:

1. Unit
2. Exterior space
3. Street







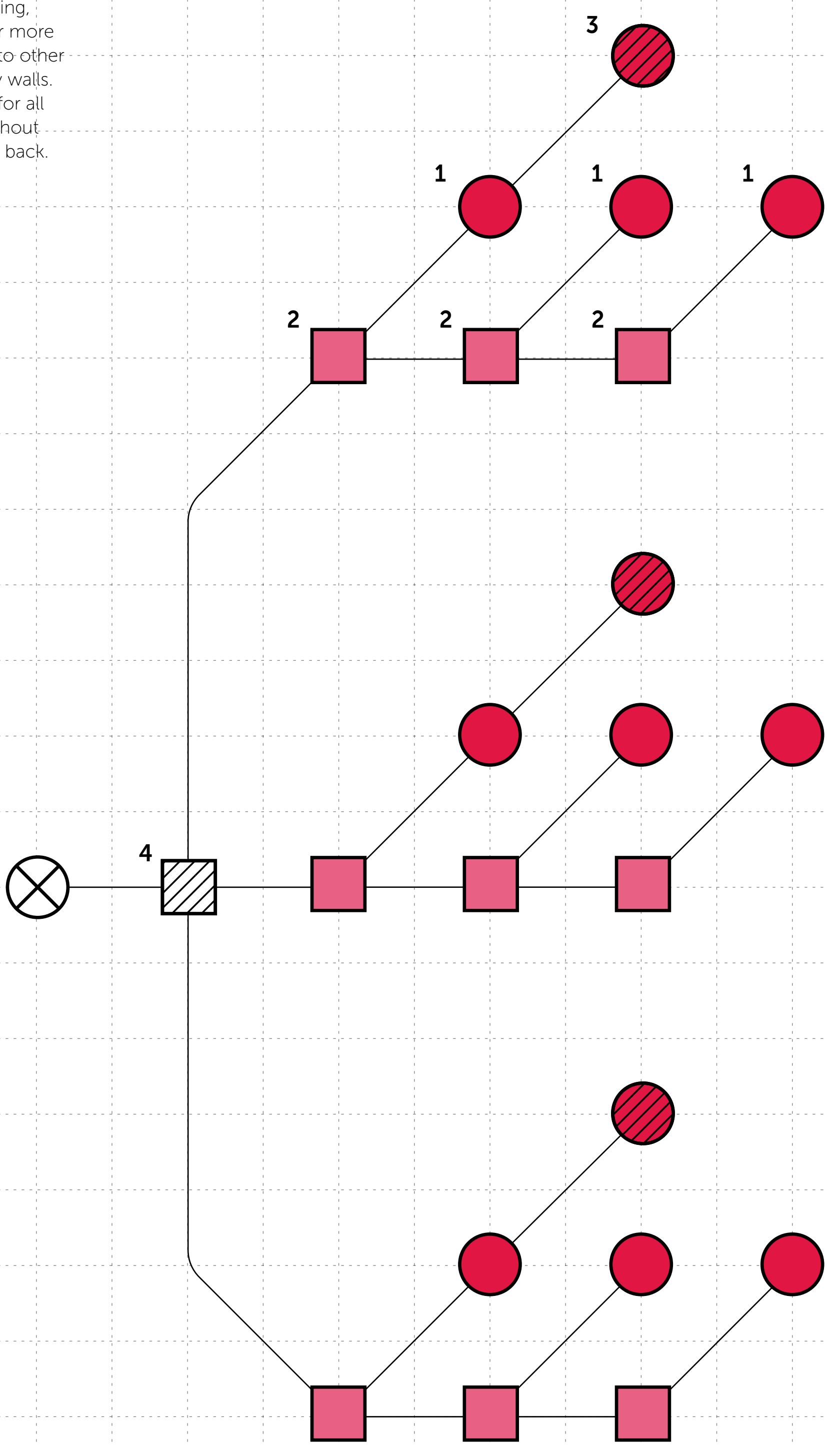
TOWNHOUSE

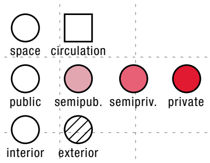
Info:

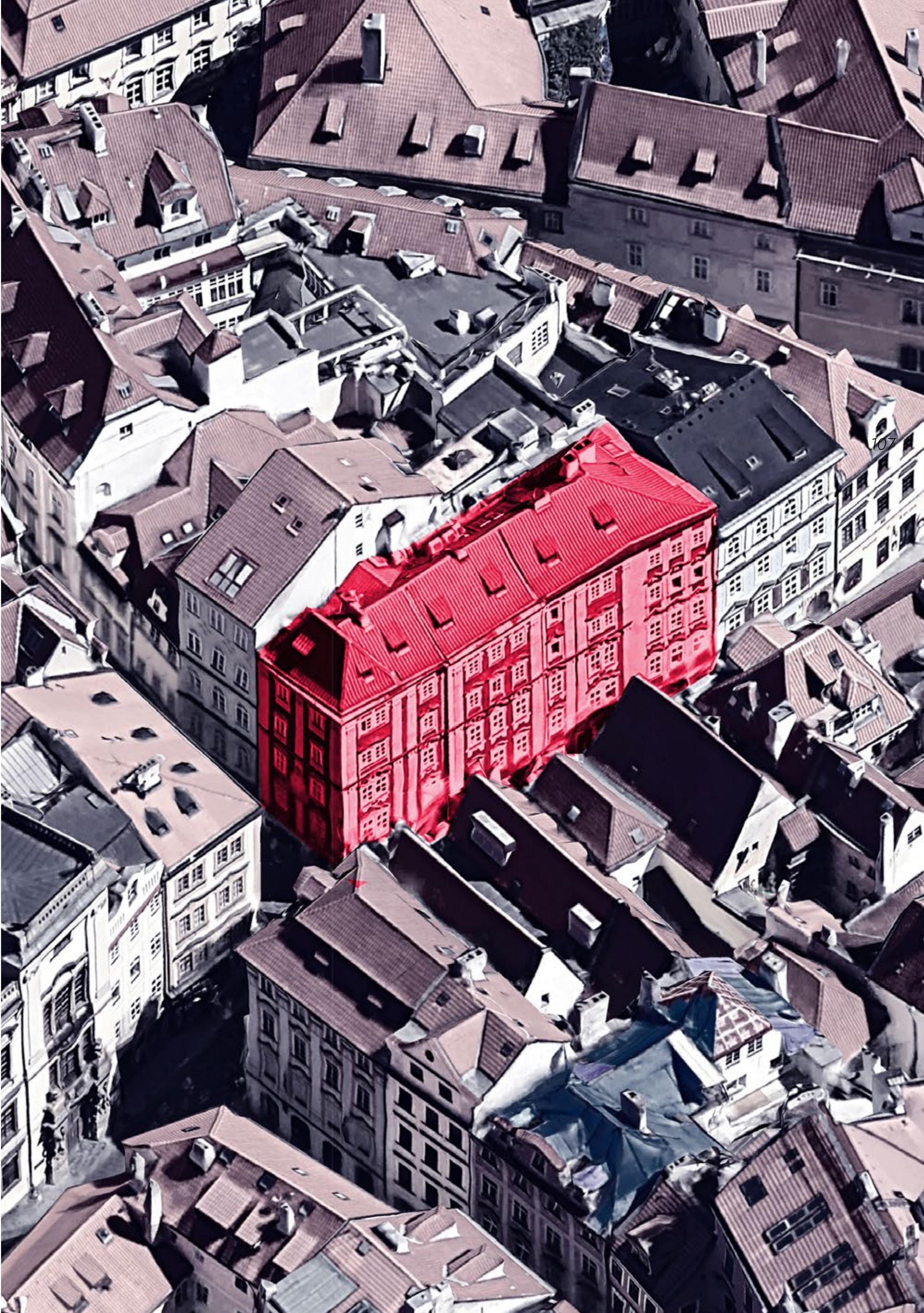
A multiple unit dwelling, generally having 2 or more floors and attached to other similar units via party walls. Shared access core for all units and with or without exterior space in the back.

Space list:

1. Unit
2. Circulation
3. Exterior space
4. Street







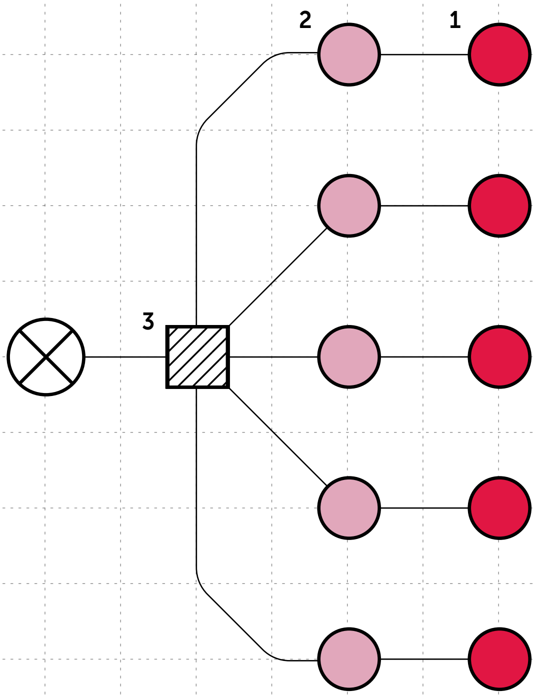
SHOPHOUSE

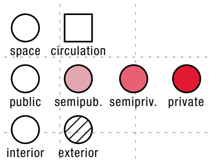
Info:

A shophouse is a building type serving both as a residence and a commercial business. They stand in a terraced house configuration and are especially common in Asia.

Space list:

1. Unit
2. Commercial space
3. Street





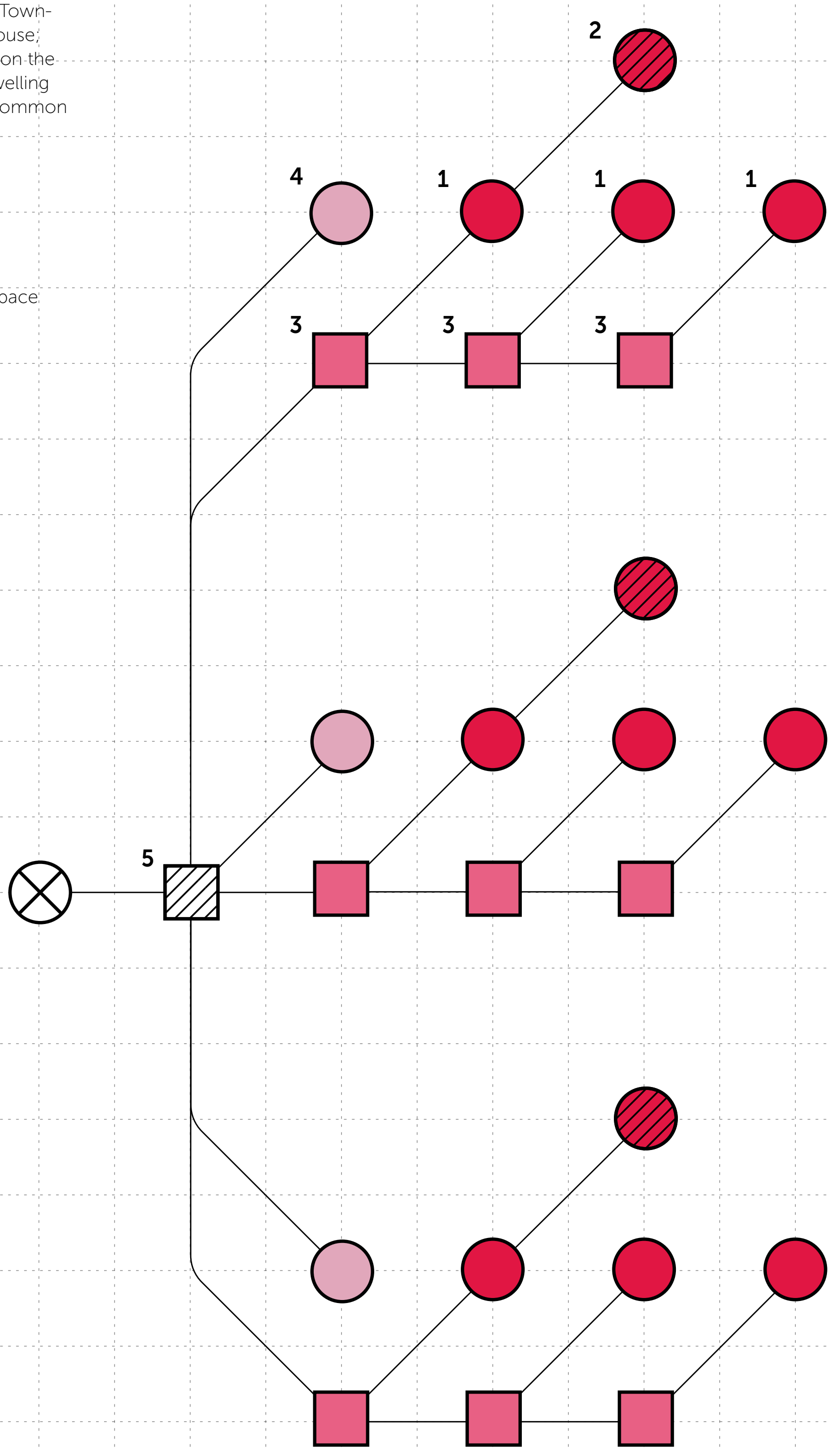
TOWNHOUSE SHOPHOUSE HYBRID

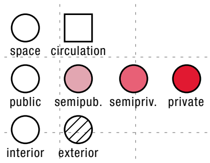
Info:

A hybrid between a Townhouse and a Shophouse; commercial spaces on the ground floor and dwelling units above with a common circulation access.

Space list:

1. Unit
2. Exterior space
3. Circulation
4. Commercial space
5. Street





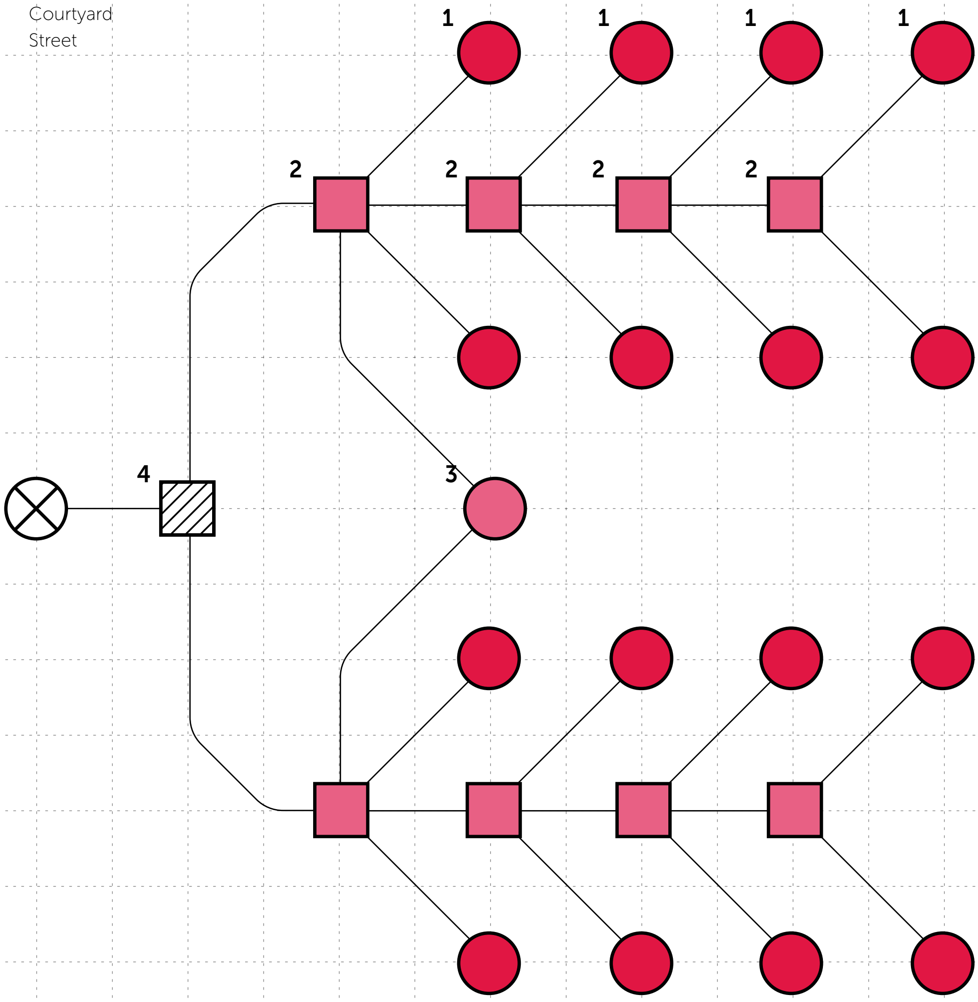
TOWNHOUSE COURTYARD

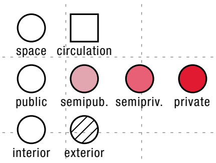
Info:

A rectangular arrangement of townhouses in the form of an urban block usually with a common courtyard in the center.

Space list:

1. Units
2. Circulation
3. Courtyard
4. Street





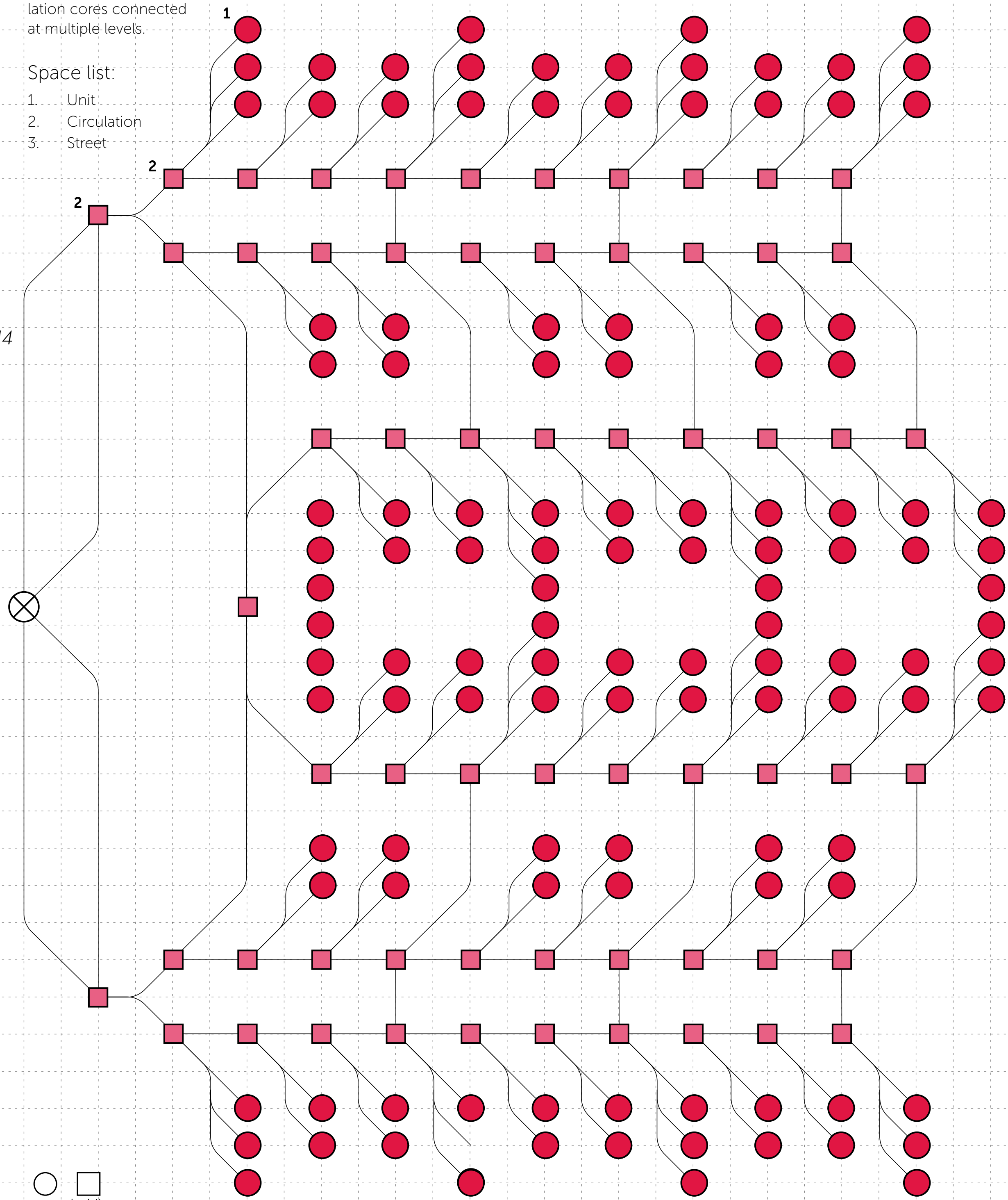
MULTI CORE SLAB

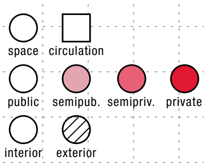
Info:

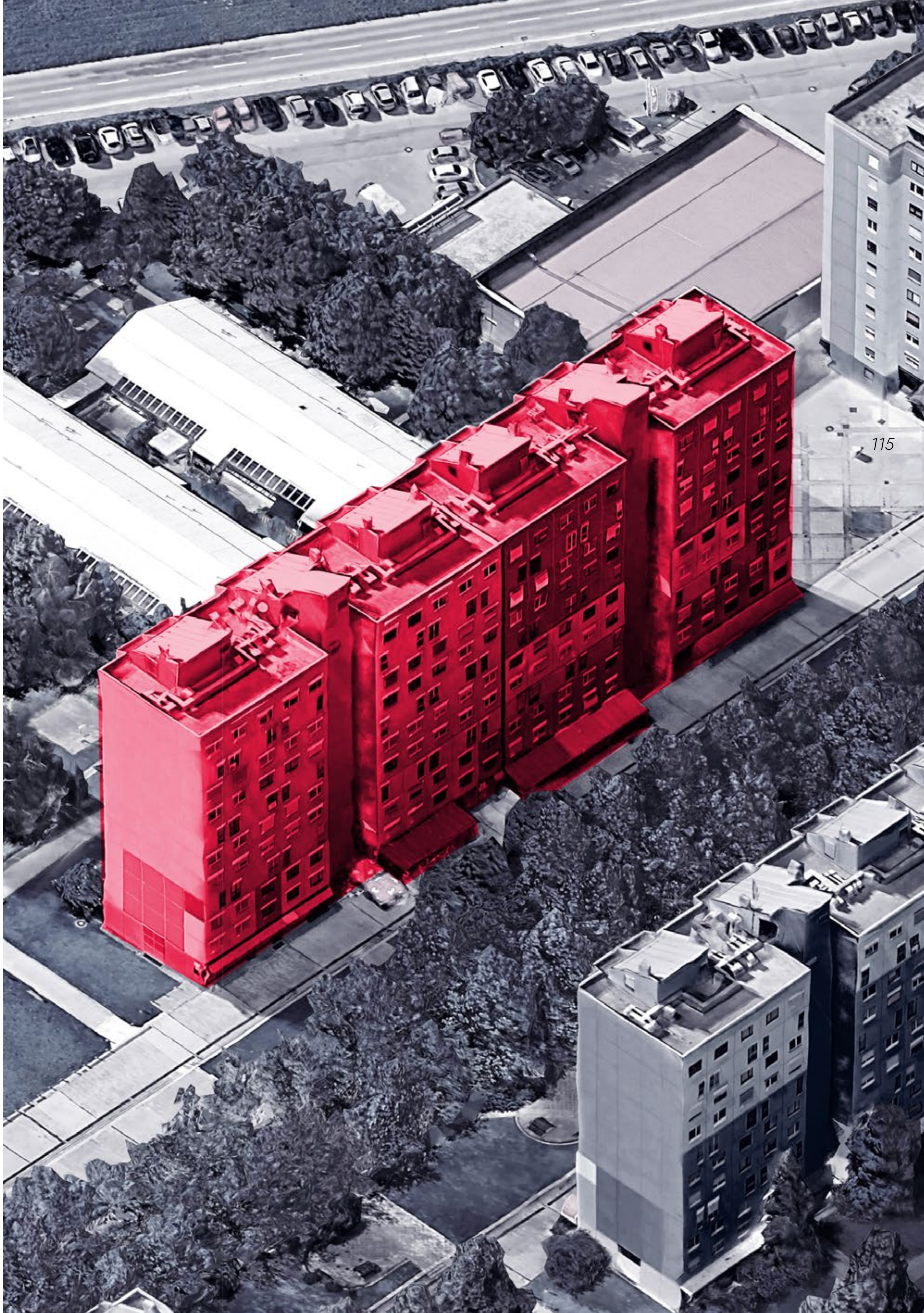
Slab with multiple circu-
lation cores connected
at multiple levels.

Space list:

1. Unit
2. Circulation
3. Street







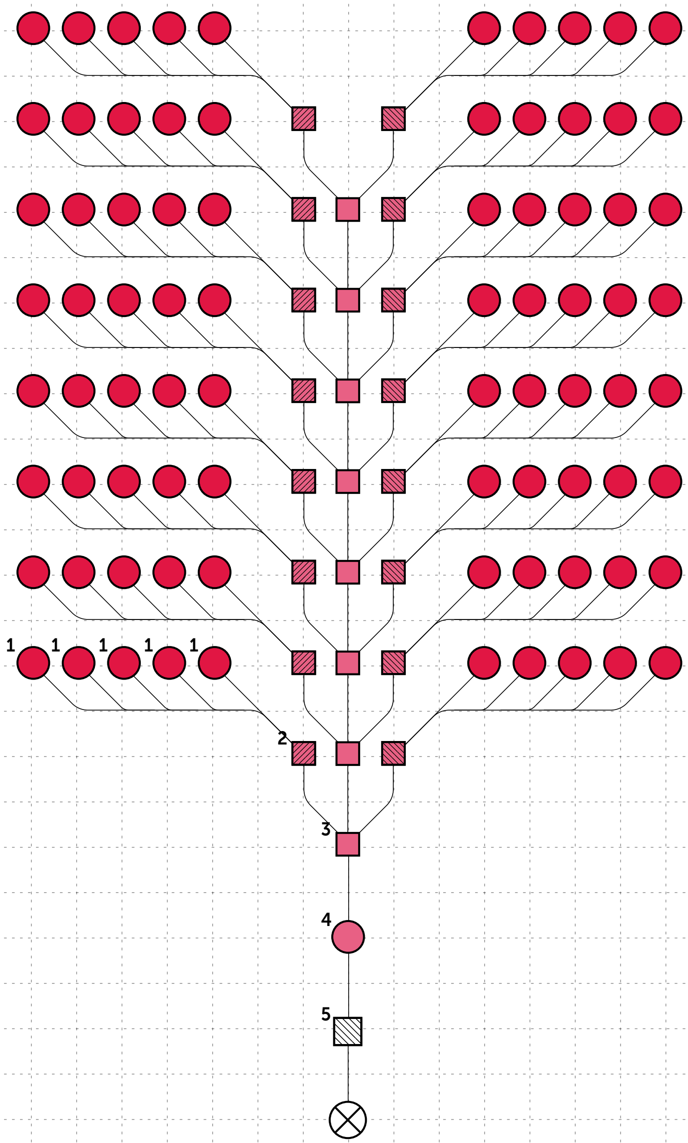
EXTERNAL CORRIDOR SLAB

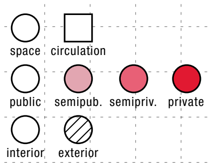
Info:

A variation of the standard slab, units have an access through a shared central circulation leading to an external hallway and from there individual units.

Space list:

1. Unit
2. Exterior hallway
3. Circulation core
4. Lobby
5. Street





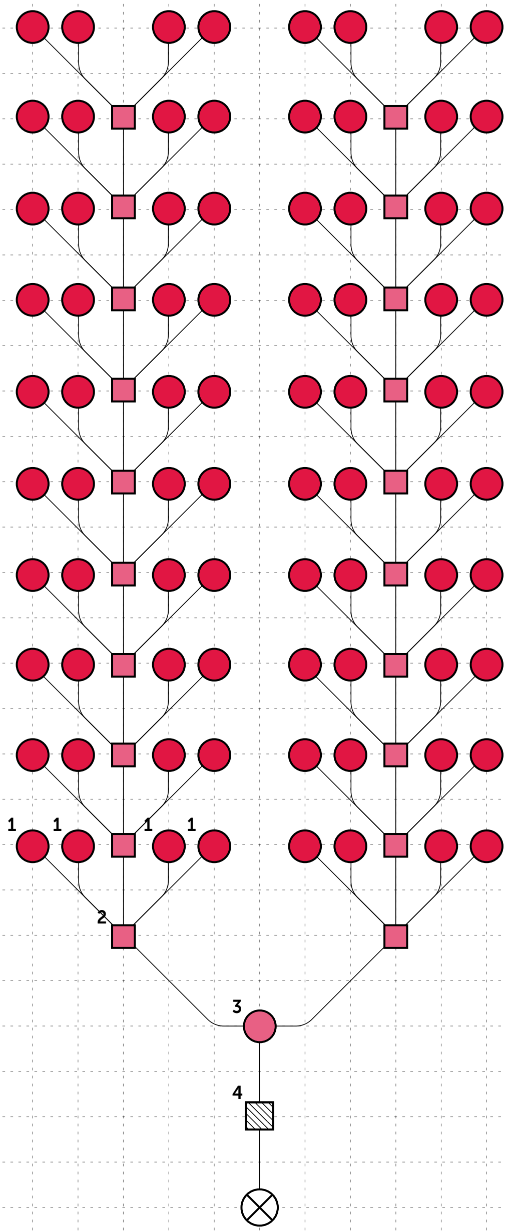
CENTRAL CORE SLAB

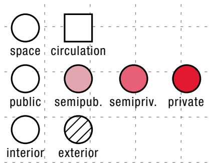
Info:

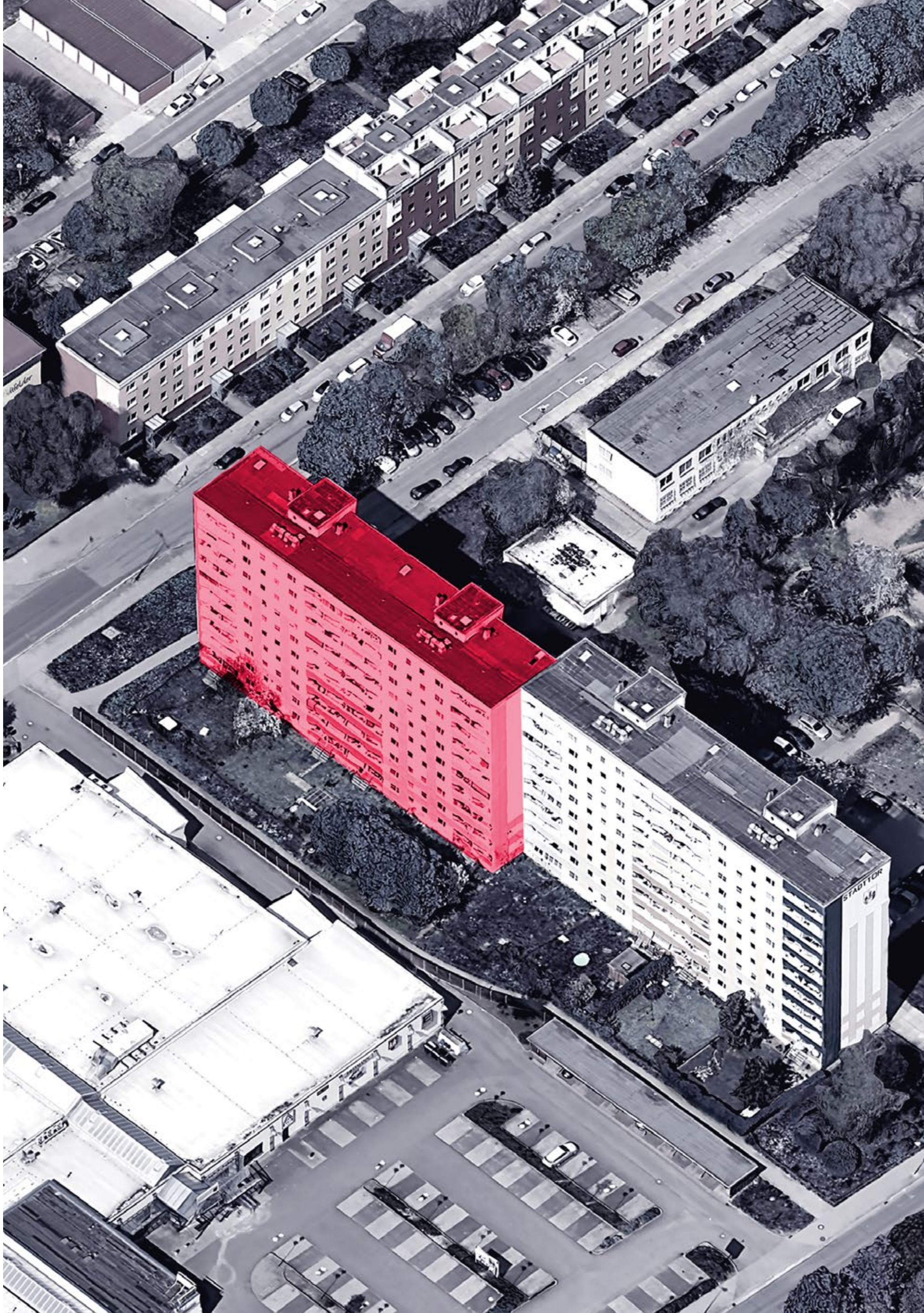
A slab is characterized by a large number of units in a single building which share access through one or more internal circulation cores. Untis occasionally have balconies or terraces as exterior space.

Space list:

1. Unit
2. Circulation core
3. Lobby
4. Street






STADTTOR

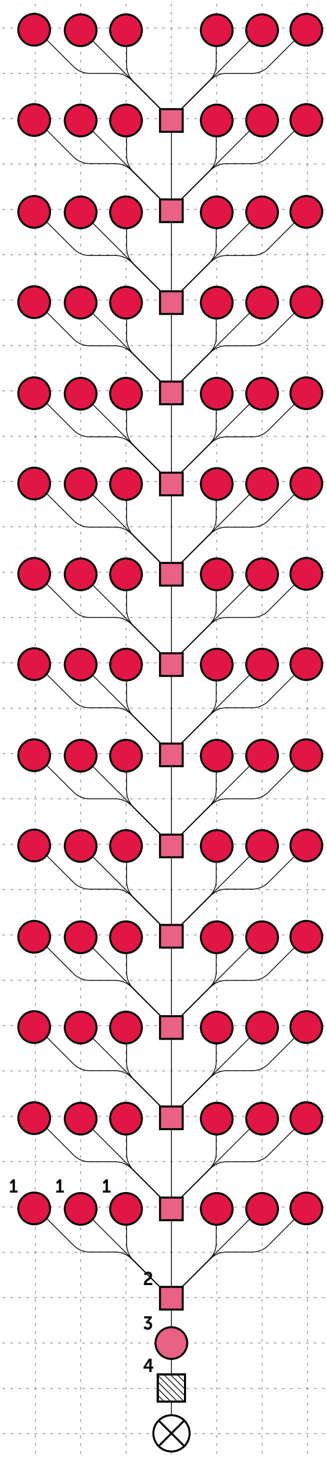
TOWER

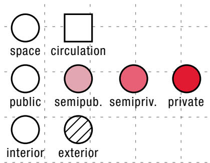
Info:

A tall, narrow, usually freestanding building, able to house a large number of dwelling units. Access from the street to the main circulation core from which there is direct access to multiple units at each floor.

Space list:

1. Unit
2. Circulation core
3. Lobby
4. Street





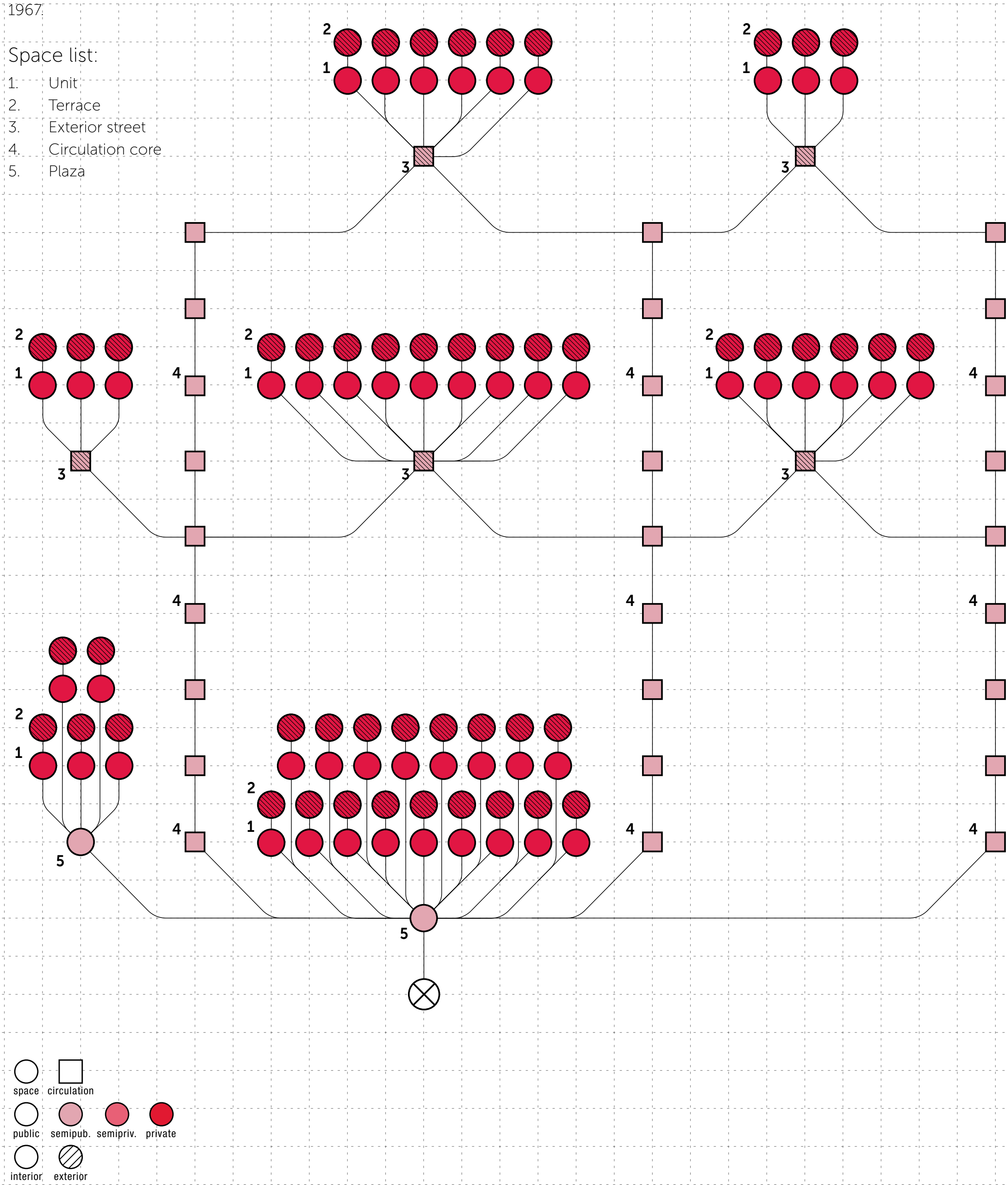
HABITAT 67

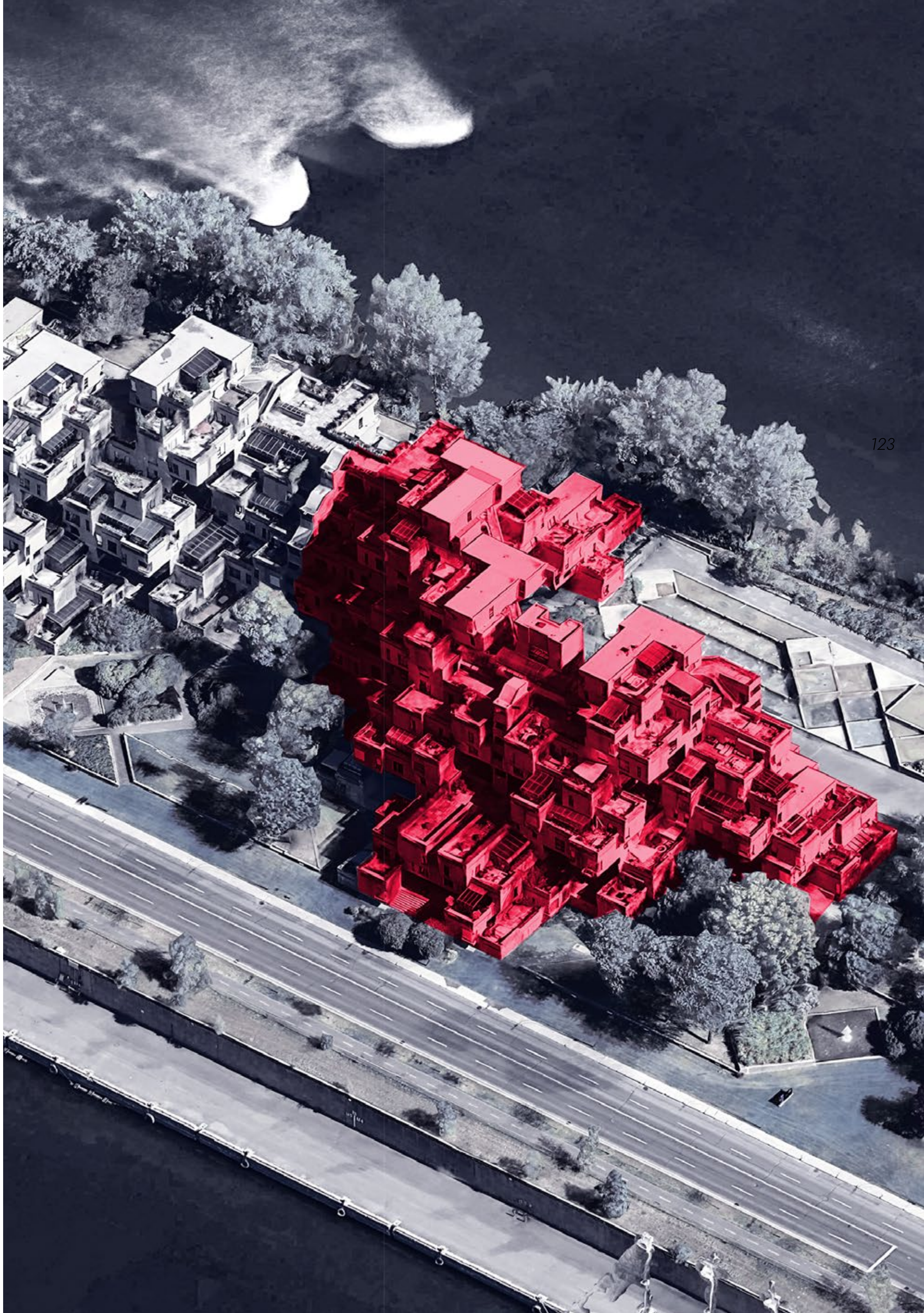
Info:

Habitat is a model community and housing complex in Montreal, Quebec, Canada, designed by Israeli-Canadian architect Moshe Safdie. It was built as a pavilion for Expo 67, the World's Fair held from April to October 1967.

Space list:

1. Unit
2. Terrace
3. Exterior street
4. Circulation core
5. Plaza





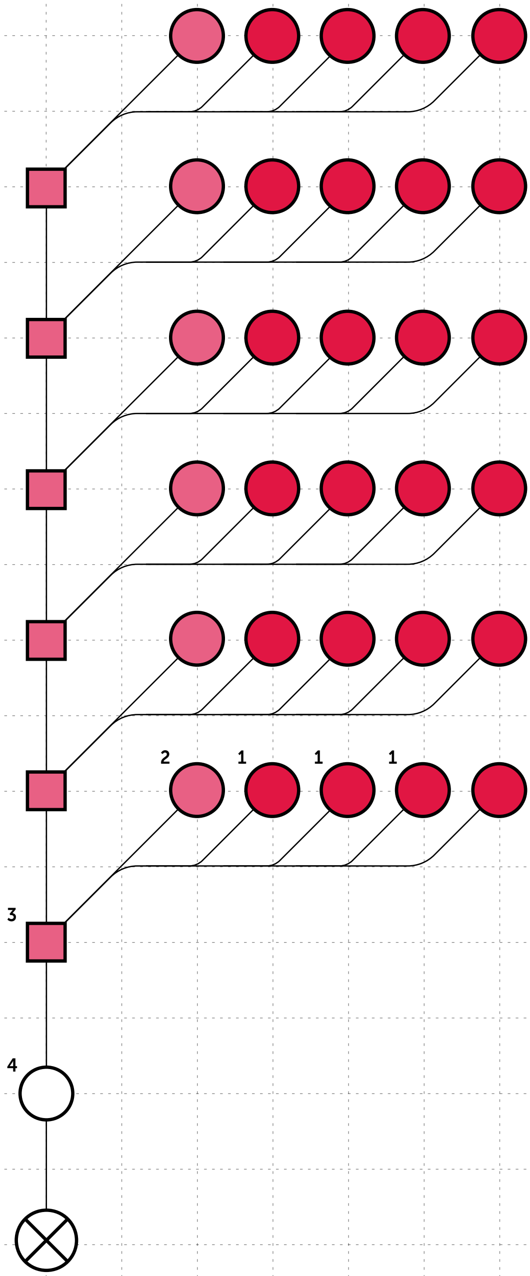
PEABODY ESTATE

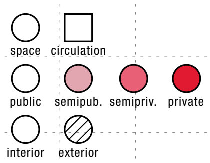
Info:

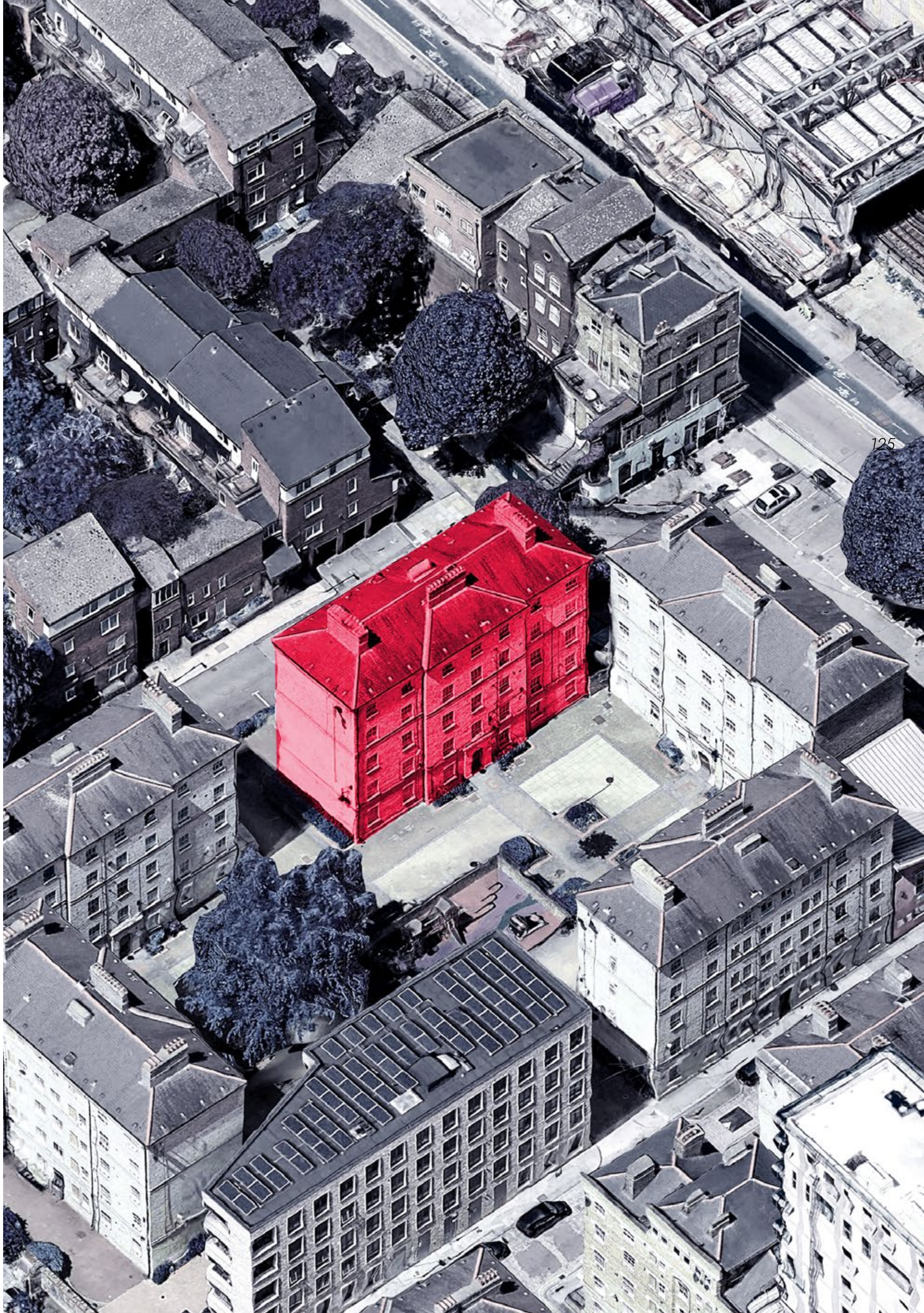
Multi - apartment collective living estates developed and mass produced in 19th century London by the Peabody Trust to improve living conditions of the working population.

Space list:

1. Unit
2. Collective kitchen and bathroom
3. Circulation
4. Square







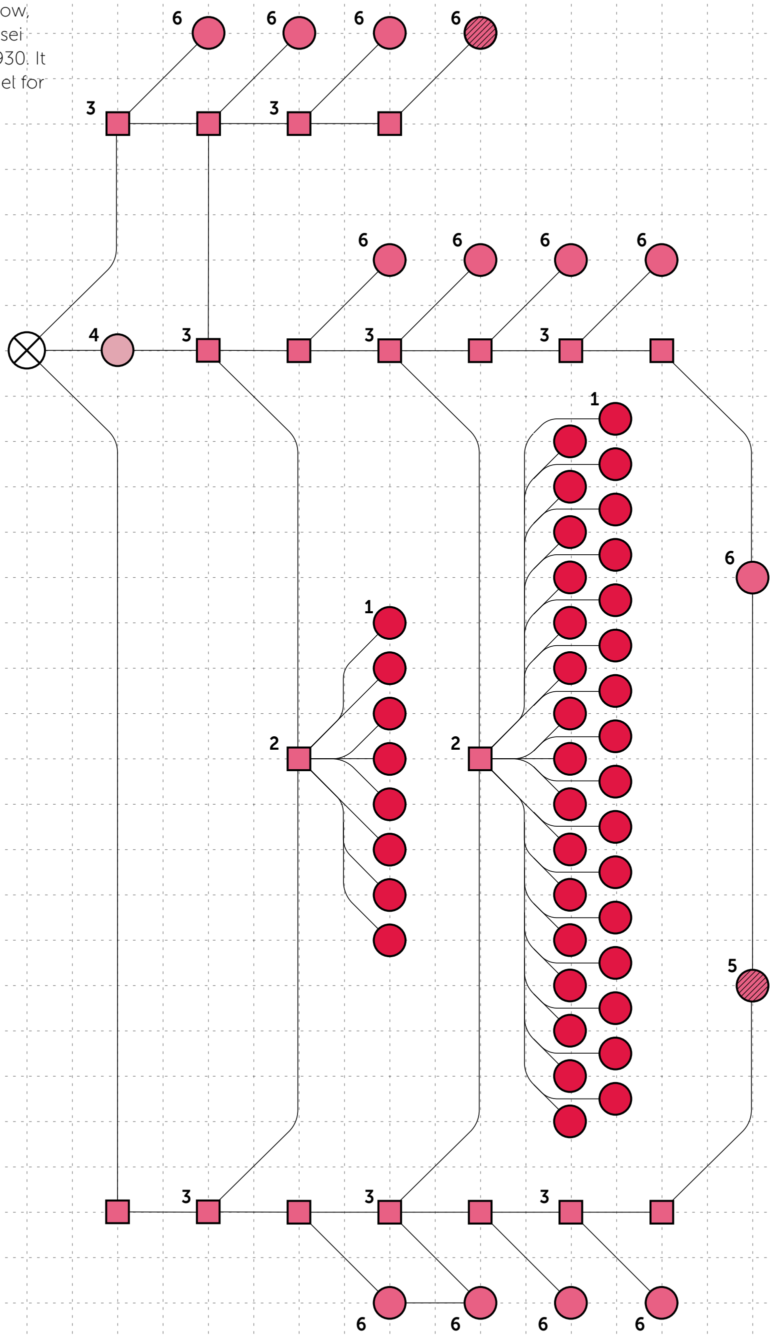
NARKOMFIN BUILDING

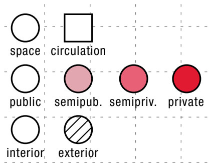
Info:

The Narkomfin Building is a block of flats at 25, Novinsky Boulevard, in the Central district of Moscow, Russia designed by Moisei Ginzburg and built in 1930. It was designed as a model for collective living.

Space list:

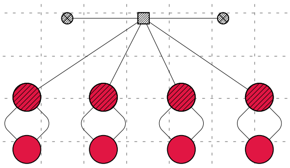
1. Unit
2. Hallway
3. Circulation core
4. Entrance area
5. Roof terrace
6. Common areas



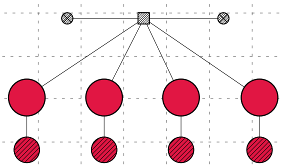


DIAGRAMS OF POSSIBLE TYPES

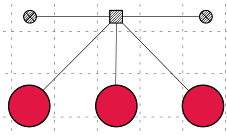
A series of sketch diagrams of common spatial types including examples beyond generic residential urban form,



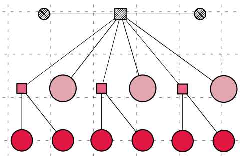
DETACHED HOUSE



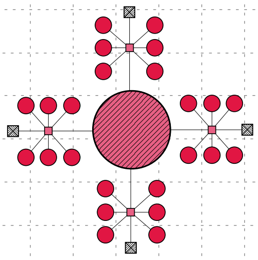
SEMI-DETACHED



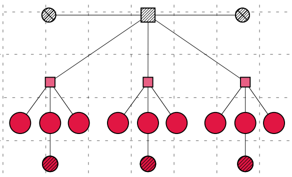
BACK TO BACK



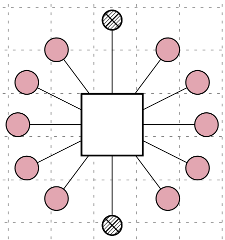
SHOPHOUSE



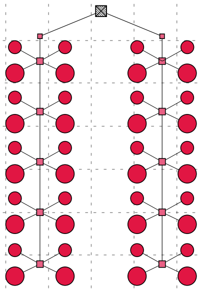
COURTYARD



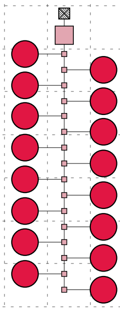
ROW HOUSE



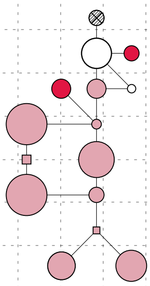
SHOPPING MALL



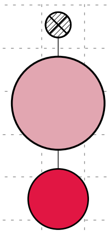
HOUSING SLAB



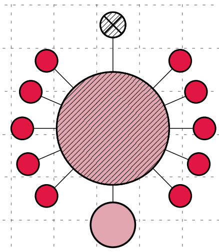
TOWER



MUSEUM



SUPERMARKET



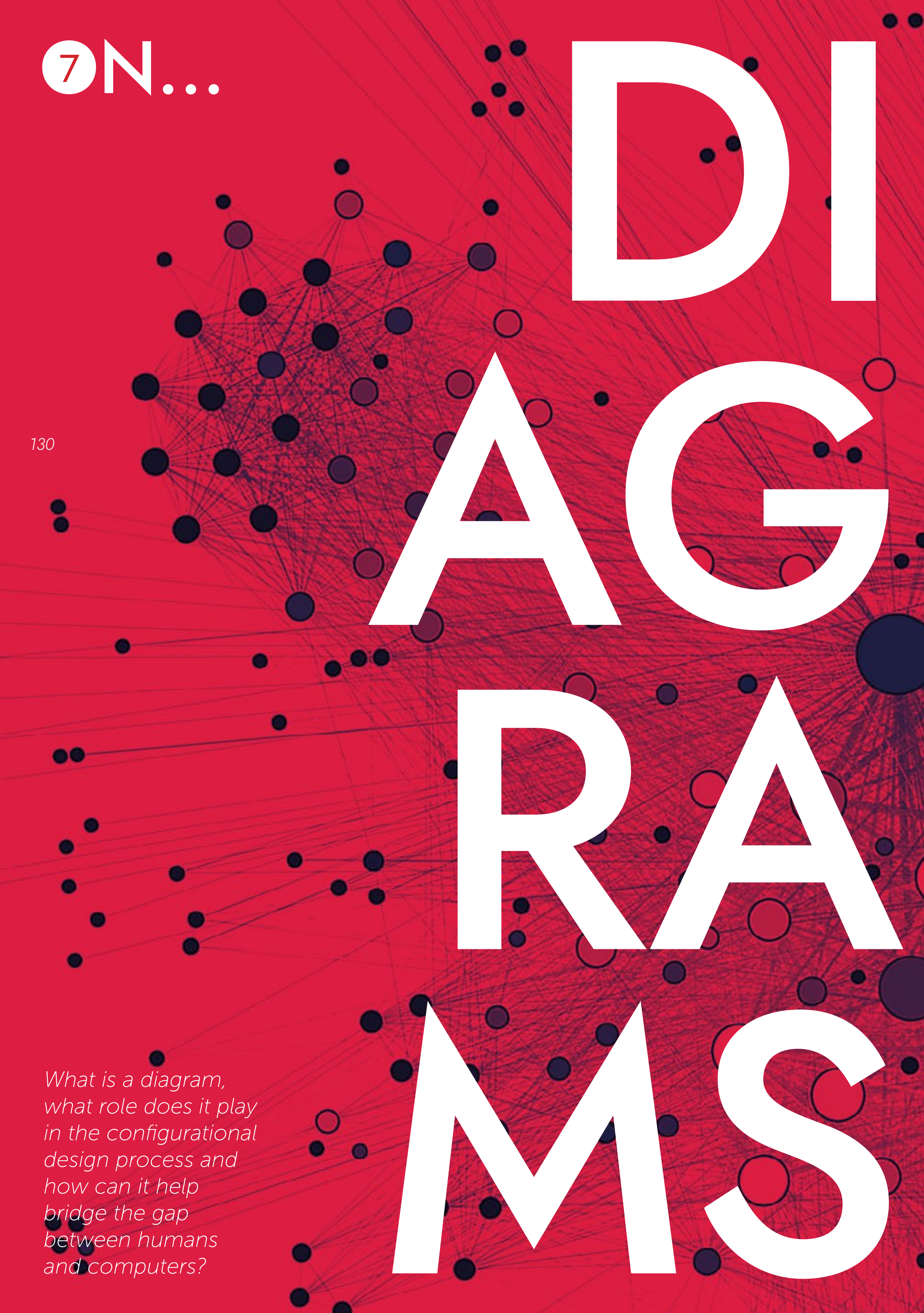
MONASTERY

Theoretical and computational innovations should allow type to become a dynamic set of relationships that can vary with pressure, situation, actor and time.

- David Grahame Shane, Transcending type, 2011

7 ON...

DIAGRAMS



What is a diagram, what role does it play in the configurational design process and how can it help bridge the gap between humans and computers?

Within the compositional design approach in architecture the **plan** drawing traditionally dominates as the object of design as well as the medium through which both design and construction take place. Due to the focus of the **configurational design** approach on spatial relationships instead of objects or forms, the **diagram** replaces the plan as the predominant medium thanks to its greater capacity for describing and visualising such patterns, as well as its adaptive and ambiguous nature.

Diagrams are defined as simple drawings that explain rather than represent and since **Toyo Ito**'s introduction of the term ***"diagram architecture"*** in 1996, their explanatory function has often been used in the architectural design process to describe programmatic, structural and formal principles to the designer, as well as an external audience.[28] Nonetheless, the true value of the diagram lies in its ability to facilitate an abstract way of thinking about **organization**; coincidentally a fundamental aspect of configurational thought.

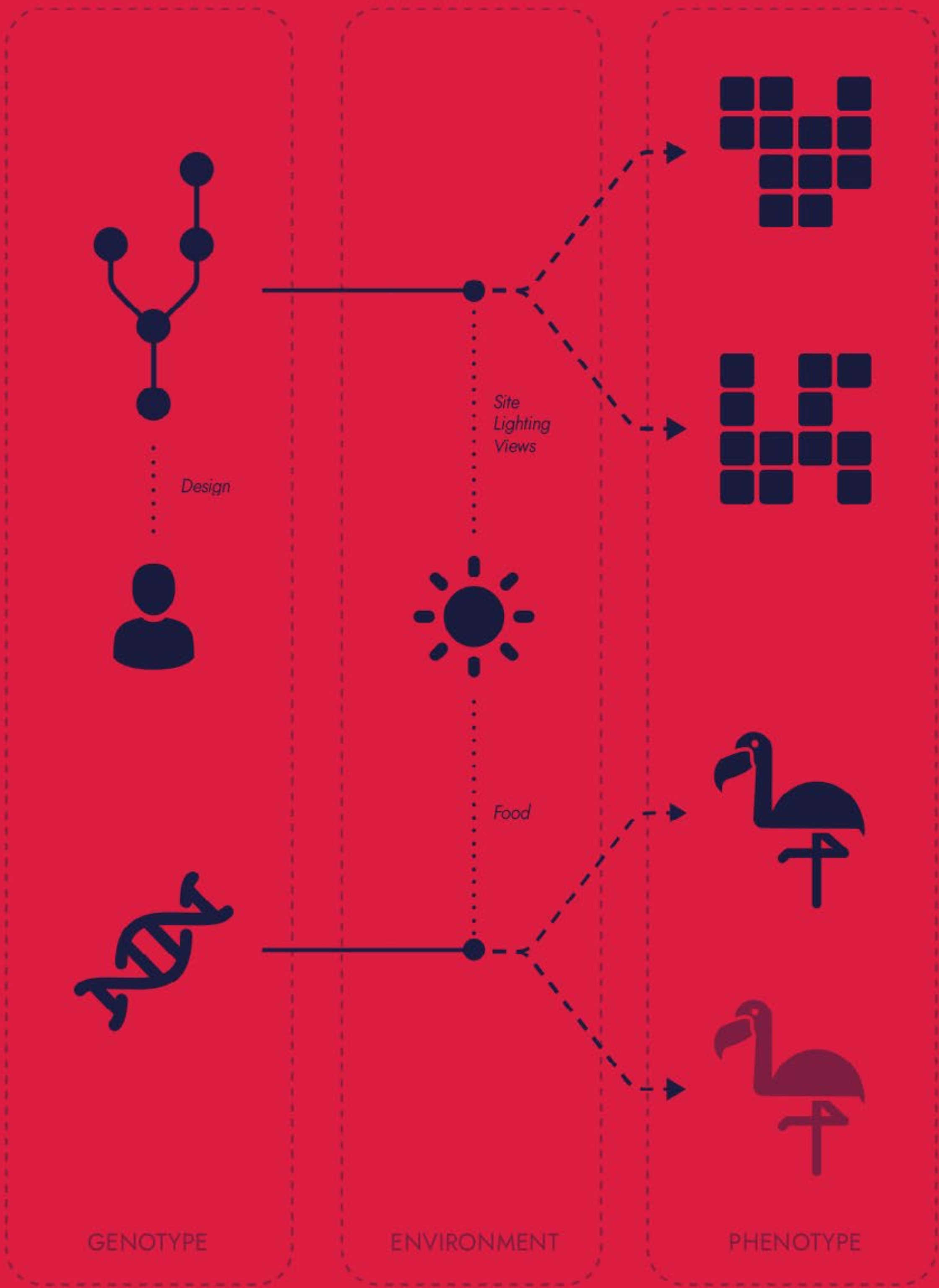
Diagrams operate through **reduction** and **abstraction**. By describing arrangement, structure and relationships they shift the focus from the (traditional) **object** to the underlying **process**, which suddenly finds itself in the centre of attention becoming the object of design. It is here where the diagram exceeds its analytical and explanatory roles to become **projective** by anticipating new organizations and yet to be realized relationships. Beyond a reduction of an existing order, its abstraction is instrumental and not an end in itself.[29] In a configurational context, this abstraction of physical space and form not only liberates the designer from any lingering formal preconceptions and biases but, crucially, makes the usually invisible underlying **configurations perceptible** and conscious, enabling the designer to act on them. In other words, the diagram materializes the relationships and connections in space consequently making them operational within configurational design.

A crucial property of the diagram is its capacity to mirror the **adaptive** nature of the very configurations it describes. While its parts and their interrelationships may be constant, its layout is ambiguous and undefined; it can twist, bend, stretch and compress as the situation dictates, potentially in response to external influences such as site, context or climate. This inherent **flexibility** opens up the door for **interaction** between (configurational) **diagrams** and the **environment** in a process akin to natural **morphogenesis** and the genotype-phenotype dynamics, a subject studied at length by the field of developmental biology. In nature, a **genotype** is defined as the set collection of genes an organism carries which define the blueprint or map for its development and defining physical traits. The **phenotype**, on the other hand, represents the actual organism with all its observable traits as they developed in response to not only the internal genotype but also the external environment.[34]

This duality is possible because, like a configurational diagram, the genotype is a topological design in that it only defines relationships and induces broad constraints without determining the final formal outcome which is instead allowed to dynamically emerge as a result of external forces acting upon it. A prominent example of this phenomenon is the colour of flamingoes, which, although universally perceived as pink, is actually not a genetic trait but a phenotype expression based on their diet. Similar dynamics are even more pronounced in plant morphology where trees of the same species are never precisely the same, meanwhile on a lower scale the leaves on a single

GENOTYPE VS PHENOTYPE

Genotype behaves as a generic internal instruction deformed by local external conditions to produce many possible phenotypes



FORMAL ADAPTIVITY

The simple topological genotype of the Chordata phylum has led to the evolution of diverse organisms including tigers, whales, falcons and humans.

Fig. Chordata - a diagrammatic structure.

tree, although following the same pattern, are never uniform but differ according to the age of the plant, their position, climatic conditions, and other influences. In more architectural terms, the configurational diagram is a medium enabling the interaction of **top-down** and **bottom-up** design. Even though the designer can define the desired configuration (and consequently how a building should function) in a top-down manner, the possibilities of its formal articulation remain undefined and infinite, only spontaneously **emerging** in interaction with conditions of the site and environment. Through the diagram, function can again become the core issue, albeit released from the restrictive dogmas of functionalism.

Such a theory of design combining topological (configurational) thinking with environmental responsiveness is put forward by philosopher **Manuel de Landa**, who, inspired by **Deleuze**, asserts that all space is morphogenetically pregnant and has the capacity to generate emergent form on its own. This morphogenetic process is based on local differences in concentrations of parameters in space (e.g. amount of sunlight), but can only take place when those differences are allowed to influence the organism during its growth, something not possible in traditional top-down compositional design approaches. It is here that the genotype/configurational diagram/topological graph plays a crucial role by defining a **topological solution space** which does not in any way limit formal arrangement; both the diagram and the emerging form are in a state of perpetual adaptation leading to the spontaneous emergence of new more responsive forms.[35] The specificity of each location combined with the adaptive nature of the diagram results in an explosion of formal diversity which could open the door for a new contextualism in architecture; an approach where similarity is not based on repetition of historical precedents or style, but on difference emerging from similar topological spatial configurations.[36]

Inevitably, applying a configurational diagram projectively leads to an exponential increase in **complexity**, which can present a substantial issue for the human designer limited by time and resources. While utilization of computation within the design process can overcome this issue, for this to be possible the diagram itself first needs to be **systematized**. Fortunately, due to the nature of diagrams as logical constructs, they lend themselves well to systematization, especially within a configurational context. This can be achieved by the appropriation of mathematical **adjacency graphs**; structures whose sole function is the mapping of topological information, usually visually represented as **nodes** connected by **links**.[19] Furthermore, they can be transformed into **Spatial networks** defined as expanded graphs in which the nodes or links are associated with spatial elements and can contain additional information enabling the layering of additional data into the structure of the graph itself, like architectural requirements of sunlight or privacy. The outcome is a configurational **dataset** of spaces, their interconnections and properties visualised by the graph diagram - a Spatial network - capable of efficiently mediating between human and machine in the design process whilst also acting as the main **design driver**.

Empowered by its role in configurational design the diagram is transformed from being descriptive and analytical to becoming a projective tool; simultaneously the medium through which a designer operates, a dataset of the configuration being created, as well as the actual design itself. In this way, as **Somol** notes, the diagram essentially becomes ***"the matter of architecture itself"*** displacing the drawing as the defining trait of architecture.[37]

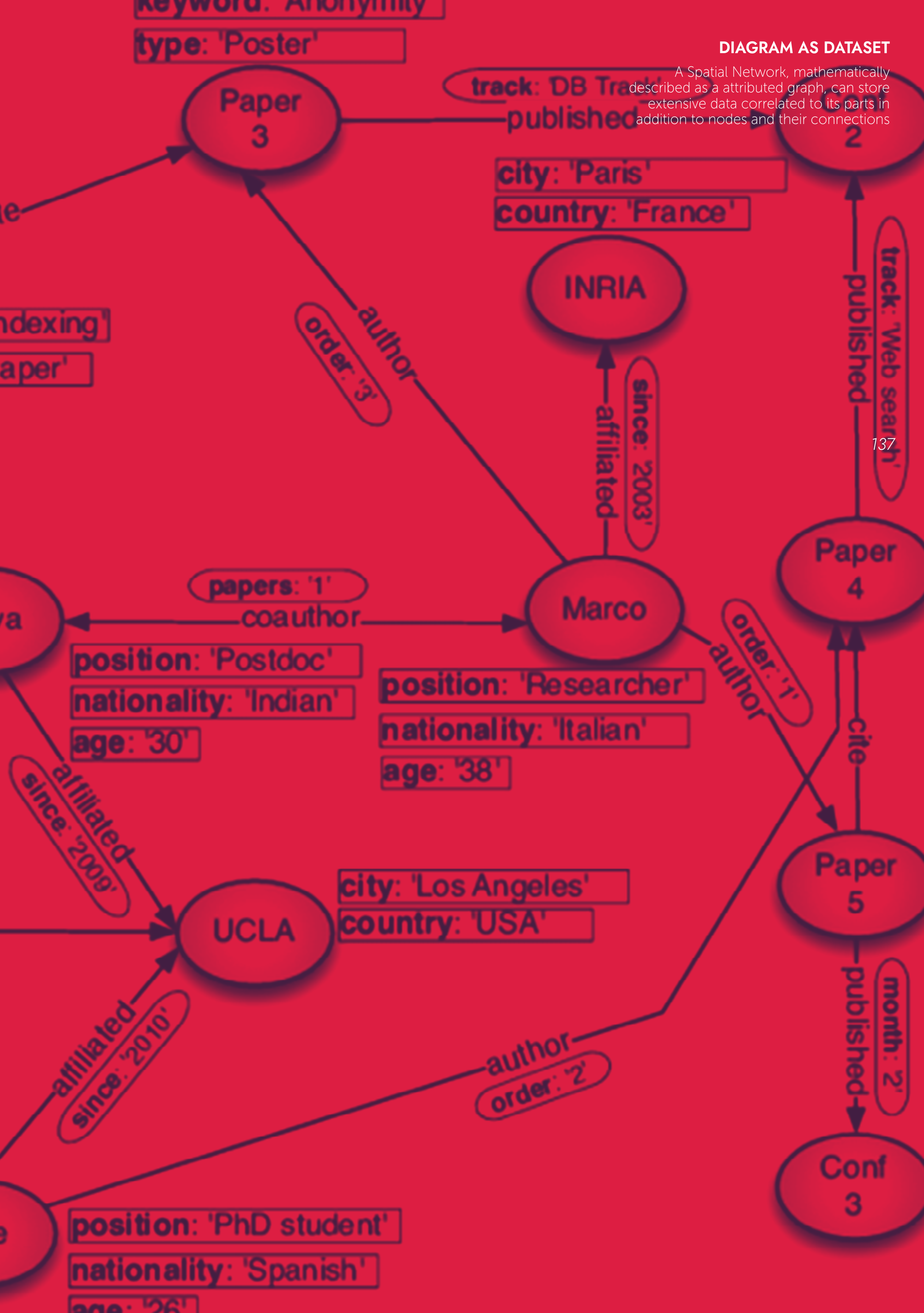


DIAGRAM AS DATASET

A Spatial Network, mathematically described as a attributed graph, can store extensive data correlated to its parts in addition to nodes and their connections

8

How can spatial networks mediate between humans and machines?

DIAGRAM AS MEDIUM

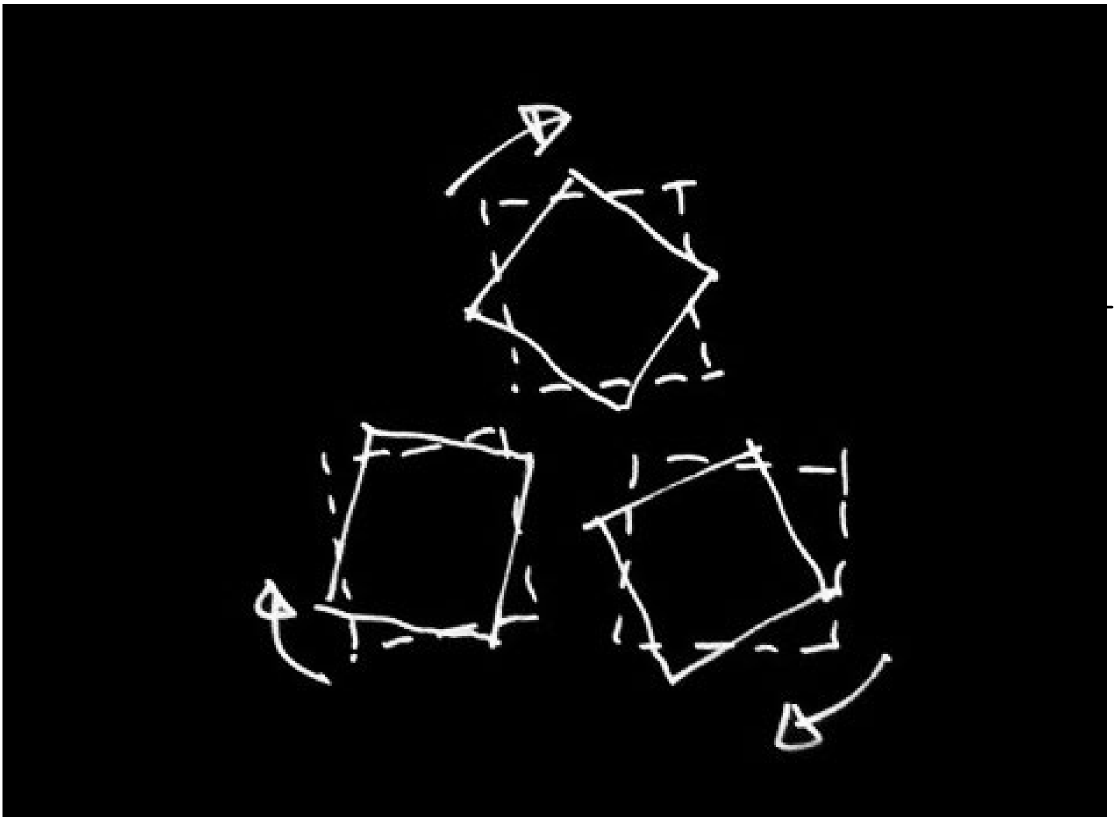
A digital configurational design interface

For the **spatial network diagram** to become an efficient and practical medium for configurational design it must behave as a natural extension of the designer, streamlining the creative process while providing as less resistance as possible in its use. Additionally, they must be elevated from diagrammatic drawings to become **digital datasets**, not only to expand their use beyond topological mapping via the inclusion of data but also to make their mediation of human-machine interactions possible.

Based on the first-hand experience gained working with spatial networks some key areas of concern have emerged regarding their practical utility as a projective tool. From the perspective of the human designer, the biggest issues relate to **comprehensibility** on one hand and the act of **drawing** on the other. No matter the level of complexity and size of the spatial network on which a designer is operating, the diagram should remain clear, legible and comprehensible at all times to ensure effective design intervention is possible. In parallel, the drawing process should not in any way distract, or worse limit, the designer, especially with issues of network layout, a problem proving to be especially pertinent with larger diagrams.

Conversely, from the perspective of machine vision, an opposing set of requirements emerges. First, the need for **continuity** of information requires that all properties of a configuration must be contained within it at all times, which actively works against simplification required for human comprehension. Second, all elements and possible operations within the drawing process need to be **explicitly defined** to exclude ambiguity and enable the fluid conversion of configurational information to digital form.

Starting from the identified issues and contradictions, as well as the elementary requirement for the transformation of the diagram into a digital data structure, the potential of a **digital design interface** was explored. After examining rich precedents in the field of **visual programming languages**, many of which increasingly popular and successful in mediating between machines and humans, it became clear that digitalisation of the drawing process within a custom structured interface could merge the intuitive visual benefits and abstraction of the diagram with the high capacity for complexity of digital datasets.[30] Furthermore, due to the underlying graph structure of spatial networks, numerous computational methods could be applied to further streamline the drawing process such as dynamic auto-layouts with the help of **force-directed graph** algorithms or the implementation of collapsible multi-level graphs functioning as a selective simplification mechanism controlled by the designer. The proposed CAD-like visual interface illustrates how a design process based configurational thinking could efficiently unfold inside a software optimized towards the use of complex multi-level spatial network diagrams, simultaneously acting as datasets capable of being utilised as design drivers in digital generative algorithms.

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0000050 00e9 6a69 0069 a8a9 00a9 2828 0028 fdfc
0000060 00fc 1819 0019 9898 0098 d9d8 00d8 5857
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0000090 3b83 5788 8888 8888 7667 778e 8828 8888
00000a0 d61f 7abd 8818 8888 467c 585f 8814 8188
00000b0 8b06 e8f7 88aa 8388 8b3b 88f3 88bd e988
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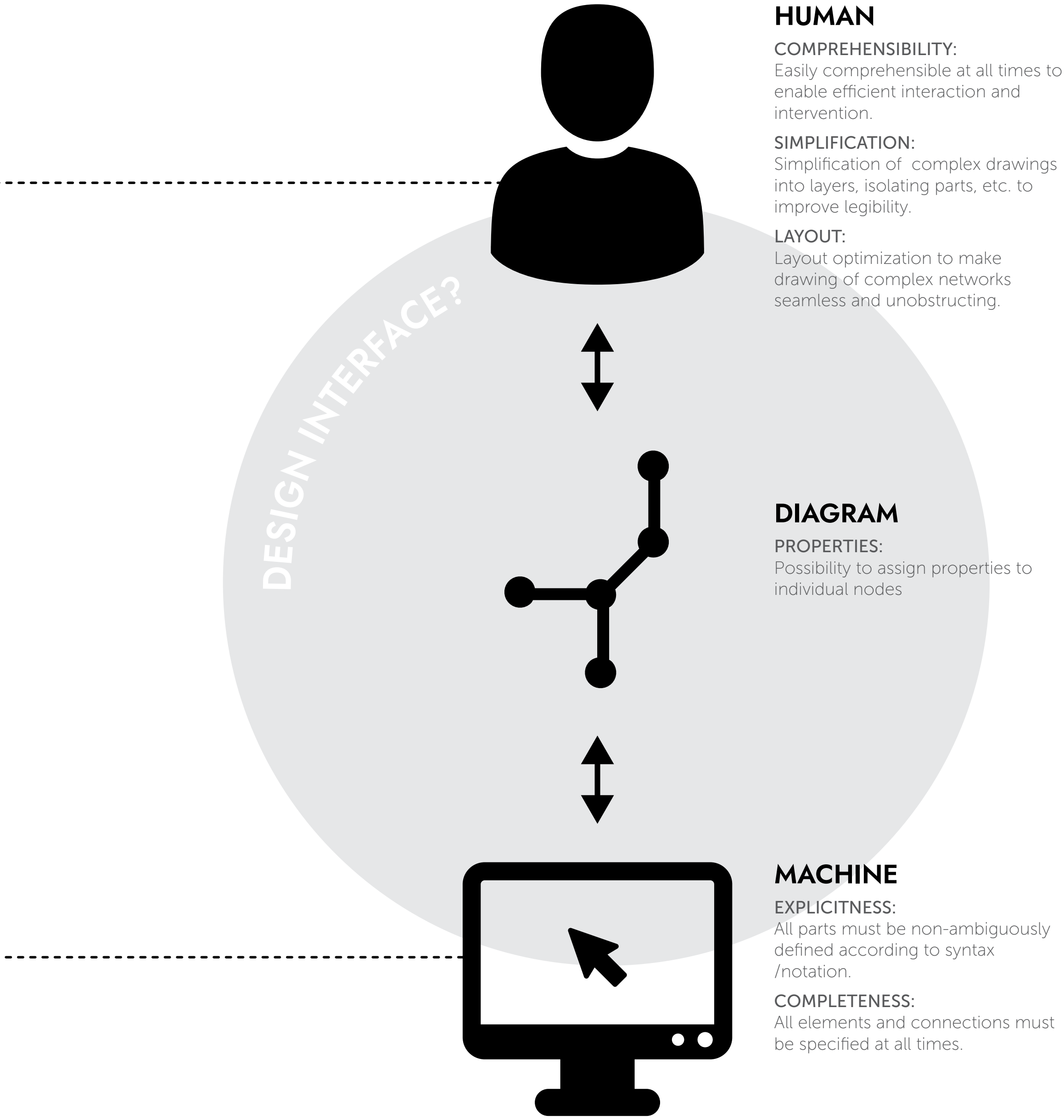
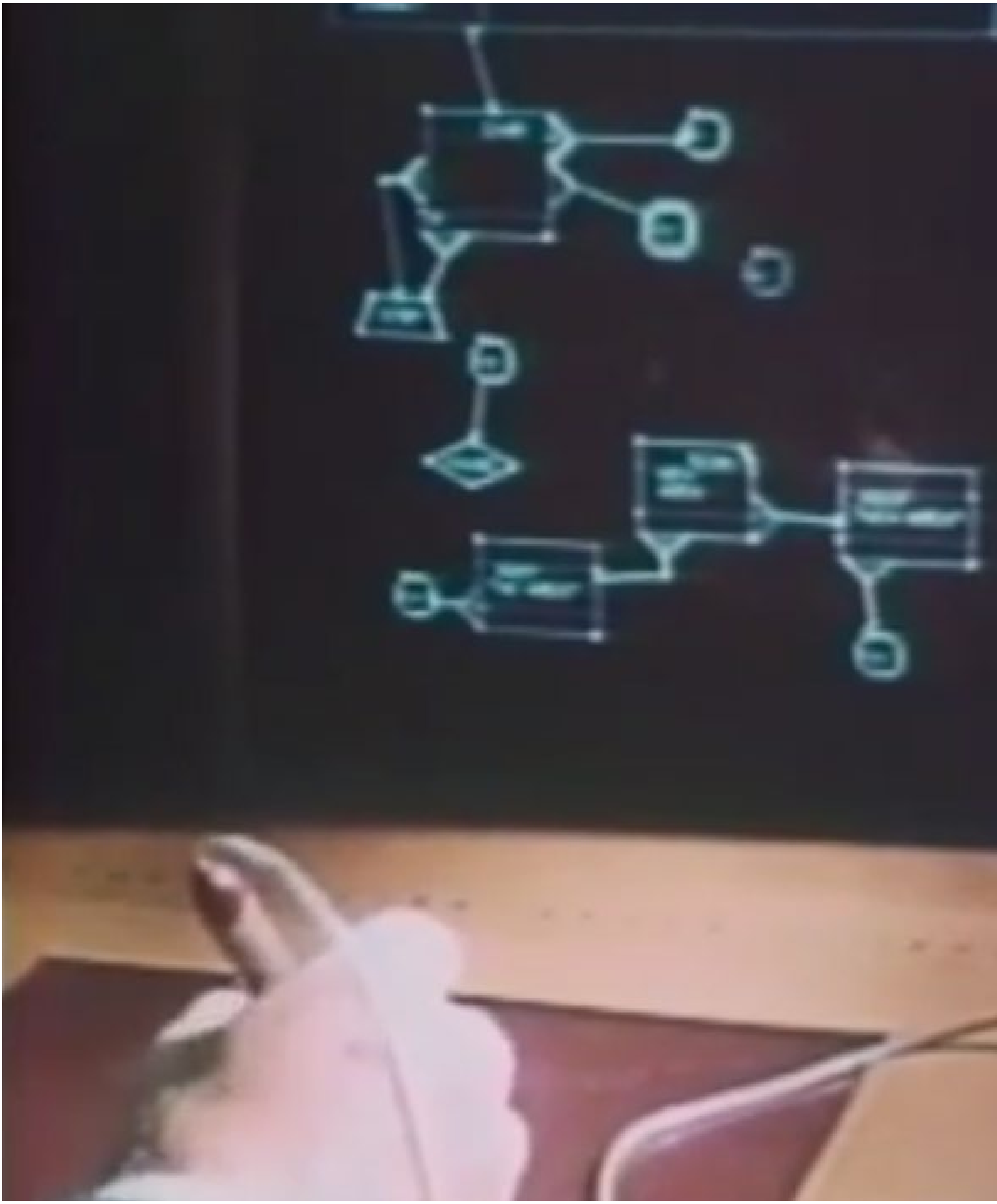
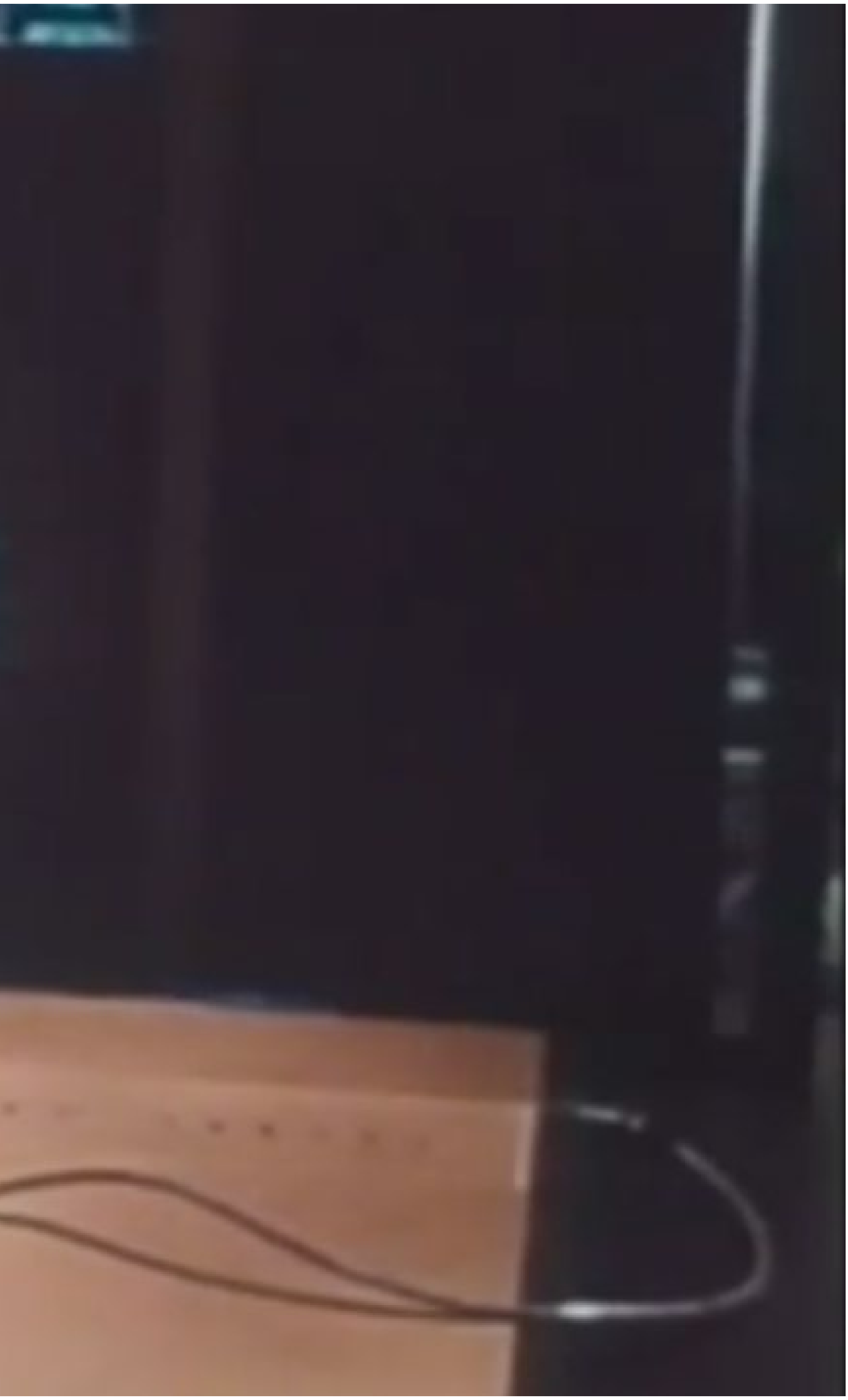


HUMAN-MACHINE INTERACTION represents a key area in the configurational design process due to its potential to digitize spatial networks and transform them from descriptive elements to design drivers in digital generative algorithms. To make this possible, there needs to exist a configurational design interface capable of seamlessly bridging the gap between the unstructured, improvisational and sometimes chaotic human design thinking and the extreme systematism required by machines, while requiring as less compromises as possible often limiting to creative thought.

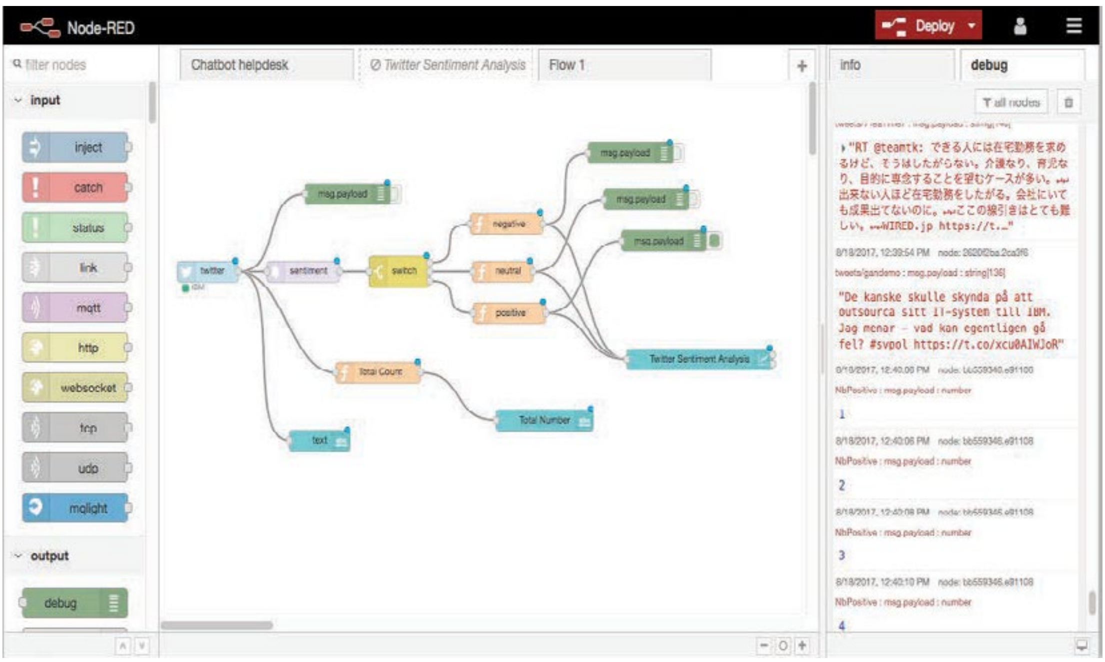


GralL (Graphical Input Language) - the first icon based programming language; 1968 [32]

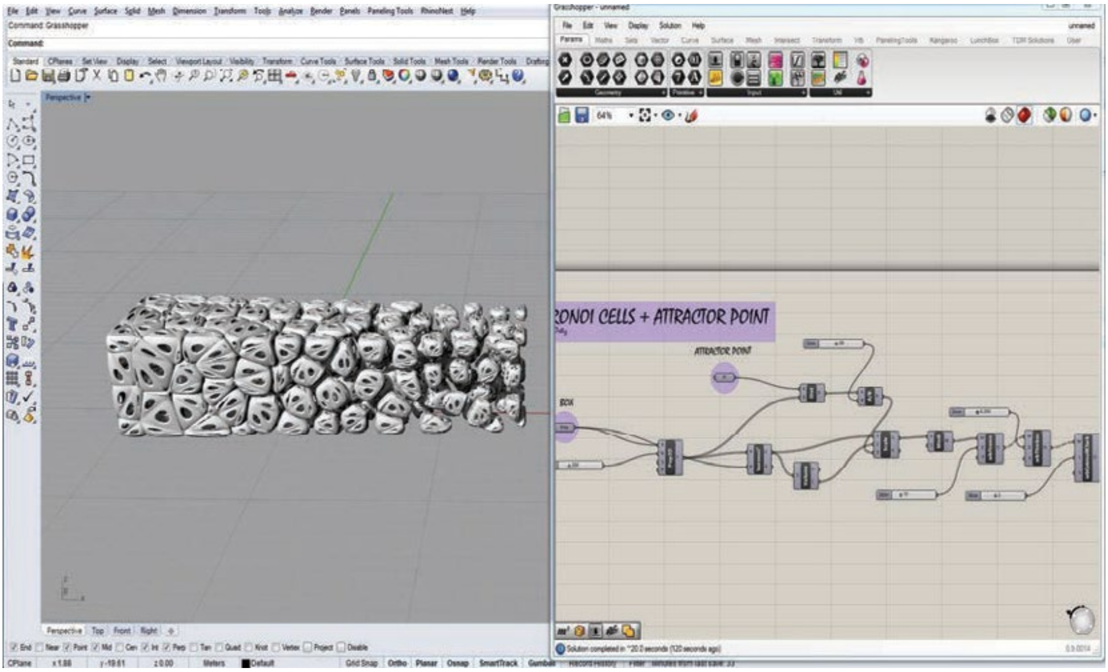


VISUAL PROGRAMMING languages allow the user to specify a computer program in a two-(or more)-dimensionsional way as opposed to conventional textual languages. VPLs usually operate on the basis of programming functions represented by graphical symbols or elements which can be connected in various ways to create functional programmes.[30] Essentially, VPLs provide a structured interface between a human user and the machine which makes the programming process more legible and easier to comprehend on the user side, while simultaneously maintaining the textual functions (machine code) complete at all times allowing the software to execute and function without the user requiring any knowledge about this. VPLs have increased in popularity within architecture in recent years namely with the popularization od Dynamo for Revit and Grasshopper for Rhino 3d. These software plugins allow for users not familiar with textual programming to reap the benefits of improved functionality and software customization which enables more efficient workflows as well as design approaches previously not feasible.

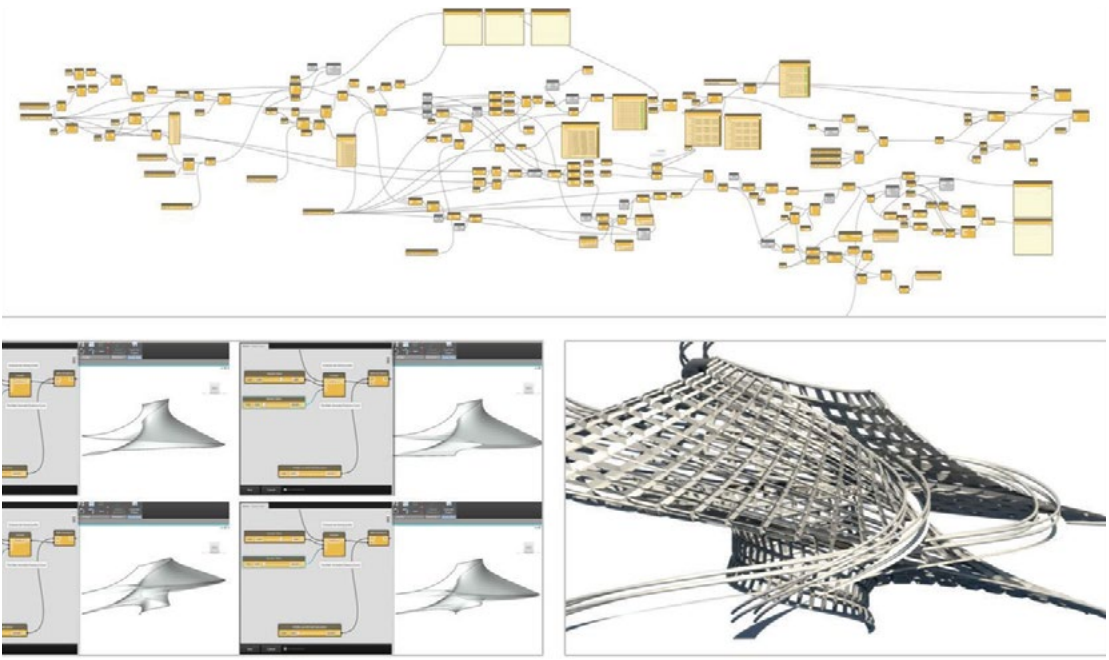
Appacitive, online data explorer for graph-based dataset viewing and editing.[31]

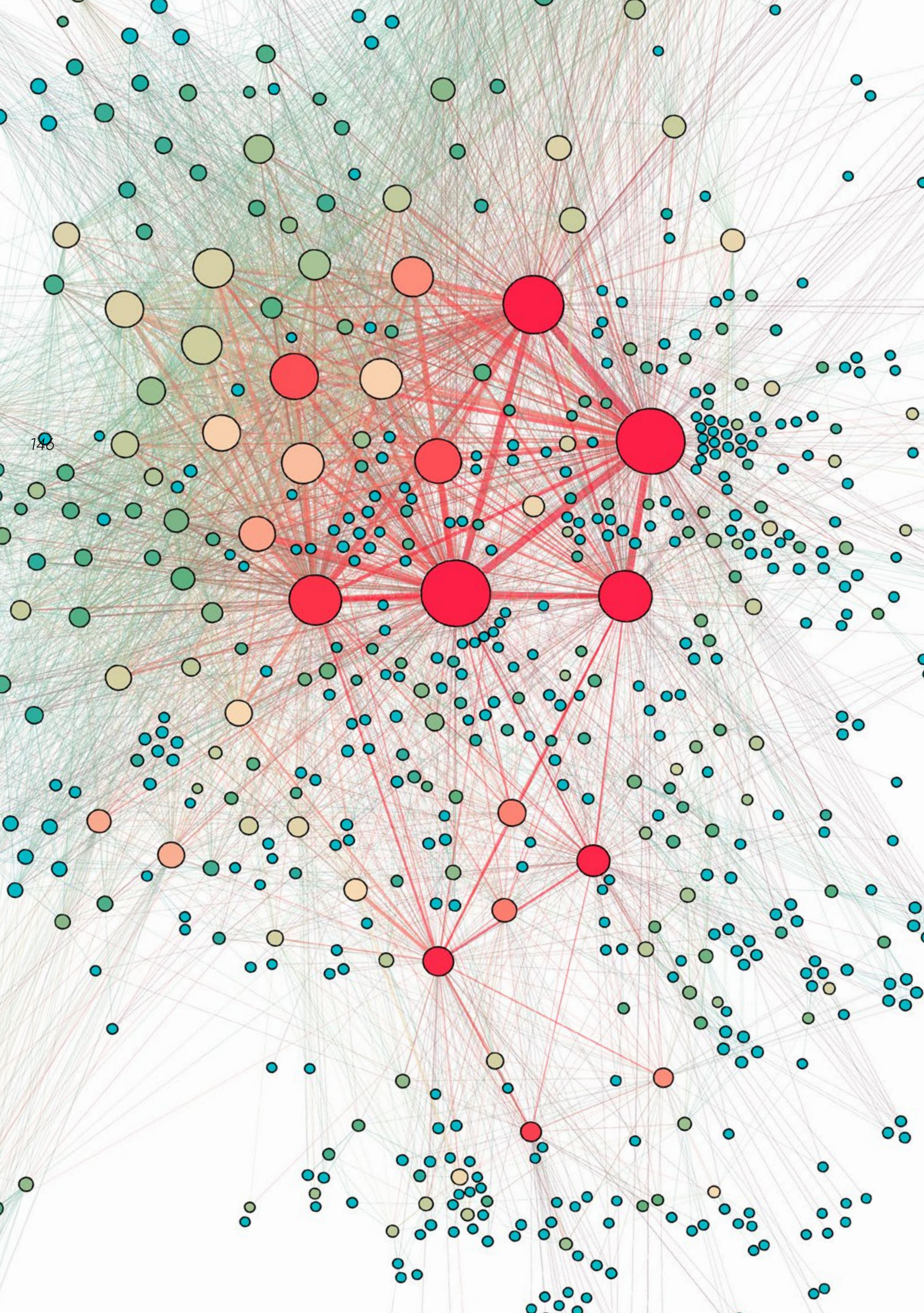


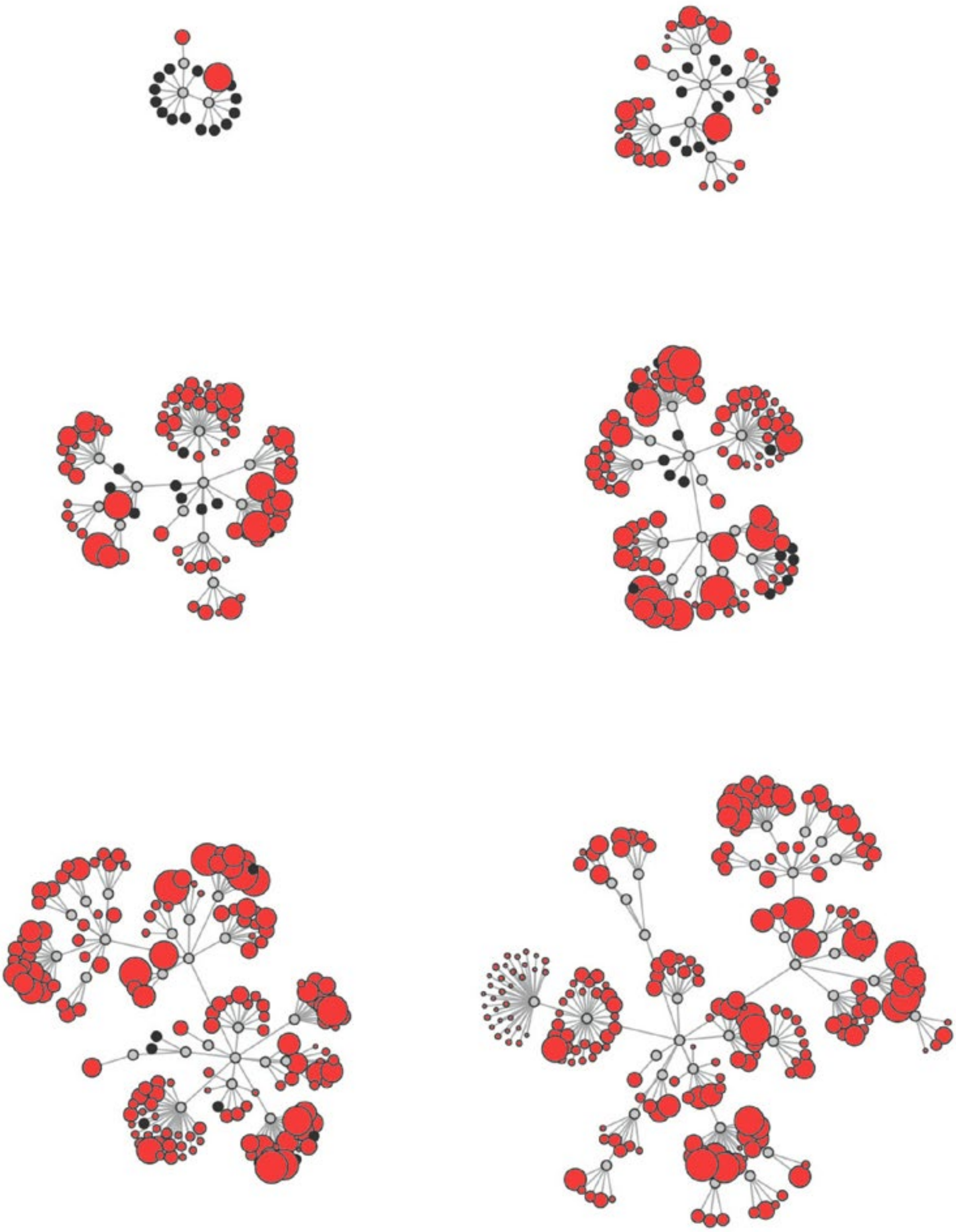
Node-RED, a Javascript visual programming tool for online applications. [32]



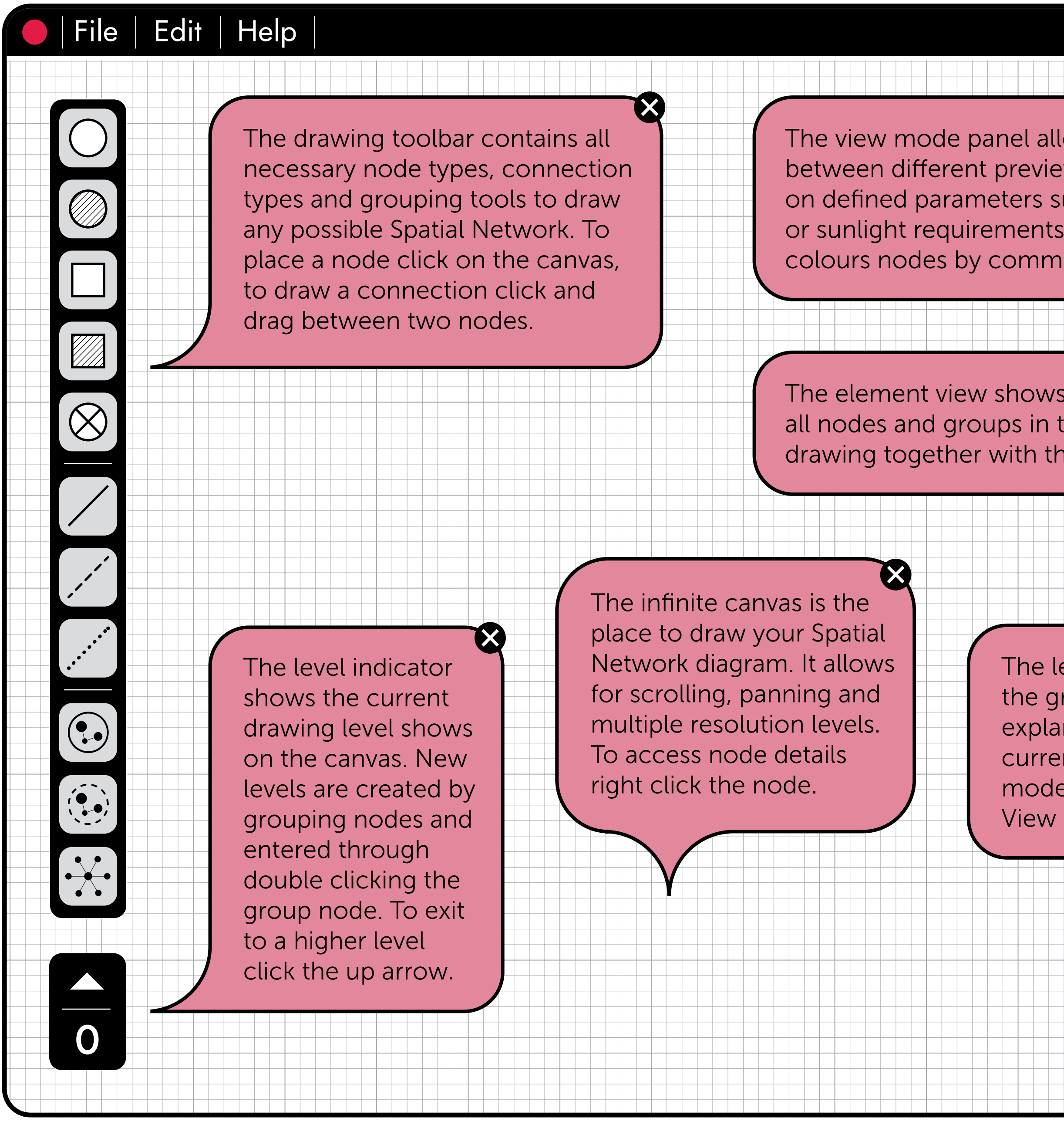
Grasshopper, parametric modelling for Rhinoceros 3d.[32]


Dynamo, parametric modelling for Revit.[32]

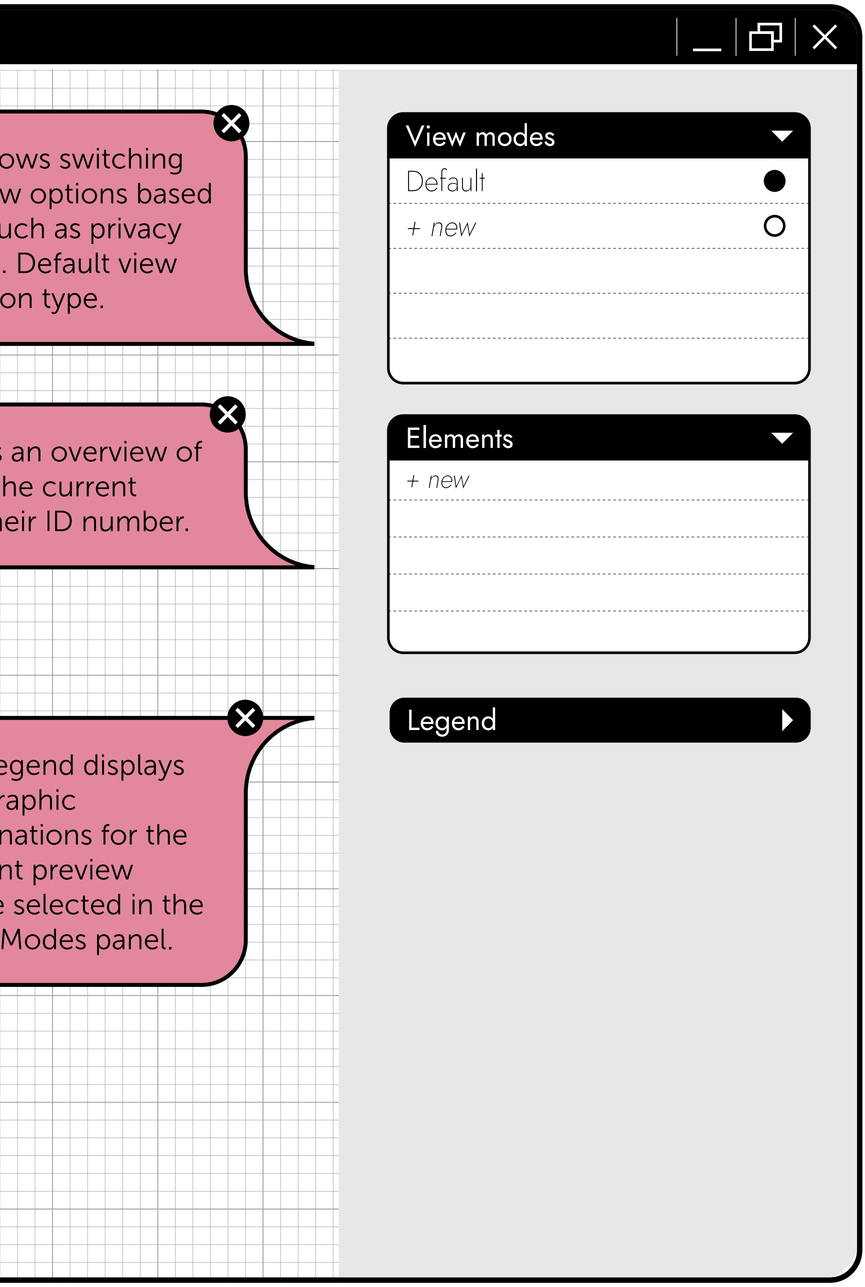




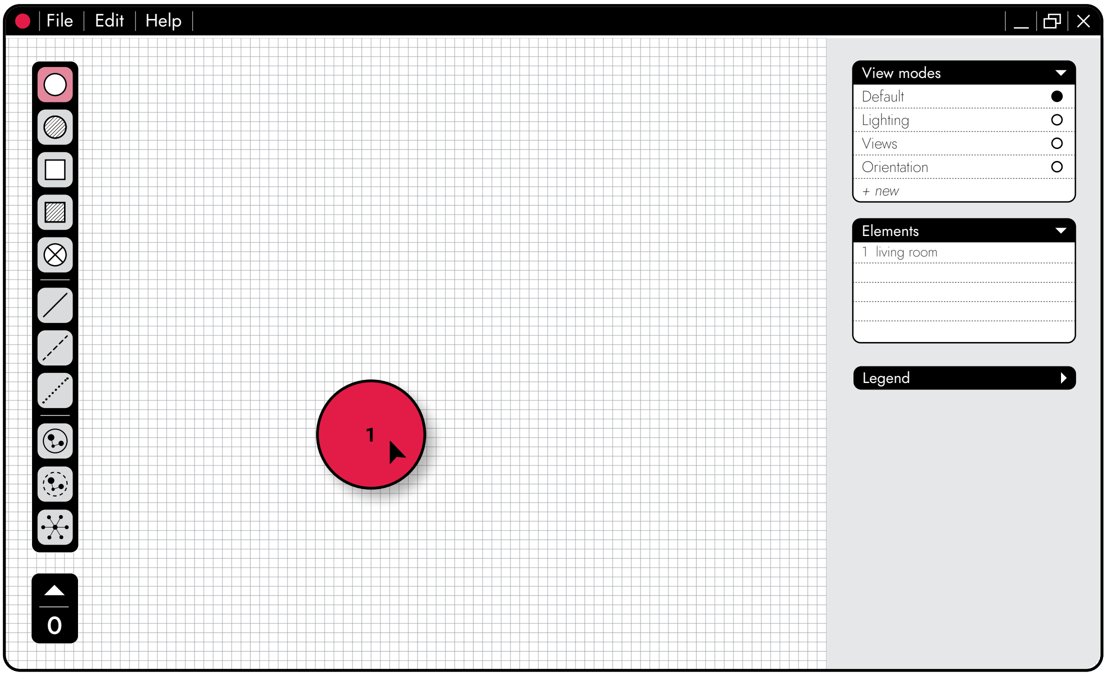
FORCE - DIRECTED GRAPH algorithms are a class of computer algorithms used for drawing graphs so as to improve aesthetics, clarity and legibility and are extensively used in data analysis and visualisation. [33] They allow for real-time dynamic layouts of hyper complex multi-level graphs which lends itself well to the visualisation of complex Spatial networks one could find in our built environment. Additionally, the capability of collapsing multiple nodes into a single parent node greatly enhances the control of complexity enabling the designer to display varying levels of detail depending on the task at hand.



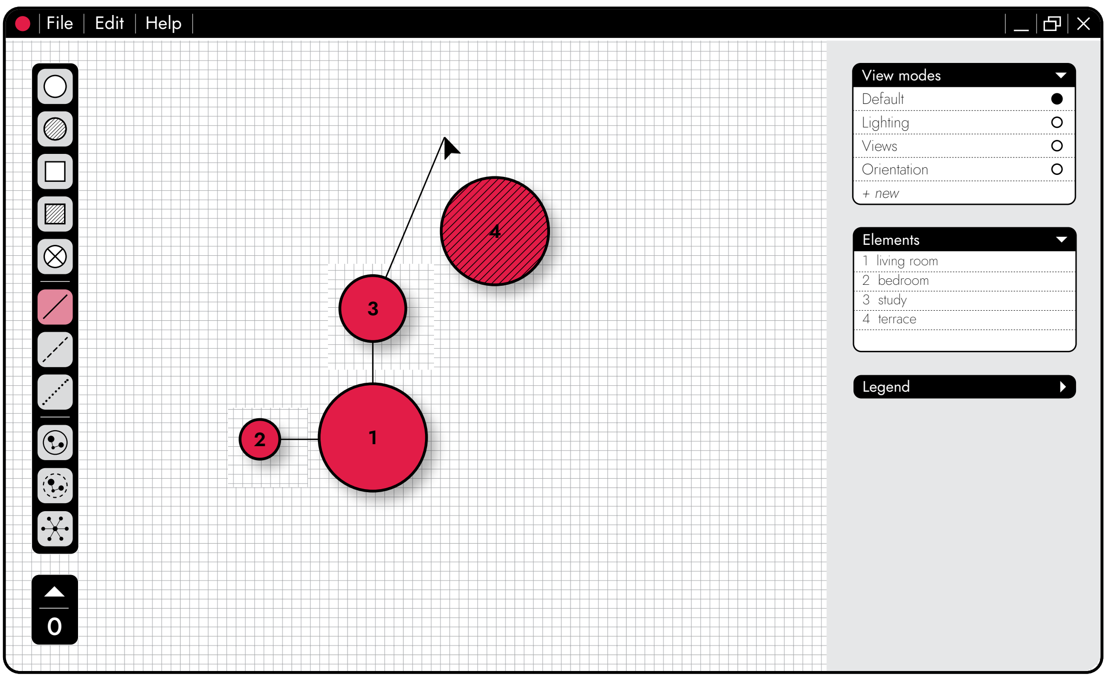
Configurational Designer© main interface window in tutorial mode



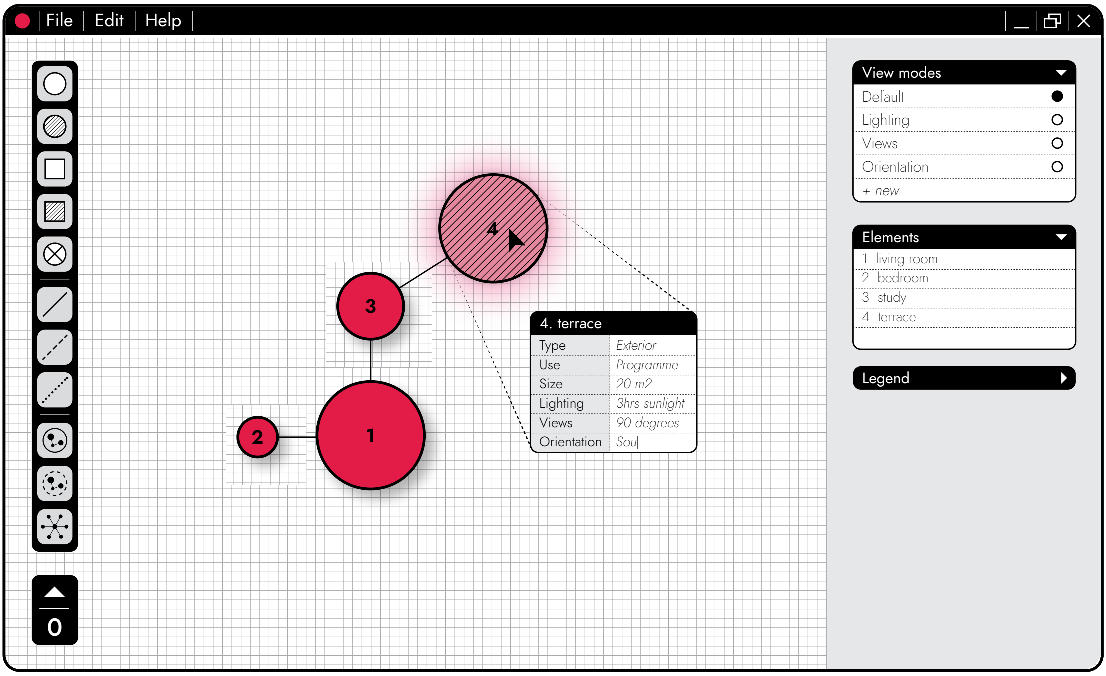
A VISUAL INTERFACE is proposed as a speculative attempt at a digital software tool aimed specifically at configurational design. The aptly named Configuration-alDesigner uses principles of Visual Programming Languages combined with graph drawing algorithms to provide a CAD-like interface which could ensure compre-hensibility, clarity and possi-bility for simplification for the human designer, streamlining the drawing process of the Spatial network itself as well as its layout and enabling the assigning of properties to nodes, all while maintaining a complete dataset at all scales at all times, while also ensur-ing precision and forcing the user to be extremely specific in his/her definition of spaces and their interconnections. While this is a sketch repre-sentation, such an interface could potentially be directly connected to a generative algorithm and a 3d visual-iation software enabling great speed and efficiency in the configurational design process.



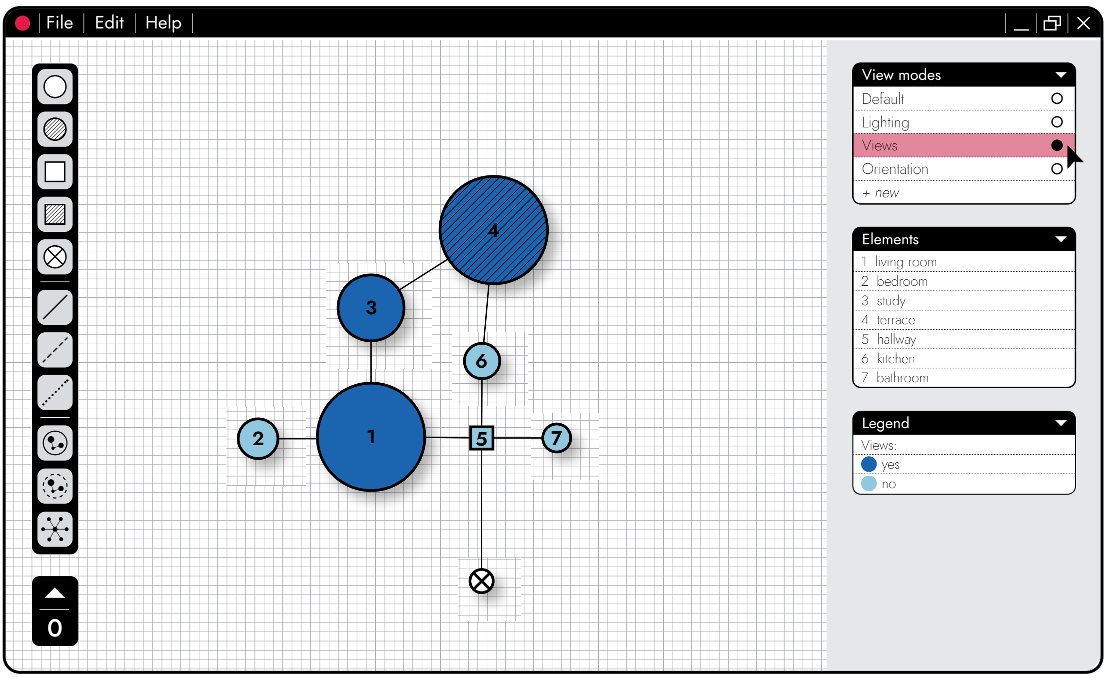
Dropping nodes representing spaces with the click of a mouse



Connections between nodes automatically snap into place

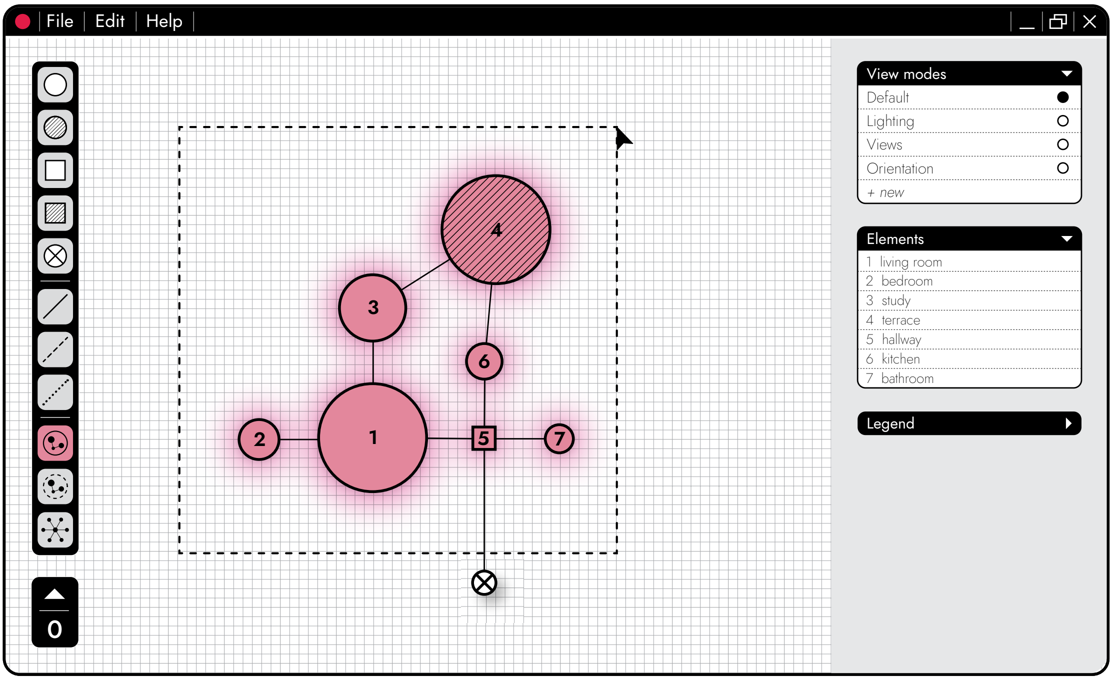


Each node can have a number of user-defined spatial requirements assigned

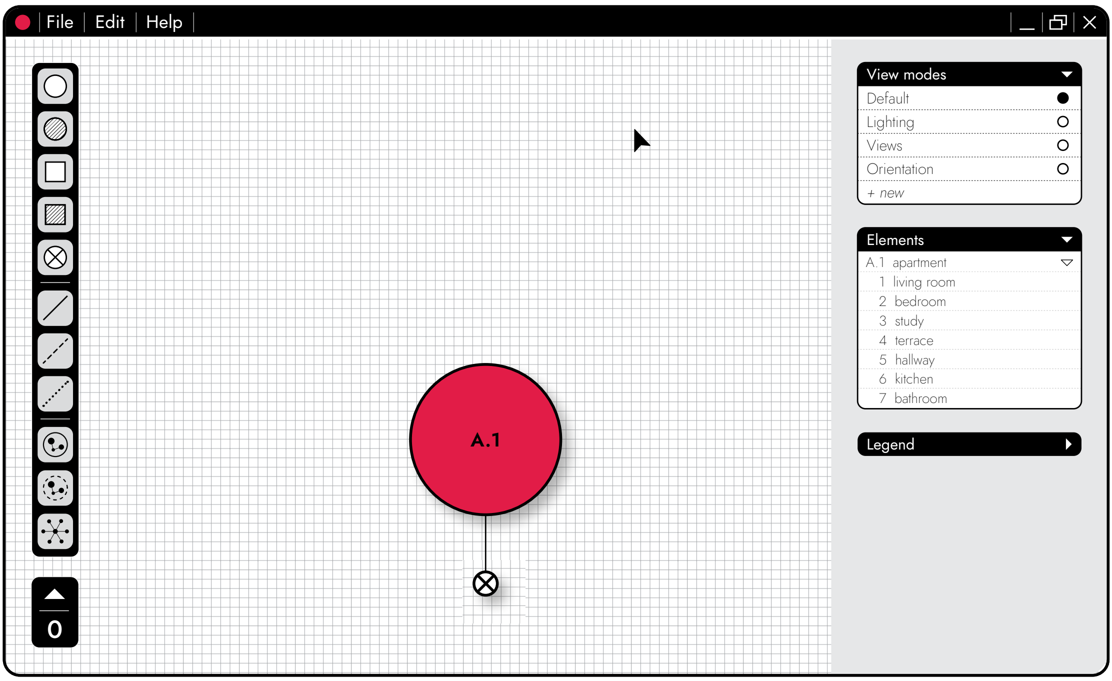


Efficient preview toggling diplaying node colours by parameter values

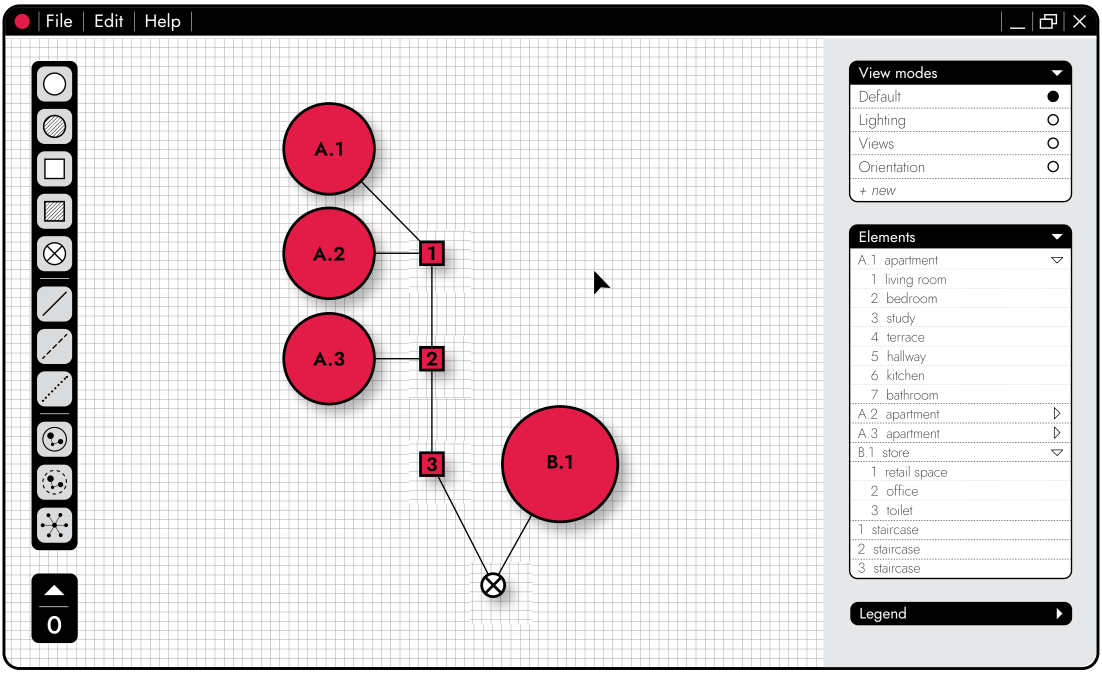
152



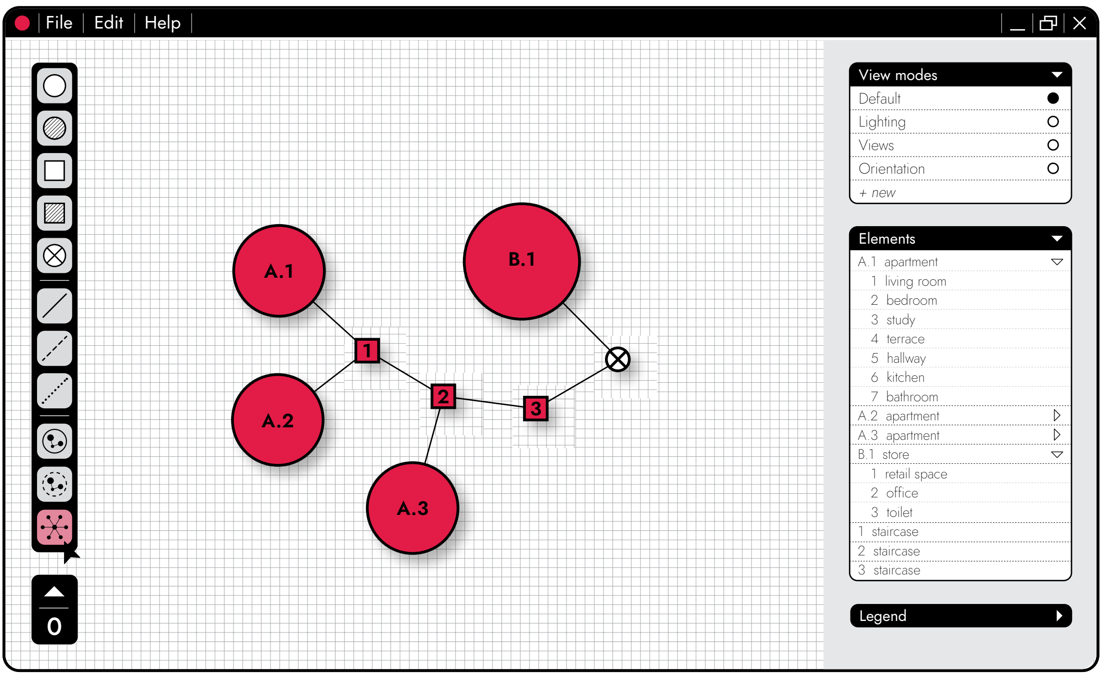
Grouping of multiple different nodes into one parent node on a higher configurational level



A parent node containing many subspaces on a lower configurational level

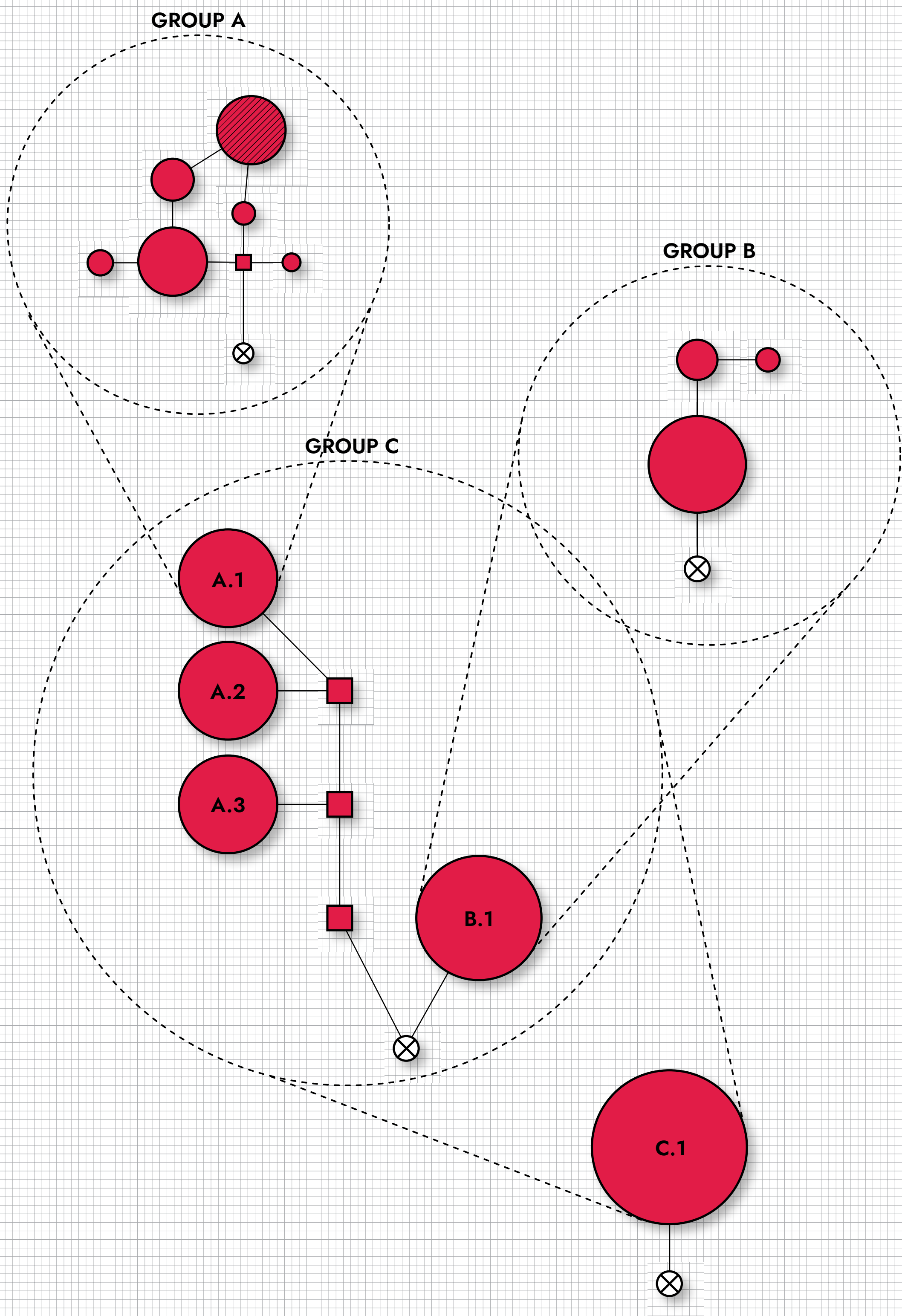


Copying parent nodes for efficient workflow, each copy editable and with unique ID.



Automatic force-directed graph drawing function distributes nodes by proximity

HUMAN VISION

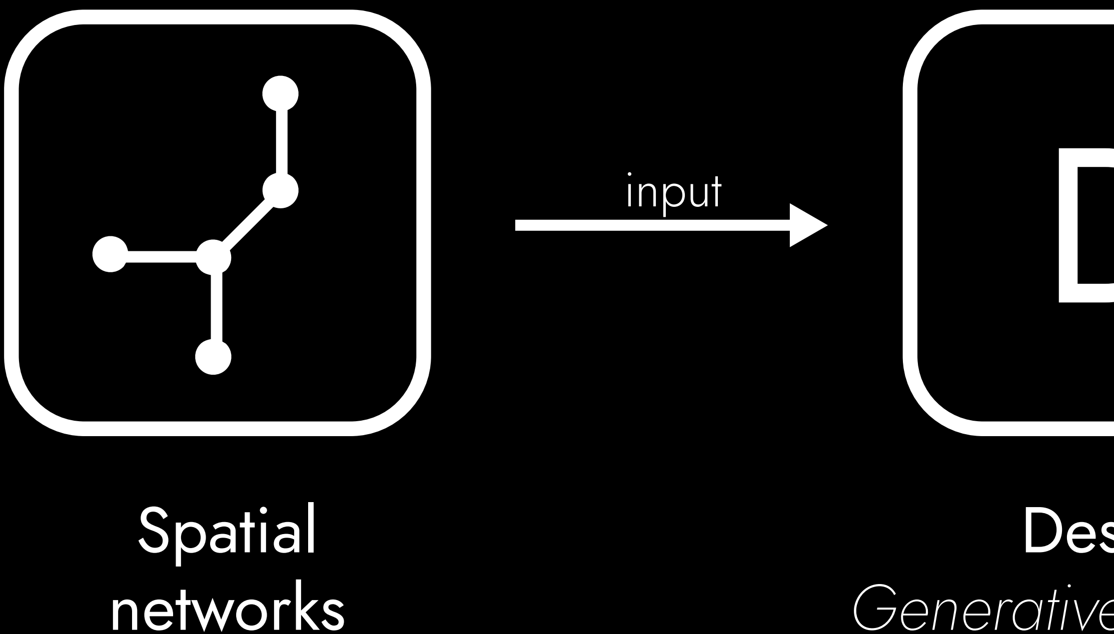


COMPUTER VISION

A DATASET is the final output resulting from the implementation of the design interface. As a user draws nodes, makes connections and defines parameters, he is in parallel creating a database which a computer is capable of reading and using as a design input. This transformation makes the Spatial network more than a representational drawing; it becomes an operational diagram mediating between human and machine.

D E S

I G N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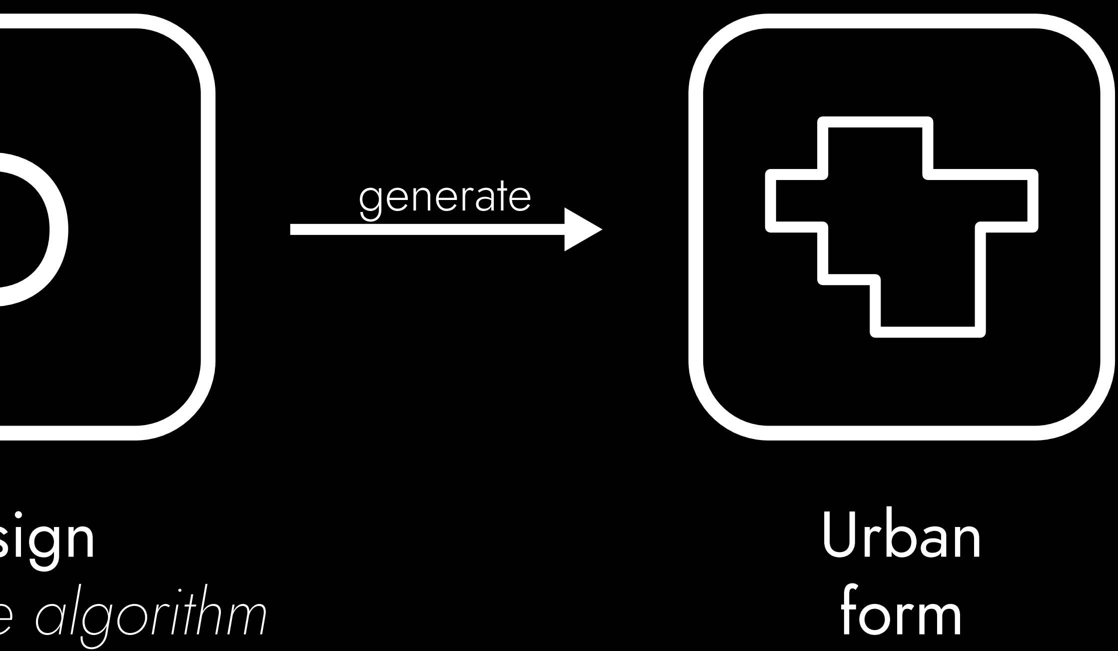

generate
sign
e algorithm
Urban
form

9

How can spatial networks interact with and adapt to the environment?

SPATIAL NETWORK & ENVIRONMENT

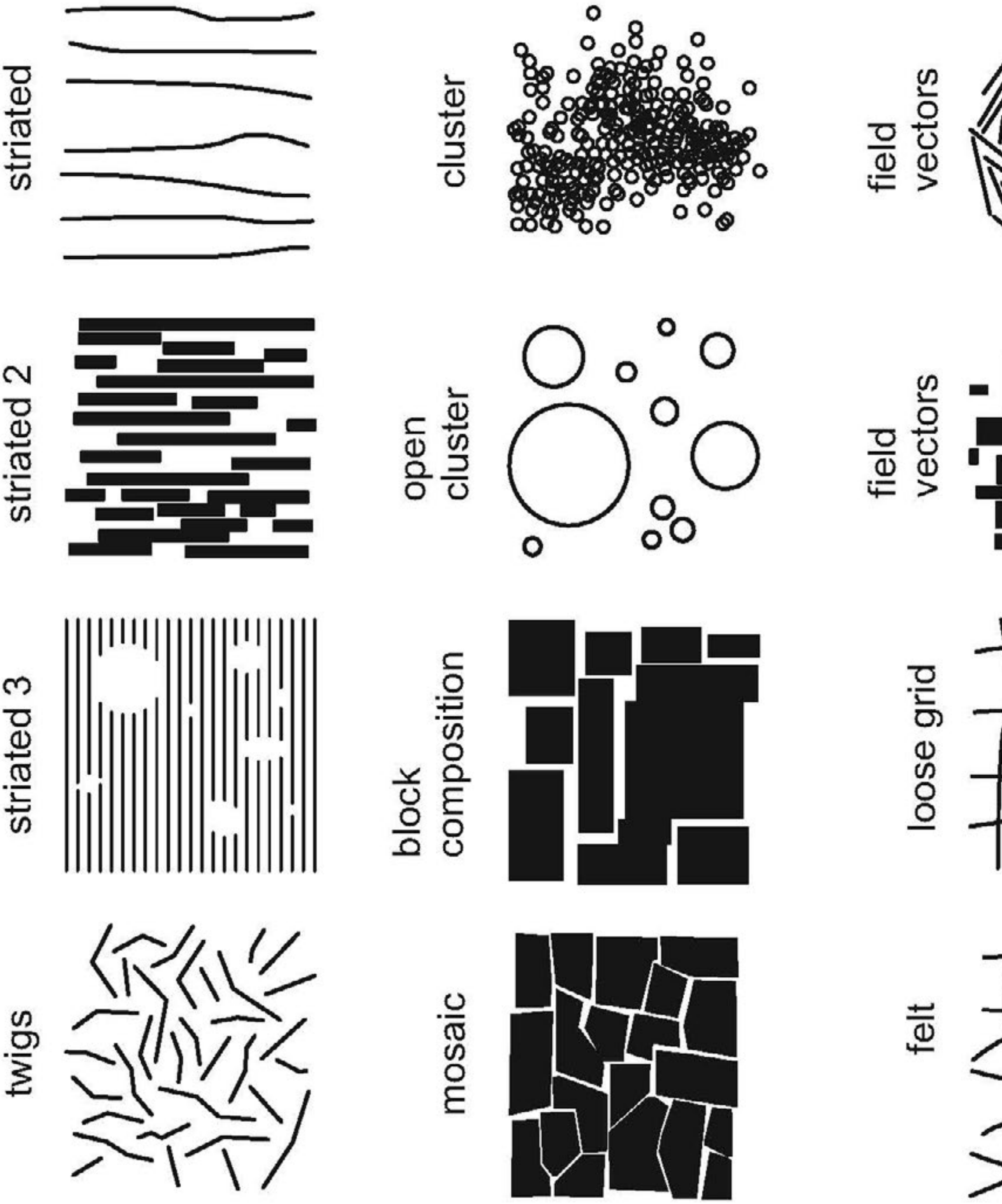
Systematizing the environment to enable interaction

Adaptive capabilities are inherent within the spatial network diagram as a result of its topological nature. Despite this, for **adaptation** to be possible an **interface** needs to exist between the diagram containing configurational information and the environment in which it is placed. The possibility of conceptualising such an interface was explored by combining approaches from the areas of applied mathematics, physics and architecture to finally arrive at the construct of an **Environmental Field**, a systematised and abstracted representation of the environment.

Due to the mathematical nature of topological graphs that underpin Spatial networks, it is only logical to look towards applied mathematics and physics for methods capable of mapping and evaluating space in a similarly systematic way. Compatible methods, in fact, do exist under the definition of **scalar** (or vector) **fields**.[31] A scalar field associates a numerical (scalar) value with every point in space effectively creating a 3d graph mapping the varying intensity of a measured parameter in different locations thereby offering an elegant way of analysing the environment. The issue with the real world and the space constituting it is the fact it is continuous and infinite, creating difficulties for measuring and quantifying it. To overcome this, the mathematical process of **discretization** is appropriated, which transforms previously continuous space by splitting it into a finite number of discrete segments suitable for efficient numerical evaluation and viable for practical application.[32] Applied to a location, this approach transforms the previously inert 2d plot of land into a 3d array of discrete voxels/cells, each of which defines a specific segment of space, meanwhile its size corresponds to the desired resolution. Each cell can be further abstracted into the point at its geometric centre which is finally used as the location at which the environmental conditions of this segment are measured. Combined, the cells generate a three-dimensional array of points spanning the entire envelope - a global **field** - as a result enabling the measurement and quantification of the environment.

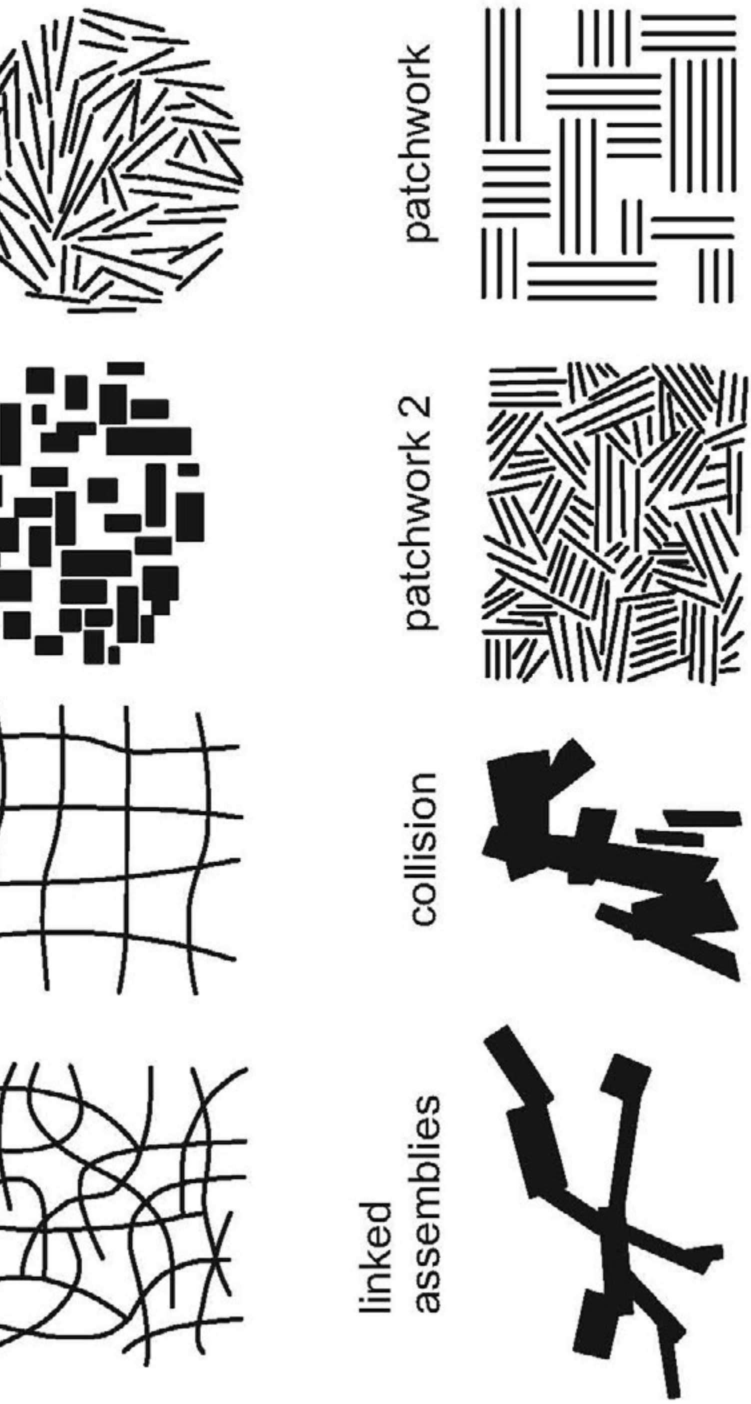
This evaluation of the environment can be performed with a range of possible **parameters** such as sunlight, view and visual privacy among others, depending on the requirements of the Spatial network and the spaces constituting it. The outcome is a multiplicity of fields, one for each parameter, which can be further combined through the use of **weighting factors** responding to hierarchies of importance between different parameters which can, in turn, respond to varying requirements of different spaces.

Admittedly, this kind of method for quantifying the environment is only as efficient as the methods used to evaluate individual parameters. Consequently, while objective influences like wind and sun are easily measured, difficulties remain with quantification of subjective qualities such as the perception of space and ambience. Nevertheless, research into quantifying aforesaid parameters is ongoing[33] and when viable methods emerge they should be compatible with the environmental field as conceptualised here.

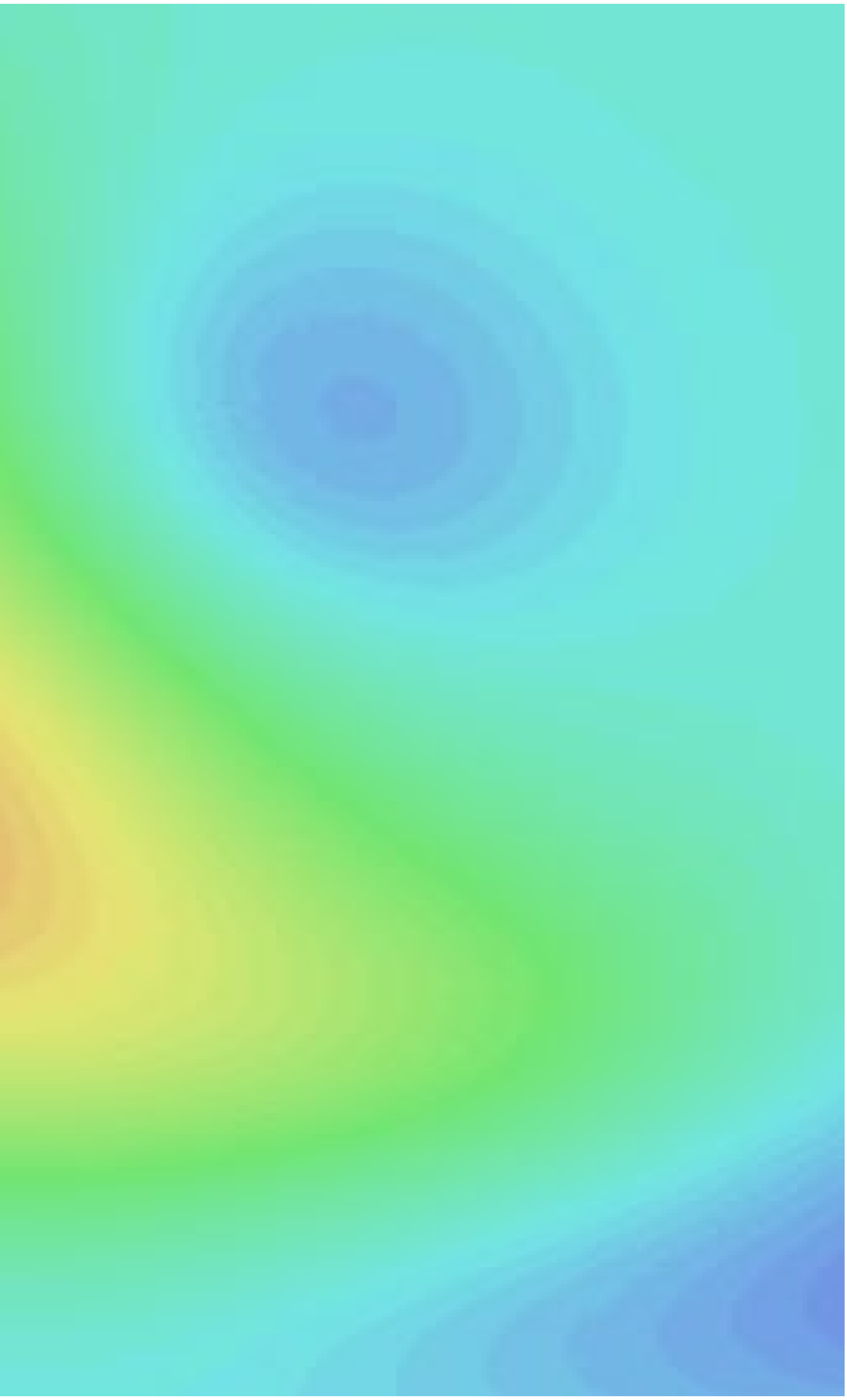


Diagrams of field conditions; Stan Allen [47]

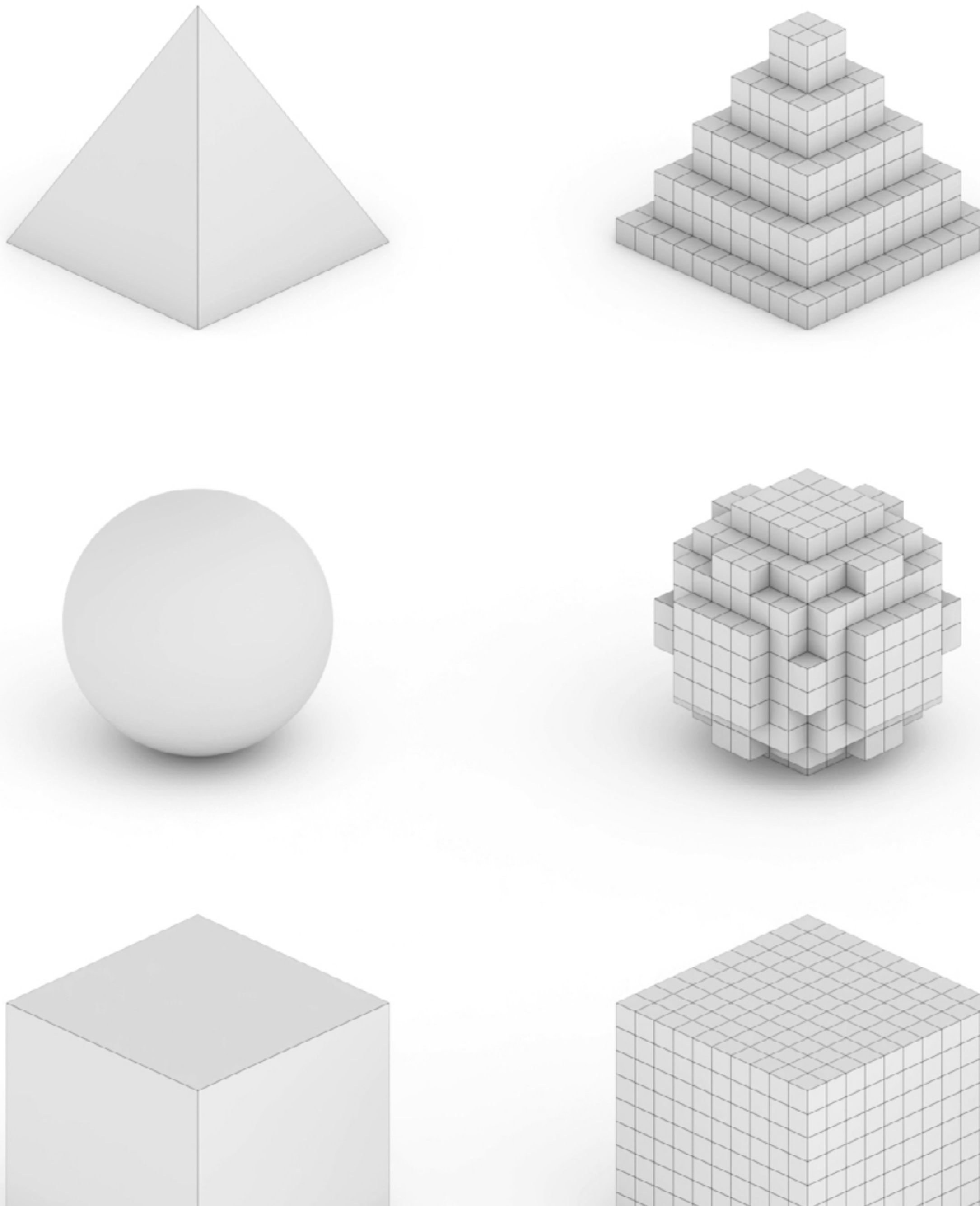
FIELD CONDITIONS were first described in an architectural context by Stan Allen in 1997 as a process-based design approach capable of unifying a multiplicity of complex influences to drive responsive and specific solutions.[47] In this way, the field can be an excellent medium to both record the complex environment to which architecture must respond as well as communicate it to the designer or possibly even a digital generative algorithm. Fundamentally, the field embraces complexity; no longer is the environment reduced to simplified diagrams of sun direction or view quality but the environment as a whole can be comprehensively recorded in all of its detail, crucial for generating truly responsive and adaptive urban form.



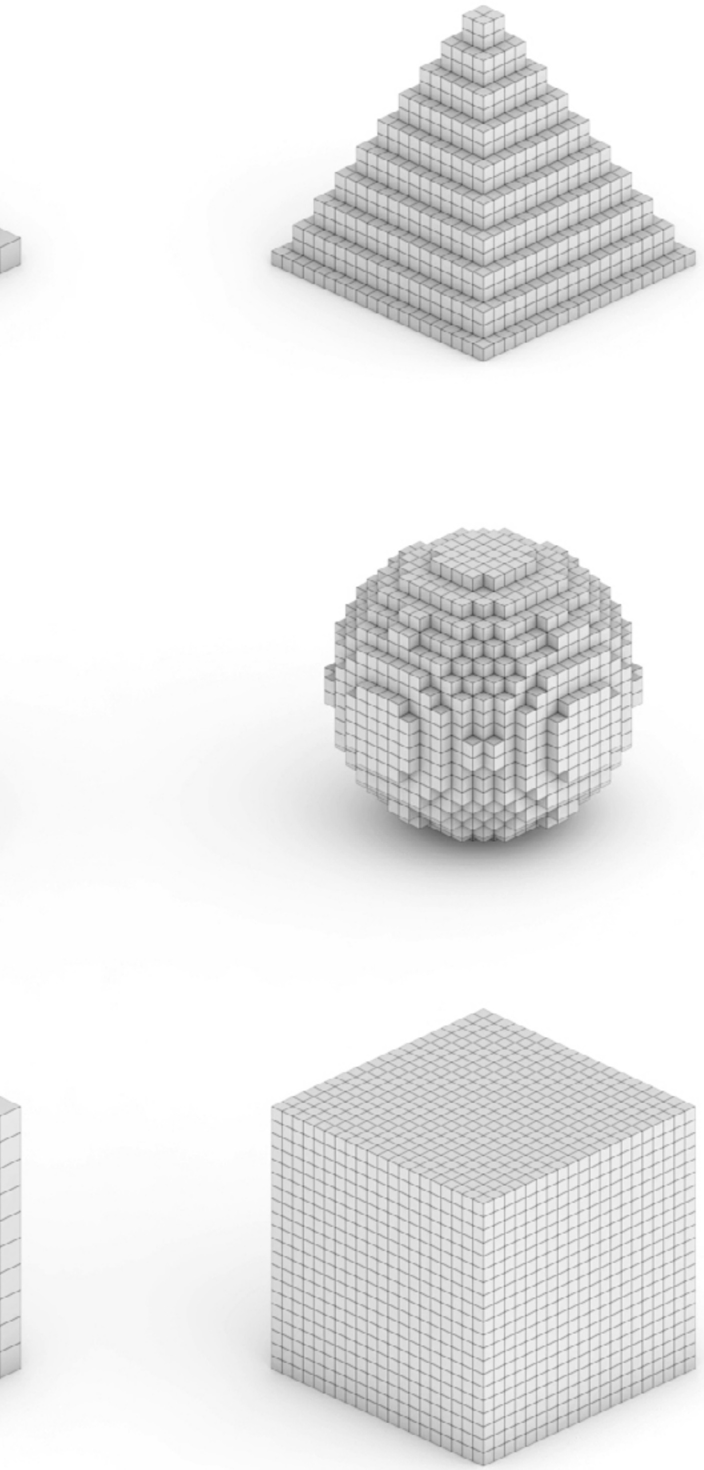
Visual representation of a 2d scalar field displaying
varying intensities of the measured variable.



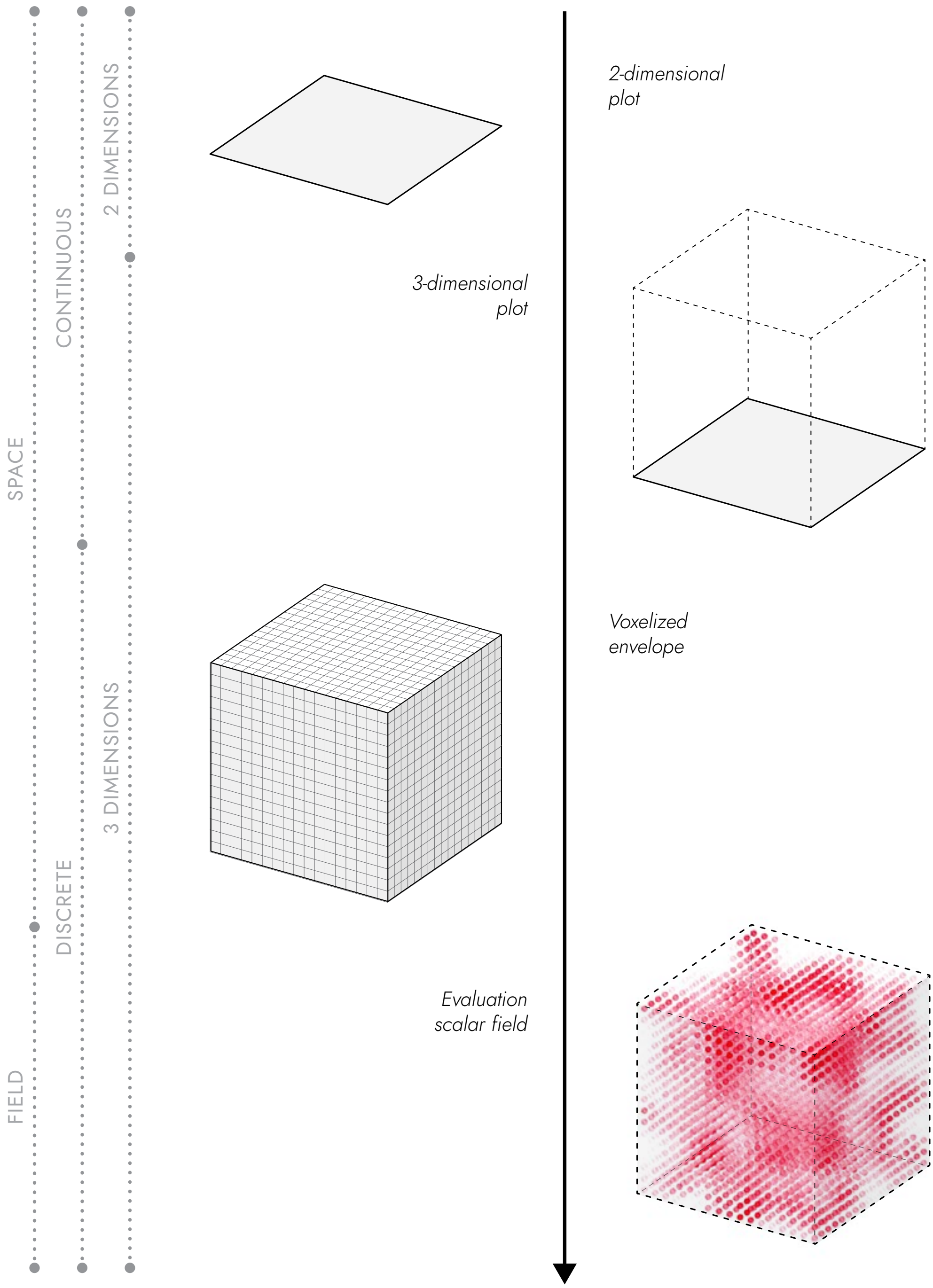
SCALAR FIELDS is a method for recording the variation of a quantitiy through a 2d ofr 3d space. A scalar field associates a scalar value to every point in a space The value may either be a (dimensionless) mathematical number or a physical quantity.[39] Examples used in physics include the temperature distribution throughout space or the pressure distribution in a fluid. In the context of morphogenesis as described by Manuel de Landa, a scalar field can be used to record the varying intensity of a quantity throughout the physical environment/context. In this way the scalar field can be a direct driver of the morphogenetic process.



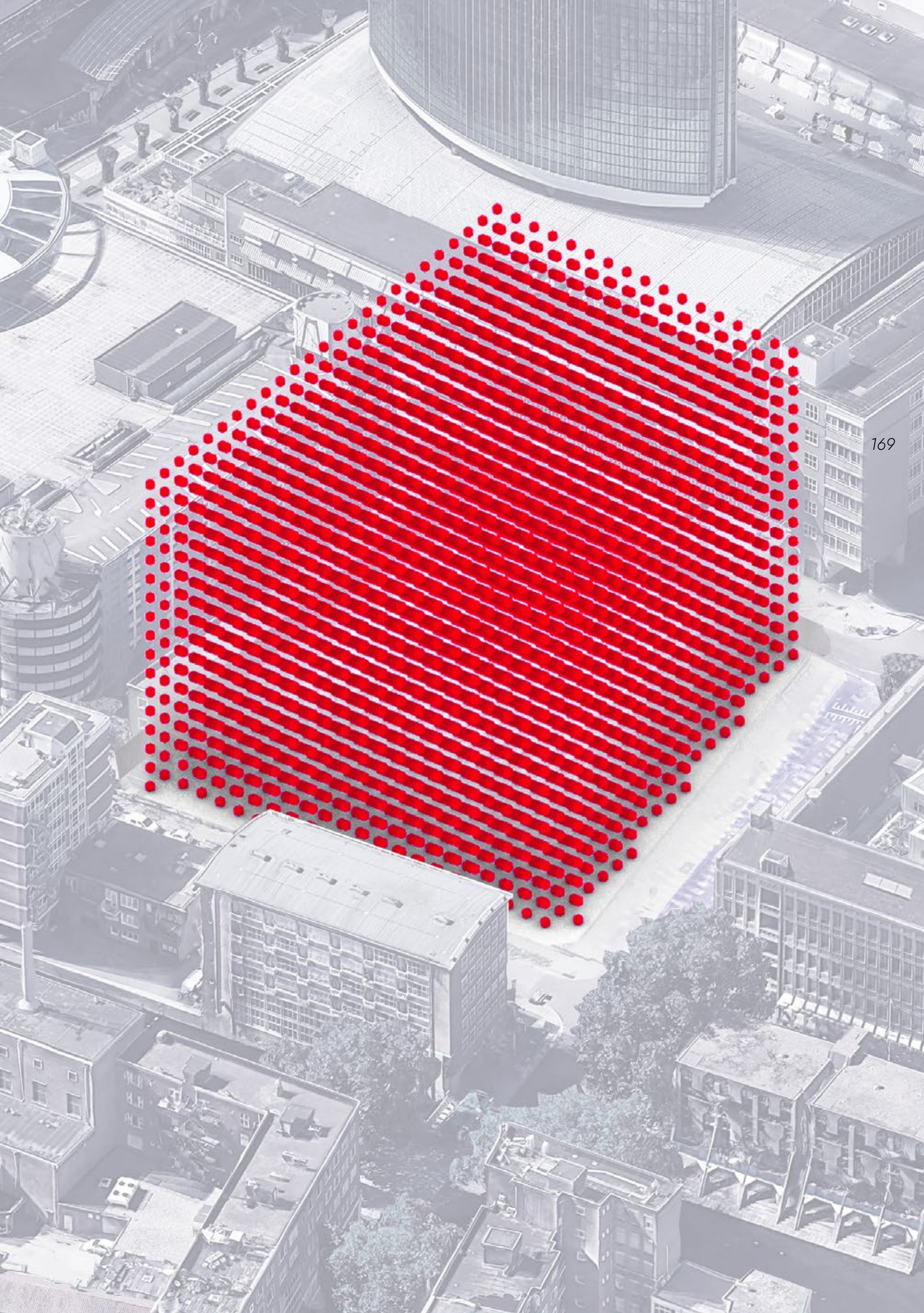
Discretization of common 3d shapes through voxelization

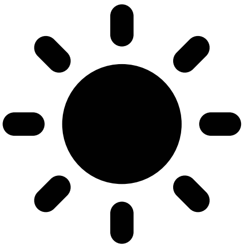


DISCRETIZATION is a process in applied mathematics of transferring continuous functions and models into their discrete counterparts.[45] Continuous models are usually represented by differential equations, which, while enabling extremely precise descriptions, also creates problems for efficient evaluation in a world of limited time and resources. It is for this reason that continuous models are often transformed into their discrete counterparts which are more suitable for numerical evaluation and are used among other applications in Finite Element Models for structural calculations. Discretization can be performed with many different elements, the most common of which are 2d meshes and 3d voxels and at various resolutions, which affect the precision and quality of the final model. For the intents and purposes of the project ed voxelization was chosen as the most appropriate approach due to its simplicity and the regular geometry of the voxel which lends itself well to architectural applications, as seen in the proliferation of voxel-like architectural projects of recent years.

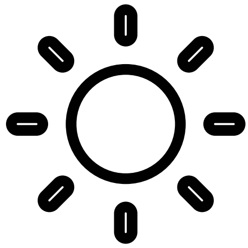


THE PLOT which was previously an inert 2d plane, undergoes a drastic transformation to become a crucial part of the configurational approach. First, the 2d plane is transformed into a 3d volume, an envelope within which a structure can develop. Second, the continuous 3d space is voxelized with a preset voxel dimension into a 3d array of discrete elements which become the basic building blocks. Finally, the geometric center of each discrete voxel is extracted as a point representation of that specific segment of space, together forming the 3d field which is the basis for evaluation of the spatial qualities within the envelope.

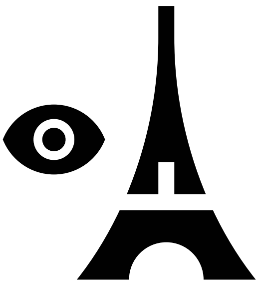




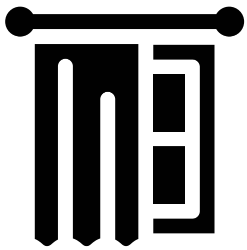
sunlight



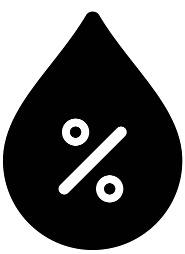
daylight



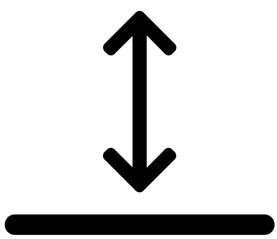
point of interest view



visual privacy



humidity



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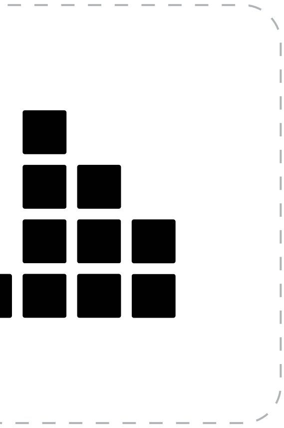

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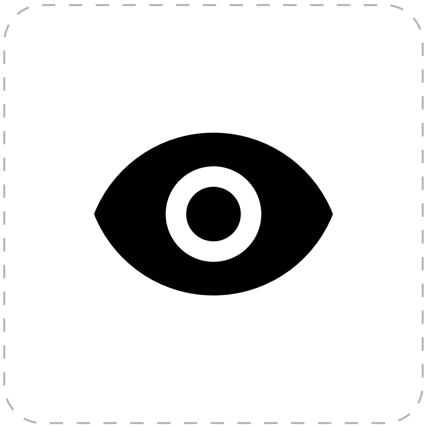
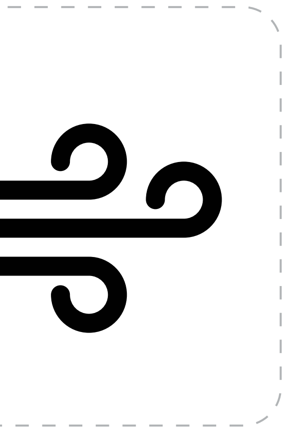
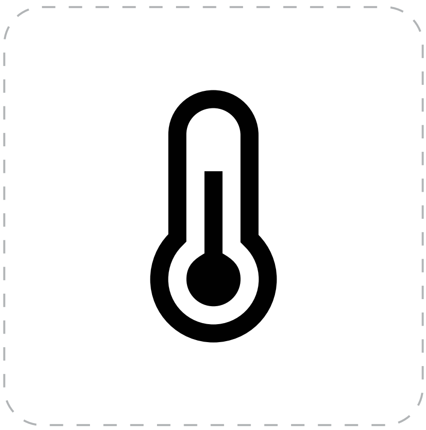


views

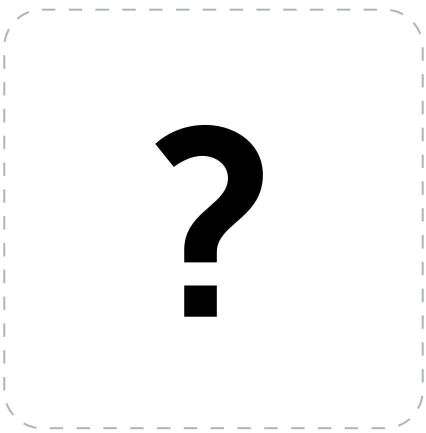


wind speed



temperature

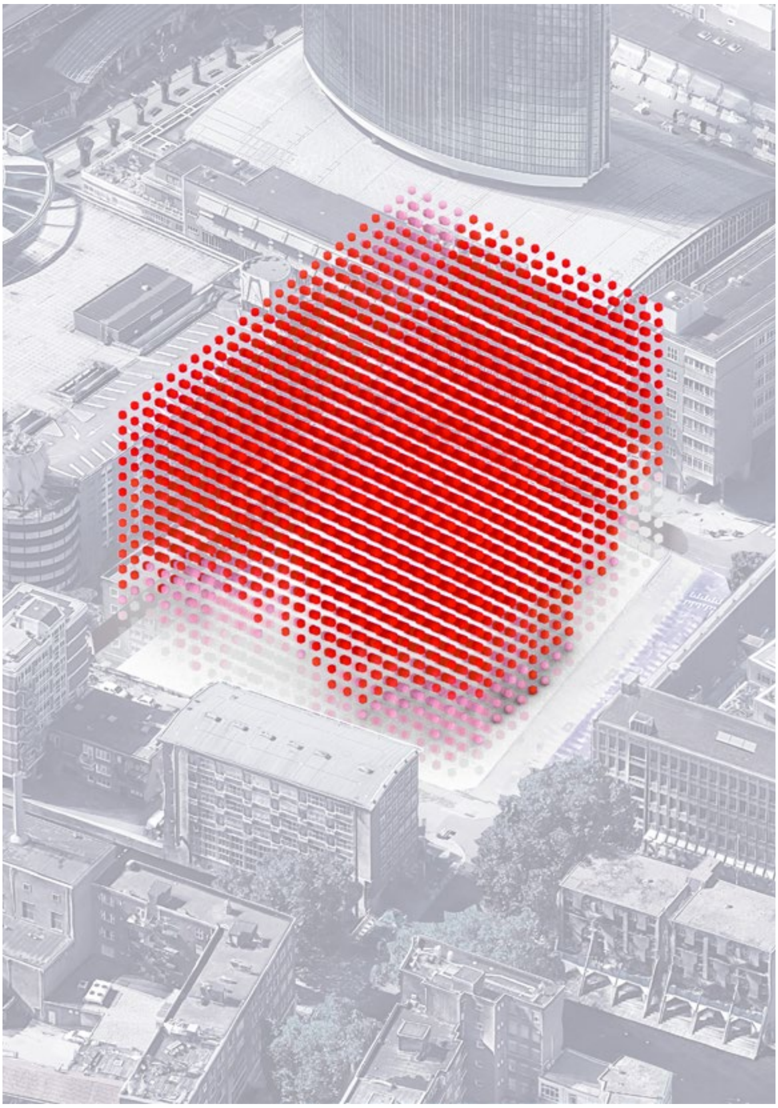
rain



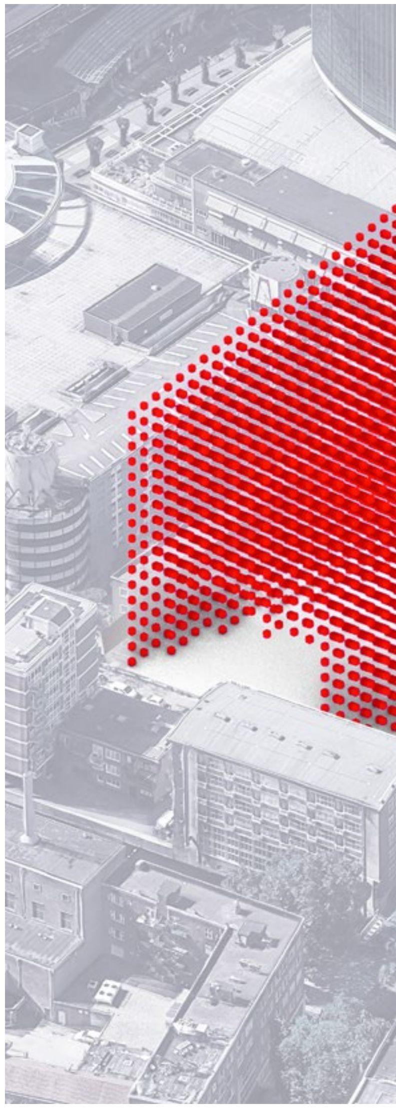
more?

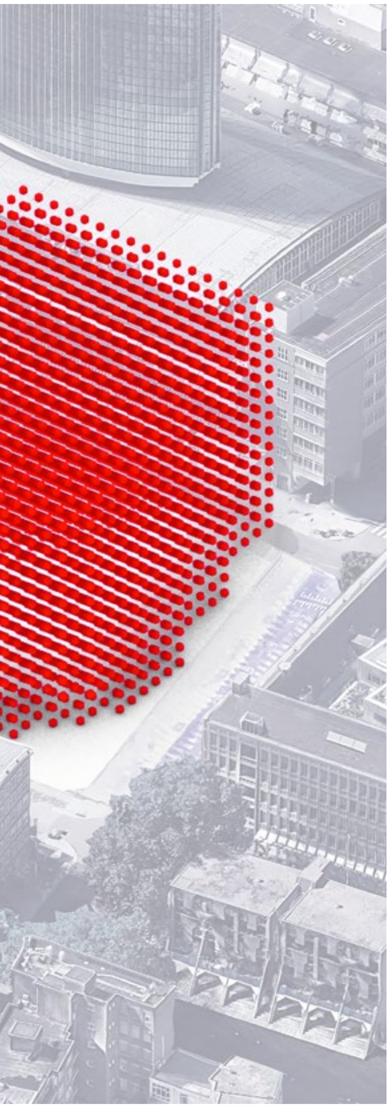
SPATIAL REQUIREMENTS in the form of defined parameters form the basis for the evaluation of environmental fields. They can be defined in response to the project brief in accordance with the requirements of specific units and thus enable the designer, as well as a potential algorithm, to identify well-performing areas within the envelope where a potential design could be constructed. The definition of a parameter is only limited by the possibility of its numerical calculation/evaluation and can, apart from a value also potentially contain a direction parameter, resulting in a vector field instead of a scalar field. This multitude of parameters naturally leads to a multiplicity of fields which can be further combined to create complex mulyi-parameter fields capable of comprehensively describing the performance of a space. Naturally, with the field being a logical and mathematical construct it is not of much help when trying to register subjective qualities of a particular space such as ambience and for such requirements a different approach would be neccessary.

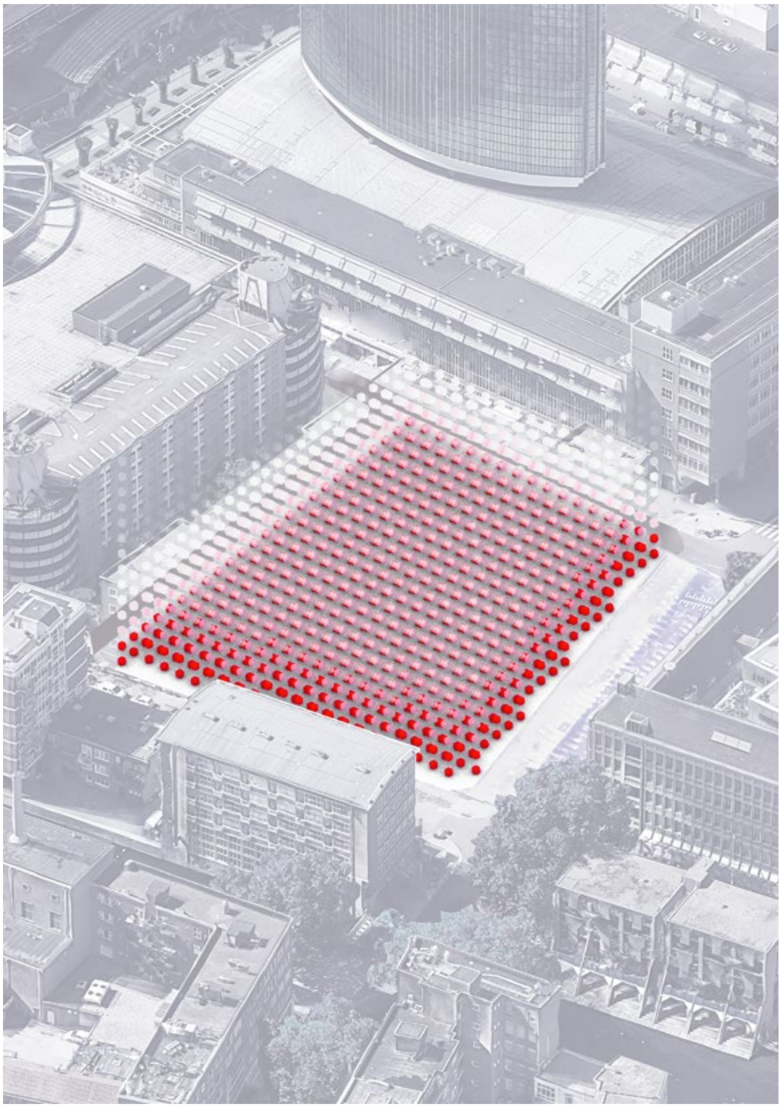
172



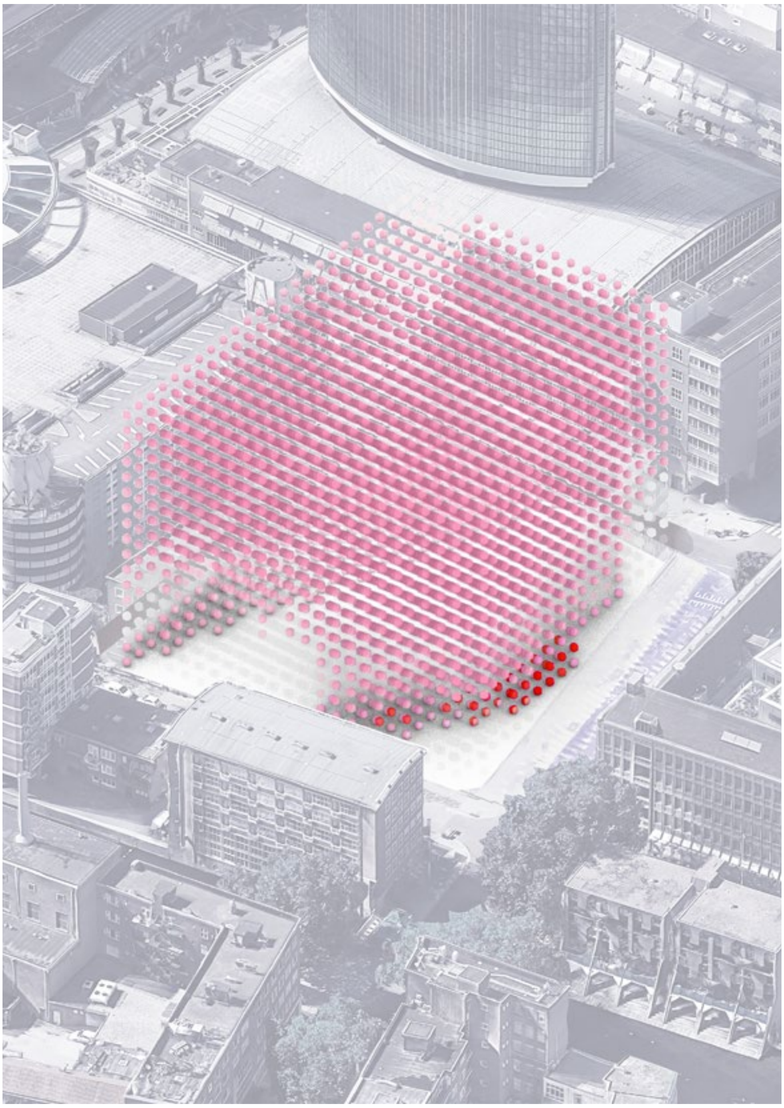
Field according to parameters of sun, views and structure

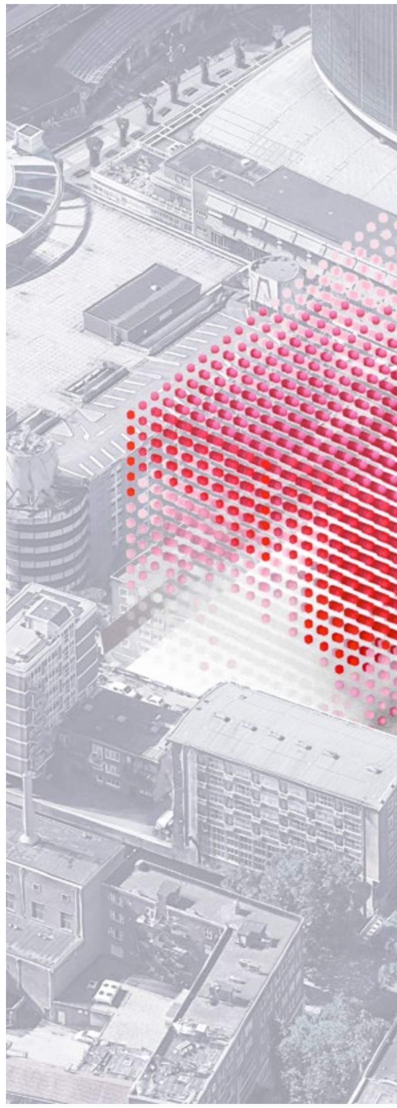




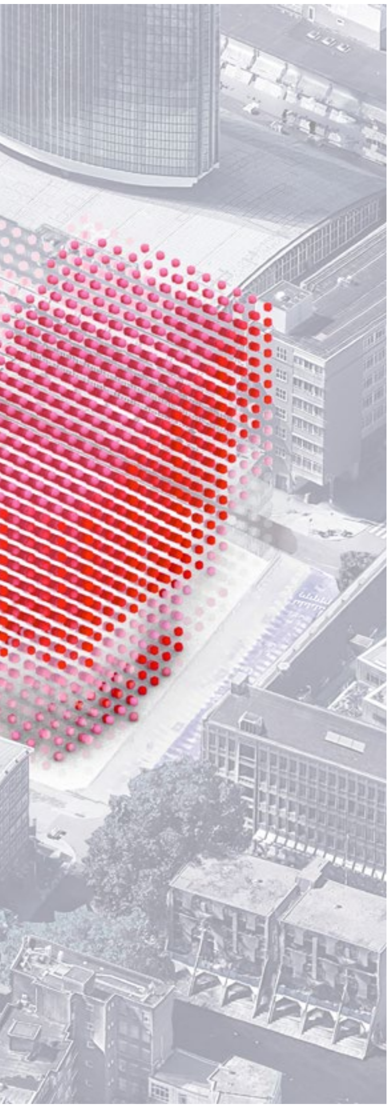


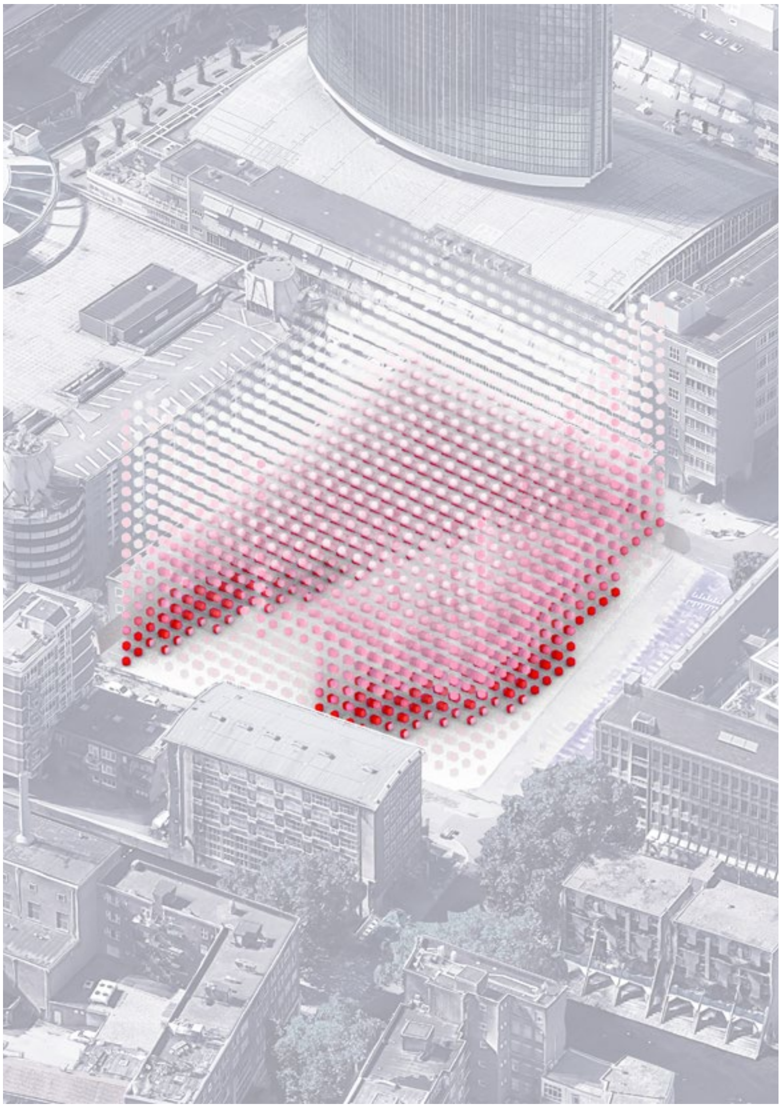
PARAMETERS are the primary factor differentiating different fields from each other. Each space can be evaluated in parallel for each parameter producing multiple fields depicting different spatial qualities in different locations.



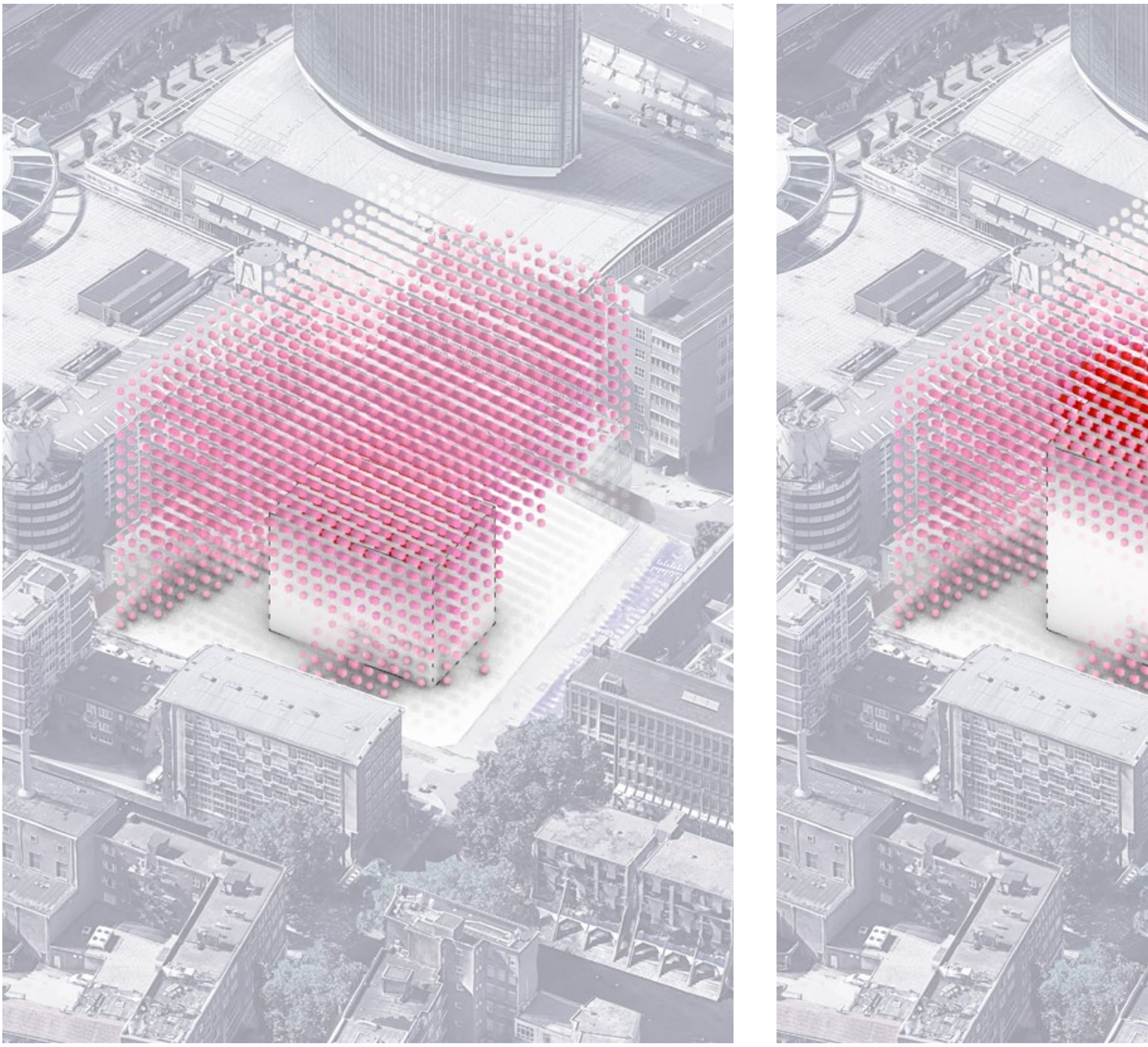


Sun, View and Structure fields merged with different weighting factors

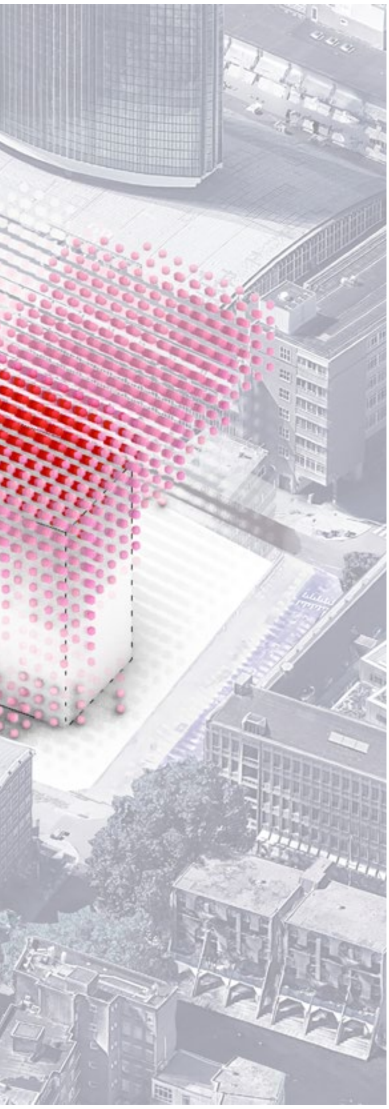


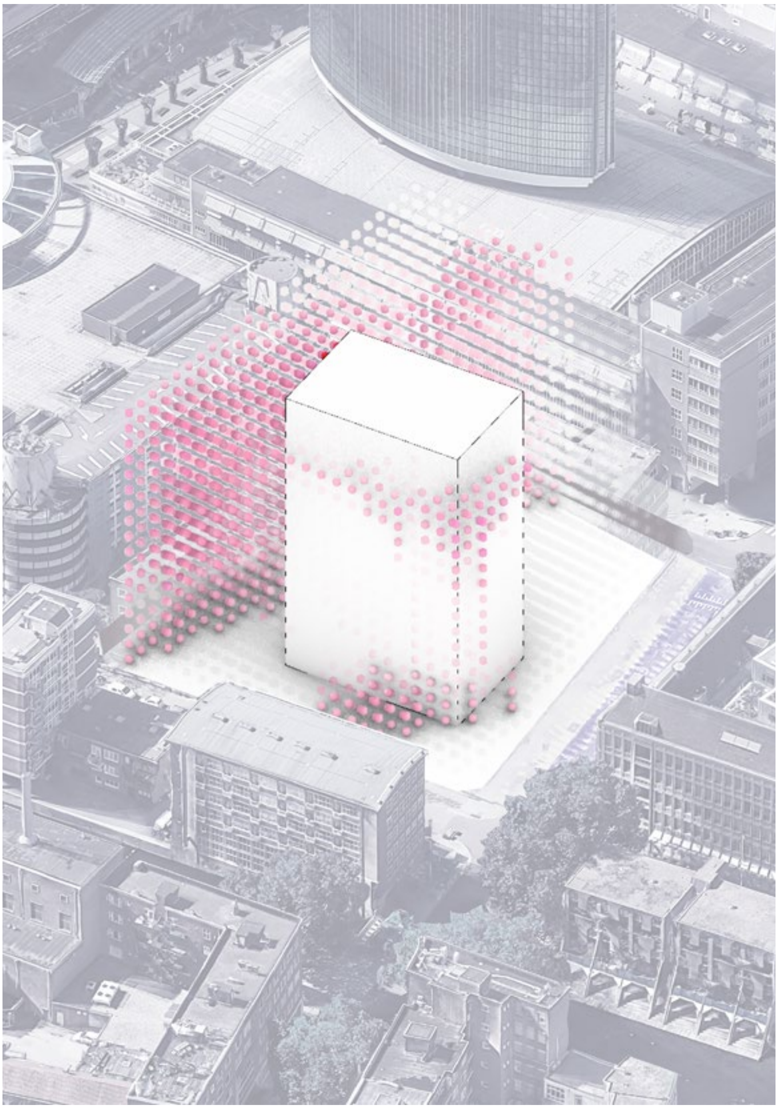


WEIGHTING factors represent a powerful way to combine multiple fields into a single hybrid field according to the proportional importance of each single parameter. This enables an infinite number of possible fields, each potentially responding to a certain progamme and its specific spatial requirements. The images depict hybrid fields generated from Sun, View and Structure fields based on different weighting combinations; Left 33%, 33%, 34%; Middle 65%, 0%, 35%; Right 0%, 40%, 60%.



An environment field at different iterations in a
hypotethical simulation

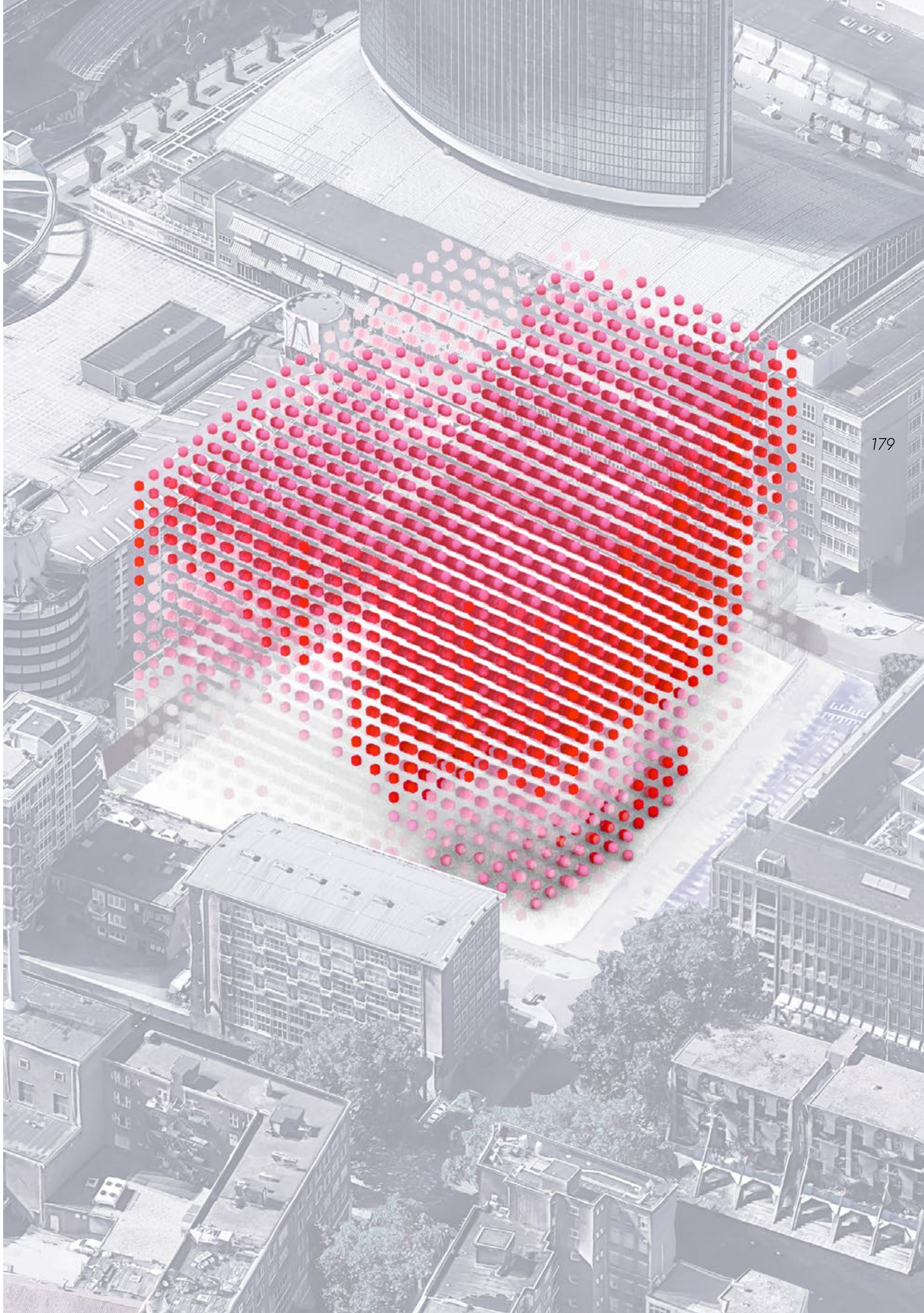




TIME is the final influence on the environment field through its continual transformation during the emergence of a new object. As a structure emerges in space it affects and transforms the field, changing its values which can in turn influence how the structure itself grows. This feedback loop enables constant adaptation throughout the entire process and its implementation in the design process could lead to better performing urban form.

Field conditons treat constraints as opportunity... Working with and not against the site, something new is produced by registering the complexity of the given.

- Stan Allen, From Object to Field, 1997 [47]



10 ON...

ALGORITHMS

How can computational design help in taking full advantage of configurational design to create responsive and better performing buildings?

Configurations could bring many benefits to architecture thanks to their **adaptability** and flexibility permitting them to respond to a multitude of influences and constraints, in turn making emergent designs of potentially superior performance possible. Inevitably, such an approach exponentially increases the level of **complexity**, often past a degree with which a human designer is capable of operating manually, leading to inefficiency at best and unfeasibility at worst. Consequently, configurational design needs to take advantage of advances in **computational** techniques capable of augmenting the architect by efficiently operating with highly complex configurations and their influences, thus making the approach practically viable as well as realising its full adaptive potential.

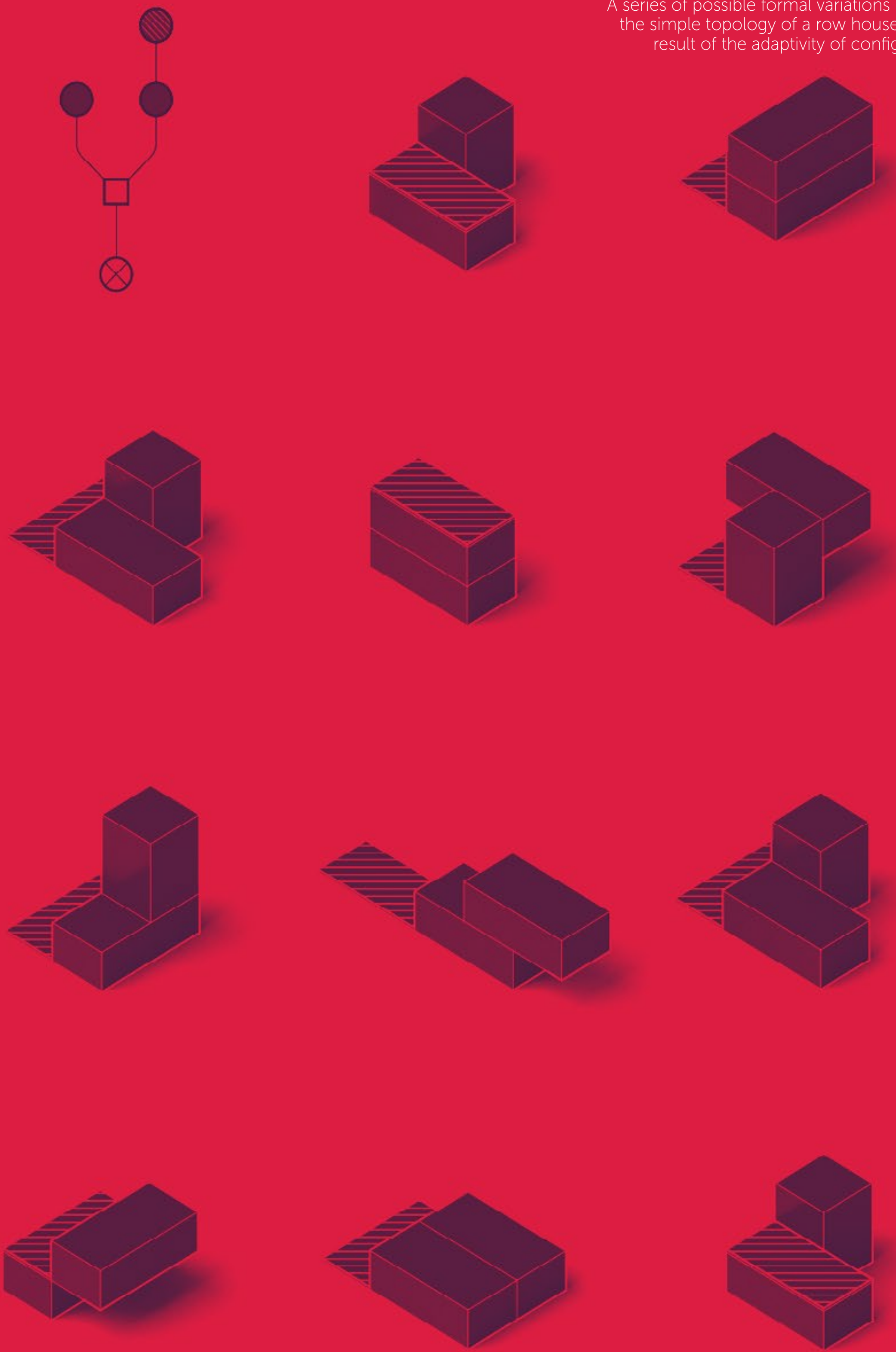
The adaptive possibilities of a configurational design lie in its capacity to be translated into a multitude of diverse spatial arrangements. To take advantage of this, the broad solution space defined by a configuration must be **systematically explored** during the design process to uncover all possible desirable solutions and make them visible to the designer. Furthermore, for adaptation to be possible, this exploration must also include large quantities of **information** about the environment to which the generated spatial arrangements can consequently respond. Although the aforementioned concept holds much promise, it brings with it a crucial issue for human designers most adept at thinking through simplification and abstraction, mechanisms which help us interpret and make sense of the complex world around us. Unfortunately, these are the same mechanisms limiting our capacity to efficiently work with large amounts of **quantitative** information necessary in a configurational approach predicated on extensive data-driven design exploration.

Unlike humans, **machines** such as computers have no need for simplification, thriving instead on explicitly defined repetitive and information-intensive tasks which they are capable of performing faster and more accurately, opening the door for their use as tools for (configurational) design **automation**.[48] Through the use of machine logic structured in the form of **algorithms** - step-by-step procedures assembled from simple logical operations - computers are able to work with large datasets describing parameters and constraints like volumetric context, programmatic requirements, environmental conditions, climate, legislation and more, and use the analysed data to generate designs in a process impossible for a human designer limited by time as well as complexity.[49] By performing thousands of calculations per second, aforementioned **generative algorithms** can explore a vast range of possible relationships and influences otherwise hidden from the analogue eye of the human designer, while simultaneously taking full advantage of the configurational approach by generating a diverse array of possible design solutions adapted to the specific site and its conditions. Beyond mere automation, by virtually simulating the influences competing in physical space, generative algorithms can predict possible future realities by assessing the impact and performance of generated designs according to desired criteria; more than mere technological development they enable organic inside-out planning based on functional and performative criteria.[50]

Combining adaptive configurational designs with data-driven computation transforms the algorithms themselves from simple linear processes to **complex systems** consisting of a web of interdependencies and feedback loops capable of unexpected **emergent behaviour**. By definition a complex system is one composed of many parts interacting with each other in multiple

CONFIGURATIONAL COMPLEXITY

A series of possible formal variations based on the simple topology of a row house; a direct result of the adaptivity of configurations.



ALGORITHM = INSTRUCTION

A segment of the computer code from the Aggregator algorithm used in computational experiments.

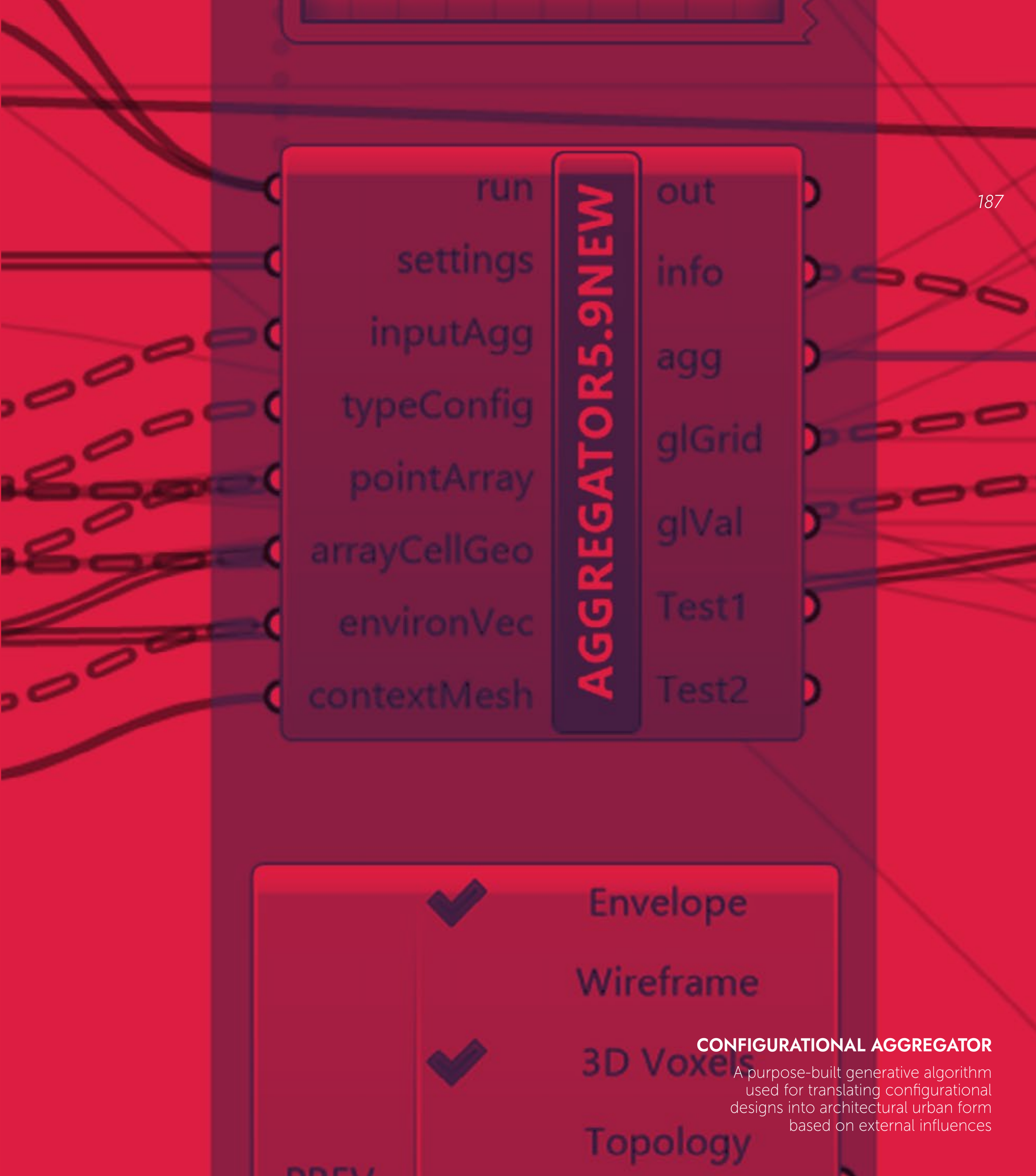

```
        //local evaluation
        double fieldValueTotal = 0;

        //is disconnected
        bool isNewDisconnectedCluster = false;
        if (testPointType != testPointClusterType) {isNewD

        //test shape
        double totalShapeFieldValue = 1;
        if (testPointGrowthType == 0 || isCirculation == t

            //find the cluster it belongs to and its clust
            List<int> parentClusterIndices = new List<int>
            if (isCirculation == true) { //if global circu
                for (int j = 0; j < currentAggregationOper
                    if (currentAggregationOperable[j].GetC
                        parentClusterIndices.AddRange(curr
                    }
                }
            }
            else { //else get only own
                parentClusterIndices = currentAggregationO
            }

            //calculate shape value
            if (shapeReq > 0 && shapeWeight < 1) {
                double maxValue = 4; //PARAMETER
                double neighbourVal = 0;
                //find the number of primary neighbours
                for (int k = 0; k < 6; k++) {
                    if (neighbourVal >= maxValue) {neighbo
                    int neighbourPt = arrayNeighbours.Bran
                    if (parentClusterIndices.Contains(neig
                }
                double primaryNeighbours = neighbourVal;
                //find the number of secondary neighbours
                for (int k = 0; k < arrayNeighboursSeconda
                    if (neighbourVal >= maxValue) {neighbo
                    int neighbourPt = arrayNeighboursSecon
                    if (parentClusterIndices.Contains(nei
```

ways according to local rules, resulting in an emergent higher-order greater than the sum of its parts.[51] Such systems have been extensively observed with examples including the global climate, natural organisms, the human brain, communication systems, economic organizations and cities themselves as complex entities where the economic, social and ecological spheres collide in massive aggregations of human habitation. These systems behave based on **bottom-up** organization allowing for a multitude of outcomes, undefined and unknown in the beginning, only unfolding as the system evolves in time; a polar opposite of traditional architecture operating through the **top-down** imposition of a global order - a design - usually justified with a guiding idea, a ***"concept"***. In contrast, complex generative algorithms, even when created with a specific task in mind, can always leave space for adaptivity and variation; a direct consequence of properties like non-linearity, unpredictability and emergence associated with all complex systems.[51]

Even though these qualities make complex systems notoriously difficult to analyze, predict or control, they could be productively channelled within the architectural design process by taking advantage of the **unexpected** to broaden the scope of available architectural solutions beyond established and expected schemes. Designing with **complexity** by integrating contextual, climatic, social, legislative, economic and other forces as parameters in a virtual environment, algorithms can simulate a holistic morphogenetic process in which designs spontaneously **emerge** as a direct consequence of the competing conditions affecting them. As the generated forms are explicit designs precisely responding to a specific set of influences, they no longer require **post-interpretation** by the architect. In this way, algorithms are capable of evolving more ***"challenging"*** designs; challenging both the architect and his personal preconceptions as well as established typal solutions within architecture as a discipline.[52] This approach in which sophisticated algorithms augment the capability of the architect to uncover new design solutions could increase our capability to deal with new increasingly complex architectural problems, as well as pointing towards previously unexplored solutions to existing problems. The existing stagnant and frozen **urban form** is a prime example of a problem which could benefit immensely from new morphological possibilities such an approach could bring.

The implied shift from top-down compositional design to bottom-up computational processes of morphogenesis also signals a transition from one to the many and the acknowledgement that a single perfect design most often does not exist. Competing schemes always exist in a diverse **population** of designs where each excels in some aspects while performing worse in others and only upon **evaluation** through a chosen criteria can preferred designs be selected in a process akin to **evolution** and **natural selection**. As a result, diversity within an evolutionary context is not an end in itself but is operationalized as a mechanism for gradual **optimization** of designs over time; difference becomes the driver of evolution and dynamic change.[12] The difference and diversity enabled by automated generative algorithms make the application of similar evolutionary principles possible to configurational design in architecture where it could initially be used to optimize simulation settings and parameters to achieve more desirable outcomes, while looking forward it could potentially allow us to completely close the loop between input and output thus enabling perpetual **self-optimization** of both the urban fabric as well as the algorithms generating it.

Such an adaptive architecture could be made possible by computationally augmented **configurational design** in which dedicated generative algorithms are used as automated tools furthering the capabilities of the architect and enabling design with complexity, leading to more responsive and better performing urban form in tune with the requirements of contemporary cities.



CONFIGURATIONAL AGGREGATOR
A purpose-built generative algorithm used for translating configurational designs into architectural urban form based on external influences

How can an algorithm translate a configuration to responsive urban form?

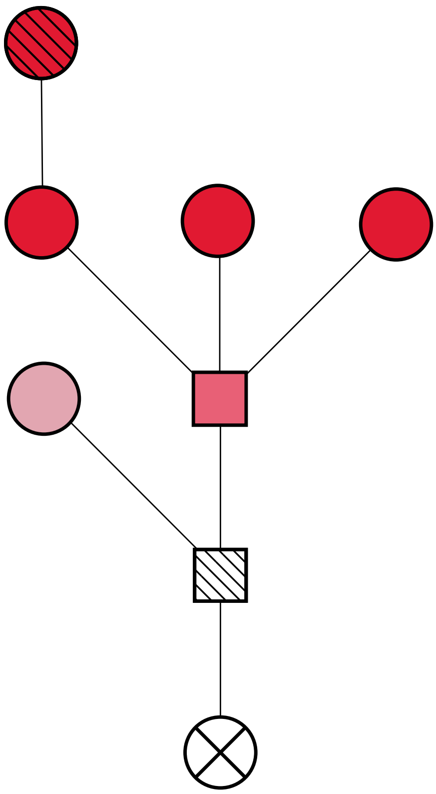
CONFIGURATIONAL AGGREGATION

Generating urban form through topological aggregation

To test the theoretical possibilities of configurational computation, a dedicated **generative algorithm** was developed, capable of combining spatial networks and the environmental field on a designated site to produce site-specific **adaptive urban forms**.

Even though computational approaches in architectural design are increasingly common, the vast majority of applications still fall into the domain of parametric modelling, merely used for elaborate formal exercises. Alternatively, the existing approaches relevant for configurational design fall into two distinct categories; on one hand, we find topological algorithms mostly performed in two dimensions and predominantly used for floor plan **optimization**, while on the other hand environmental optimization algorithms try to connect form to climatic performance, albeit most often in a global **top-down** manner. In short, no existing technique successfully manages to unify topological (configurational) design with environmental responsiveness.[40] As a result of this gap in precedents, a new approach was developed combining generative principles of **shape grammars** and **cellular automata**. The system operates by translating the nodes of a spatial network into spatial types, each containing growth instructions including topological information and spatial requirements. Responding to the environment field, the structure grows in a 3d voxel space through recursive voxel **aggregation**. This approach eschews computationally costly global optimization for gradual local **adaptation** where the structure perpetually adapts and adjusts both to the context as well as itself in a process of gradual growth. While introducing certain constraints such as the restriction to hierarchical tree-like topologies due to computational limitations, this approach was pursued due to its efficient adaptation to environment and context consequently producing better performing outcomes. To function, the algorithm depends on a series of inputs defined by the designer; the overall desired **configuration** defining spaces together with their interconnections and the individual spatial, and environmental requirements guiding the aggregation of each type. These inputs are fed into a **simulation** process during which a spatial composition organically emerges in response to external influences. This kind of simulation can be performed multiple times under the same conditions to generate a set of possible designs which are evaluated and displayed to the architect for selection.

Although the algorithm is capable of generating functional, rational and well-performing aggregations in most cases, its efficiency occasionally tends to suffer as it can be difficult to manually define the optimal parameters to achieve the desired result; an issue which could be minimized with the implementation of self-optimizing parameters utilizing **evolutionary systems** or **machine learning**. Nevertheless, the aggregations generated through this configurational algorithm by virtue of their performance and spatial quality affirm the approach as a proof-of-concept, which could, with further development, once become a practically applicable tool for generating responsive urban form via configurational design.



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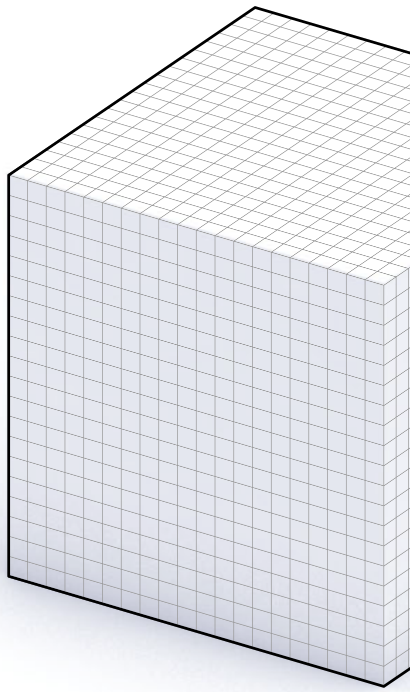
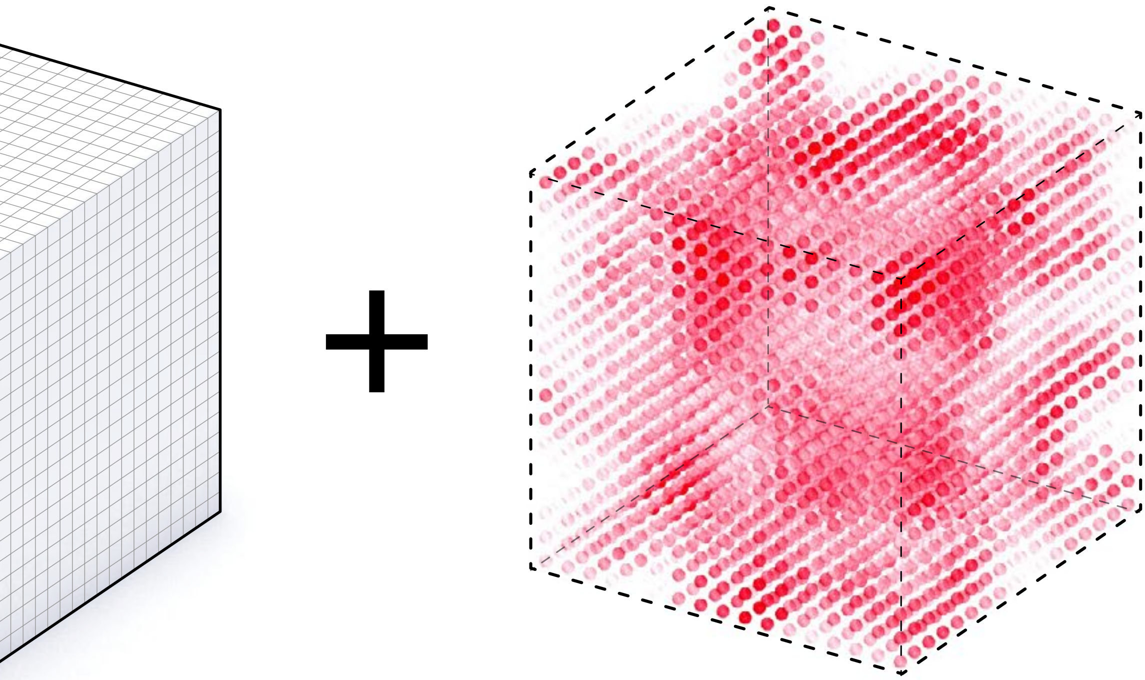


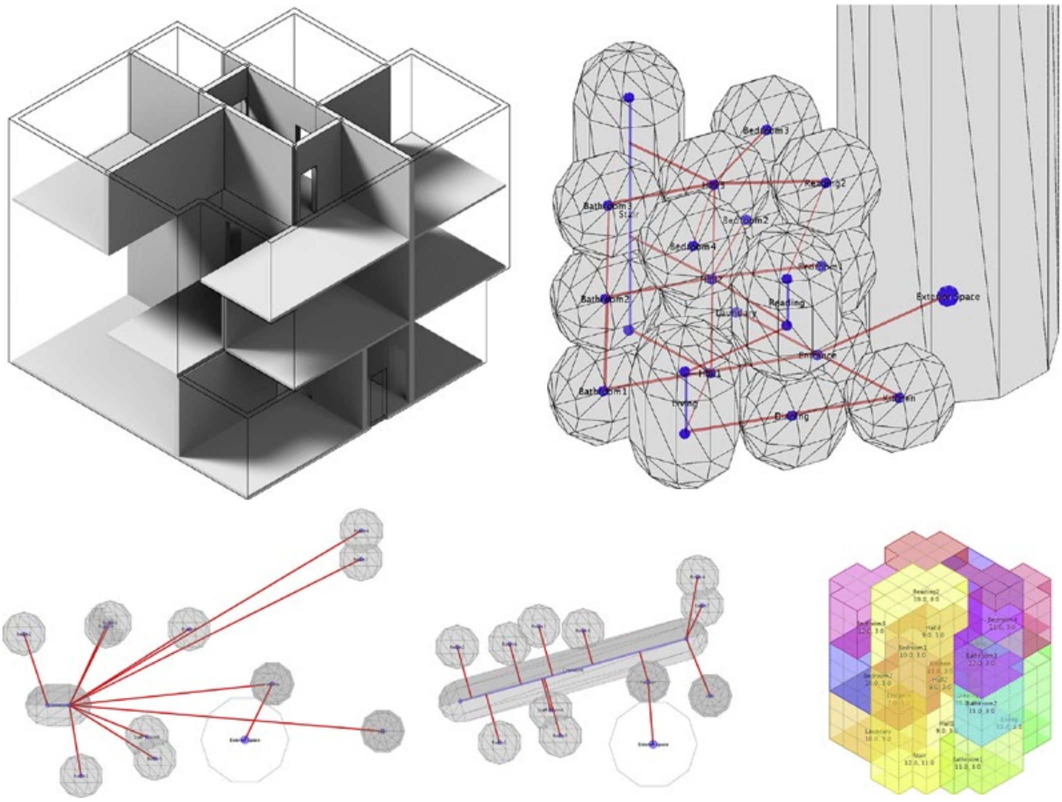
Spatial network

Voxel envelope

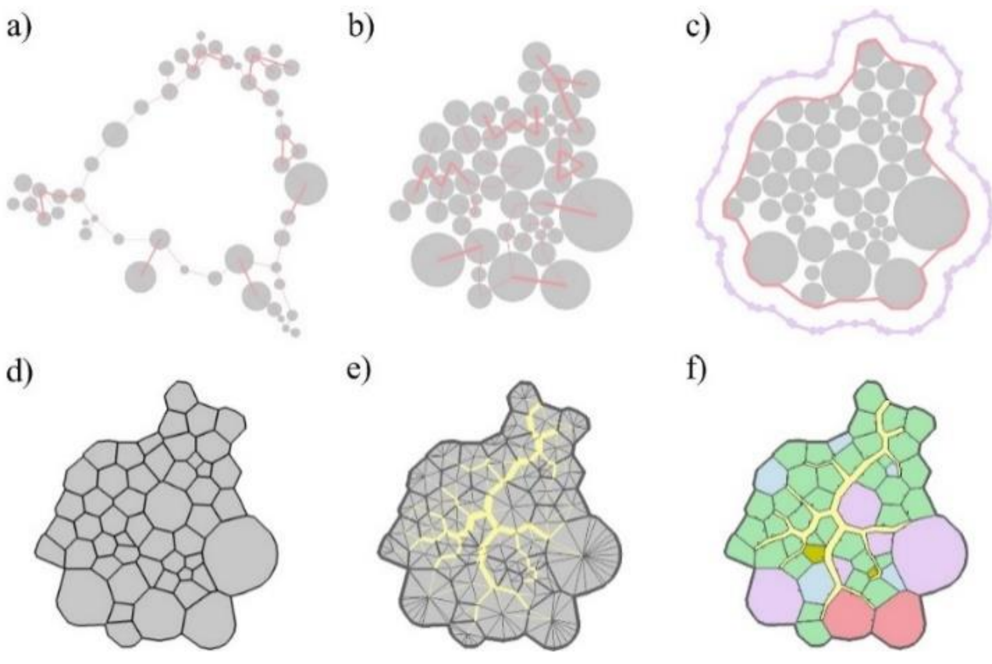


Environment field

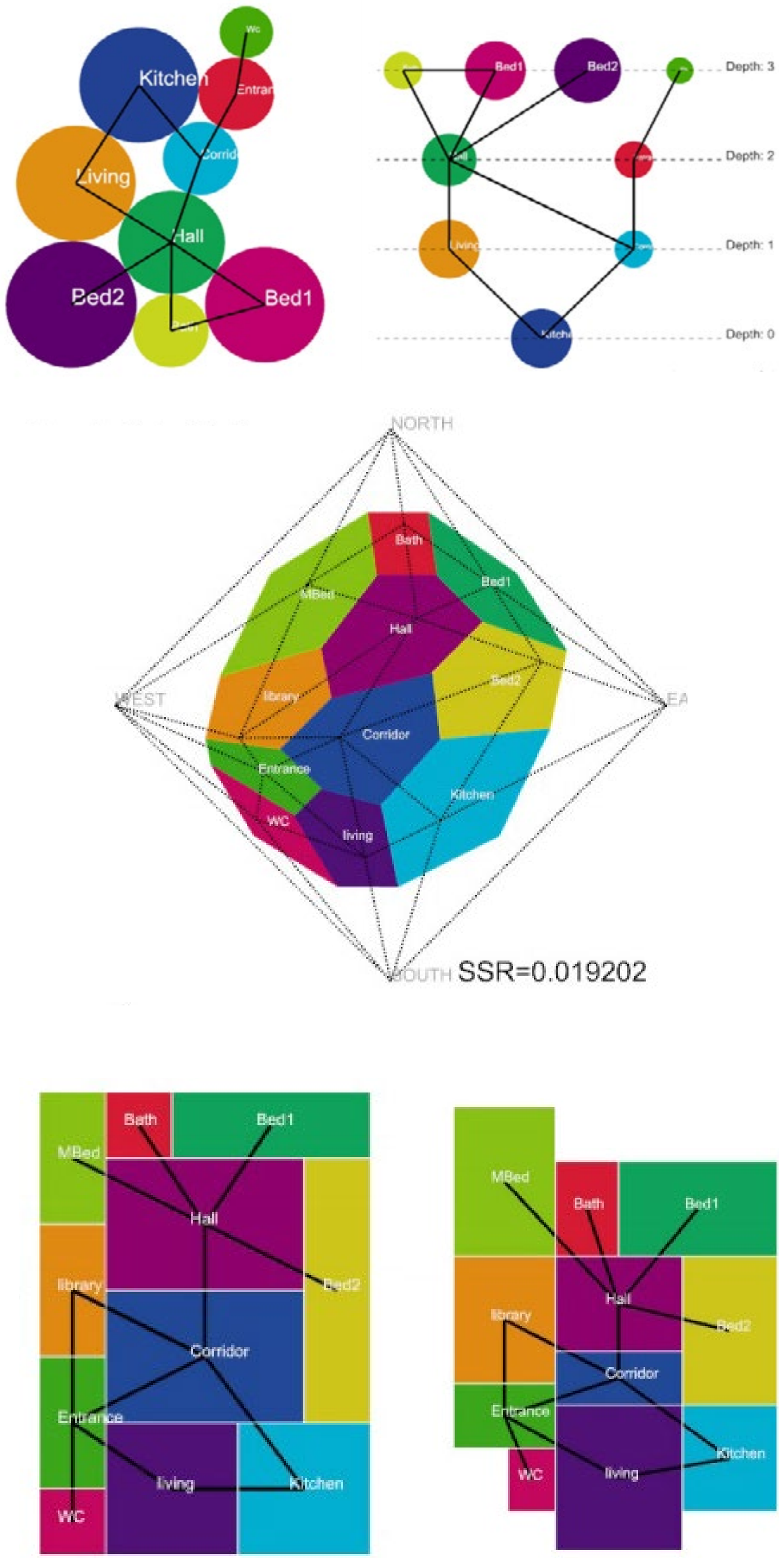
A GENERATIVE ALGORITHM for creating responsive, site specific urban form, while being capable of controlling the topological configuration of space needs to unify three basic elements as defined in previous chapters. First, the spatial network defining the spaces, their interconnections, as well as spatial requirements of each such as need for sunlights, views or privacy. Second, a predefined spatial envelope in which the generative process should unfold, divided into discrete elements, units of space that define the resolution of the simulation on one hand, as well as the last required element; the field. The field represents a 3d point field through which the environmental conditions can be measured, guiding the simulation and enabling adaptation. In short the algorithm must be able to find the bes possible disposition of the defined spatial network within the available envelope according to the environmental conditions as represented by the field. How could such an algorithm function?



Multi-Agent Evolutionary configurational design; Zifeng Guo, Biao Li [40]

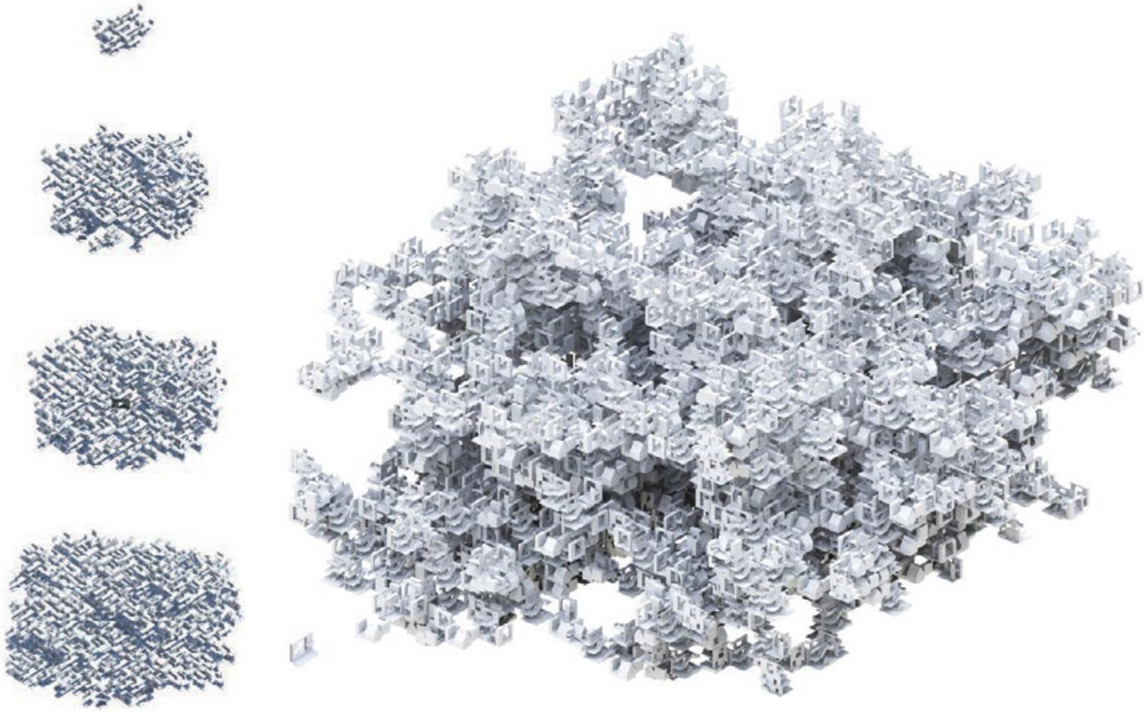


Evolving floorplans; Joel Simon [40]

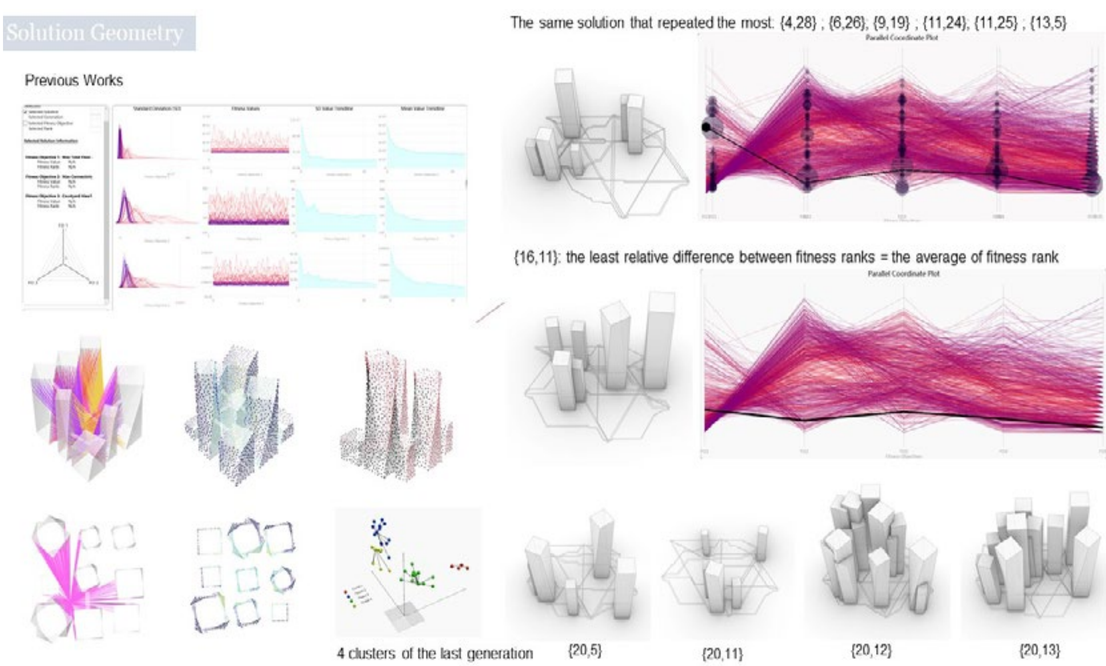


Syntactic, Grasshopper tool for configurational design; Pirouz Nourian [41]

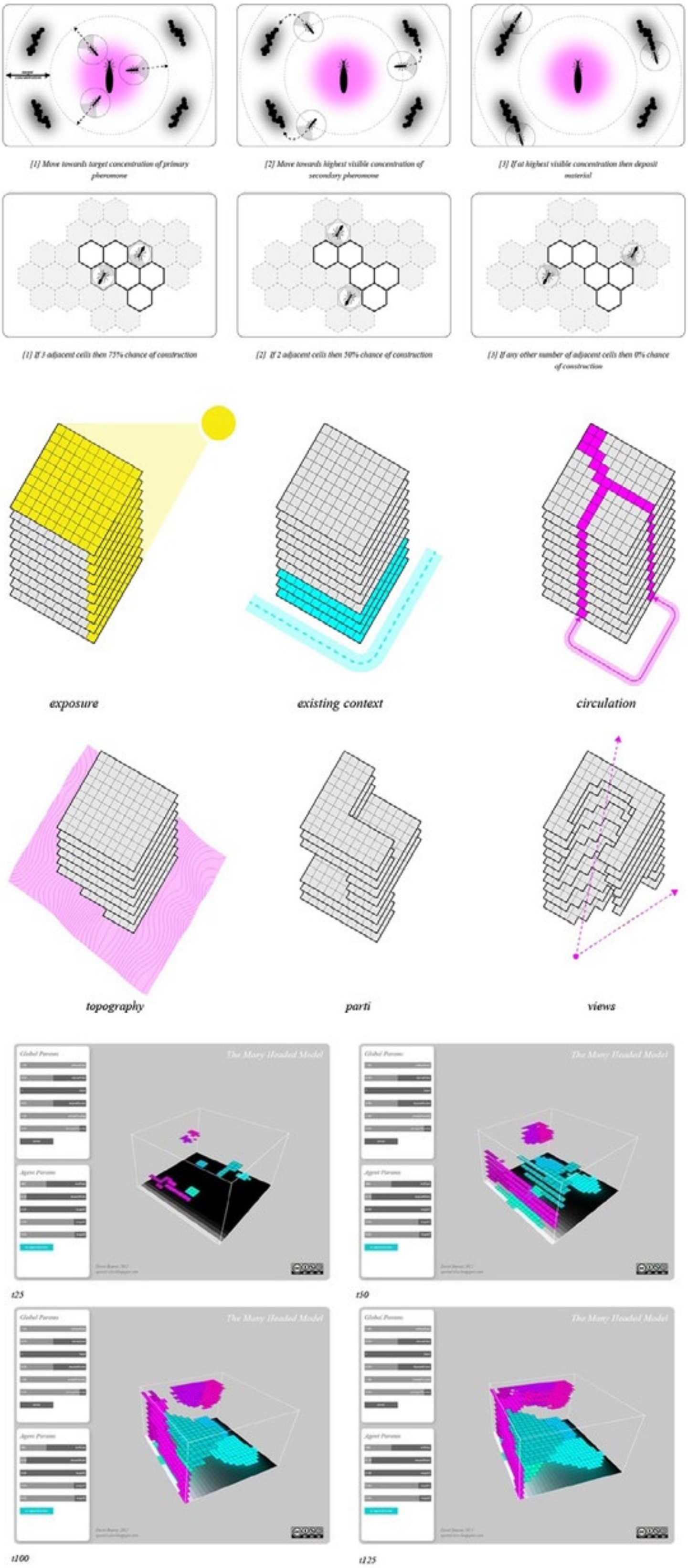
TOPOLOGICAL precedents in the field of spatial generative algorithms are small in number but they do exist with notable examples such as Syntactic and Configurbanist, tools for configurational design of floor plan layouts and urban districts respectively. Asnother similar example is Evolving Floorplans which utilises spring system mechanics to pack circles of programme to achieve optimal adjacencies which is then transformed into a plan via a voronoi space division. Unlike most existing configurational approaches that operate almost exclusively in two dimensions the Multi-Agent evolutionary configurational design tool by Guo and Li uses the same spring system mechanics to translate topological organisation into three dimensions which enables the creation of spatial compositions based on topological input. While these examples illustrate the existence of configurational design tools in architecture, unfortunately none of them attempt to merge topological requirements with external influences such as the environment which could be used to generate responsive and site-specific spatial compositions.



Mereologies, WanderYards; Chen Chen, Genmao Li, Zixuan Wang [42]



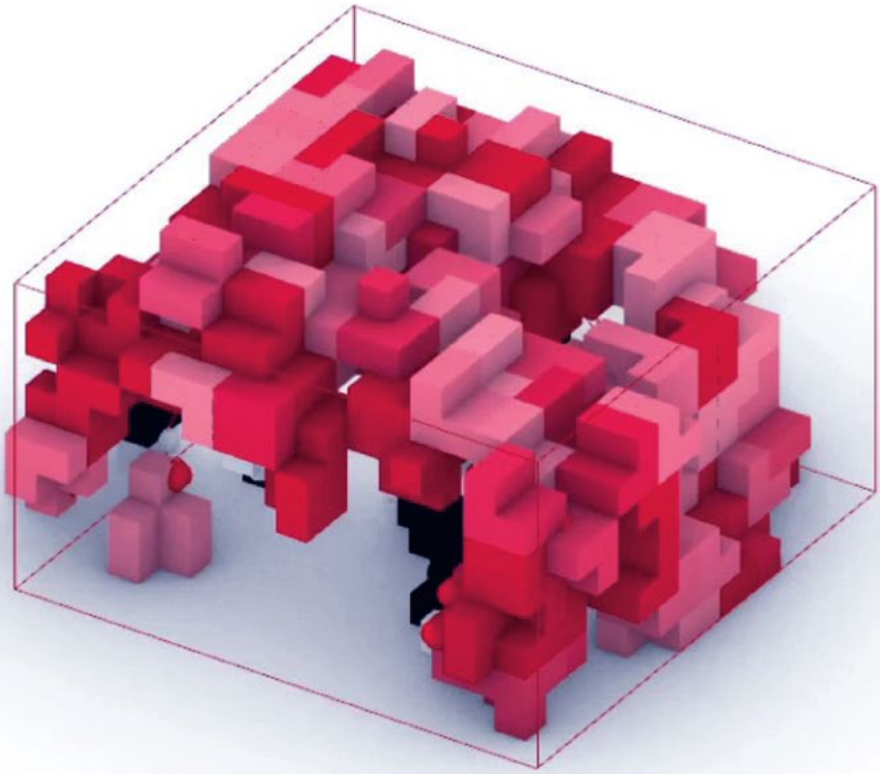
Wallacei ecolutionary solver [43]

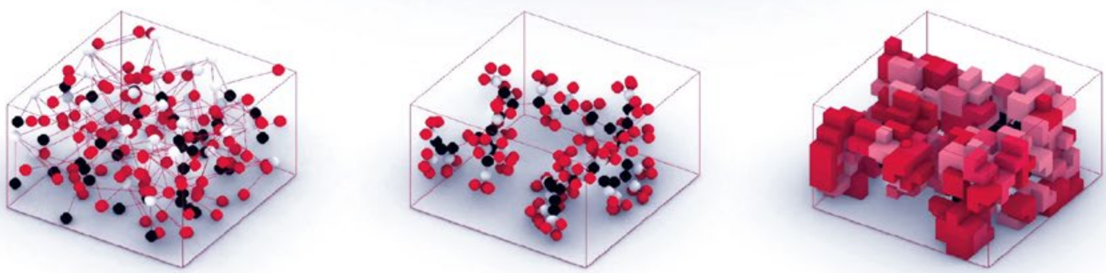


Stigmergic Space; Annalisa Meyboom, Dave Reeves [44]

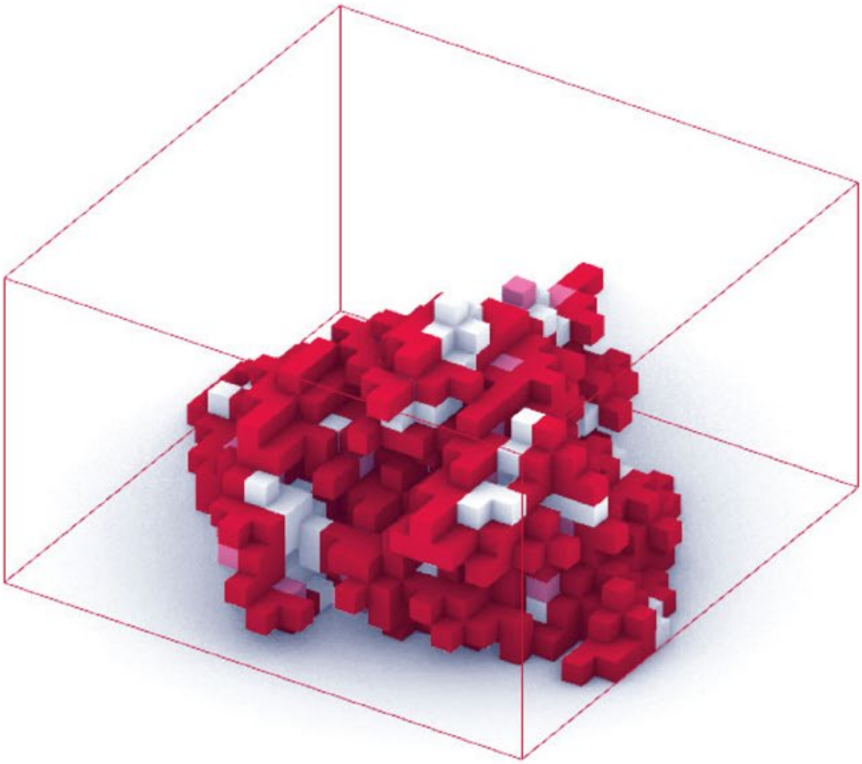
ENVIRONMENTAL design approaches in computa-tionhave become relatively widespread in recent years and utilize a diverse range of generative techniques to create spatial compositions. These approaches range from agent-based systems utilizing swarm intelligence (Stigmergic space) through evolutionary and genetic systems combined with parametrized form (Wallacei) to aggregation systems based on shape grammars and L-systems (Mereologies, Wa(o)nderyards) to name only a few. Crucially, none of the existing precedents include topology of space and its configuration in their generative process, but in the vast majority of cases only create self contained volumes to be refined at a further stage. One of the main issues here is the inherent complexity and the increased number of parameters that topology brings which often leads to issues of multi parameter optimization conflicts or unfeasible calculation times making the implementation impractical.

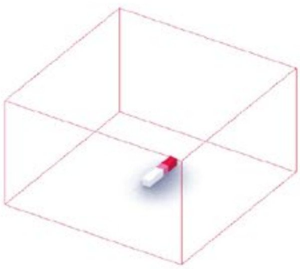
ALGORITHM

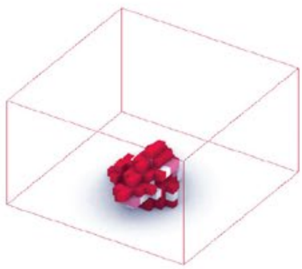


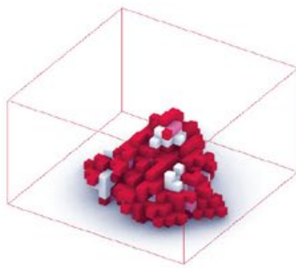


AGENT-BASED MODEL represents the first tested algorithm in which spatial network nodes are represented by agents moving in 3d voxel space and links are a physical spring system pulling connected agents closer. Each agent represents the seed of a space and at each iteration aggregates into its surroundings. The entire composition is then evaluated and all clusters with insufficient values attempt to move towards more optimal positions in the envelope according to environmental and topological parameters. While the approach offered significant advantages such as direct translation of a graph into space and no topological restrictions,

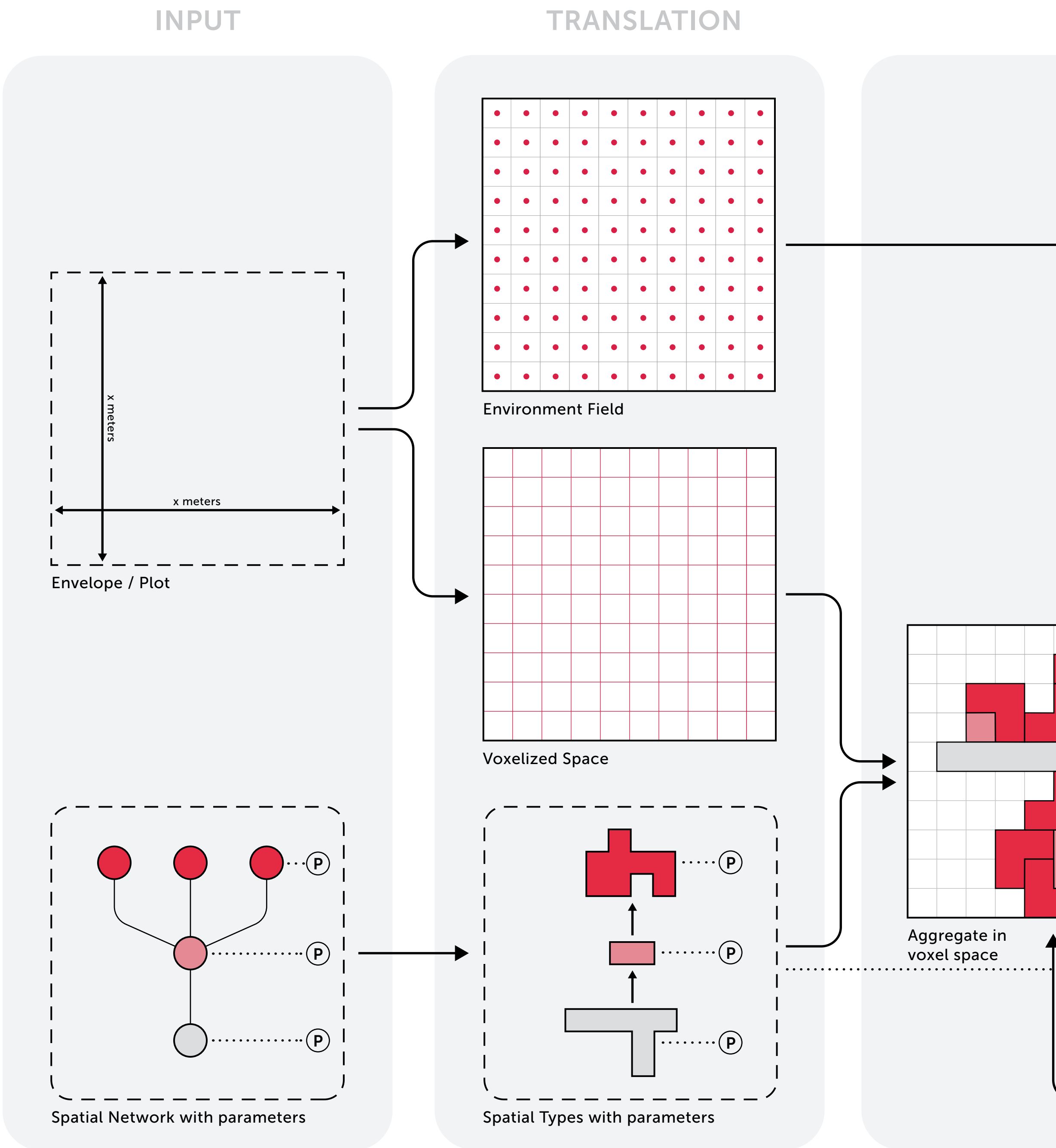


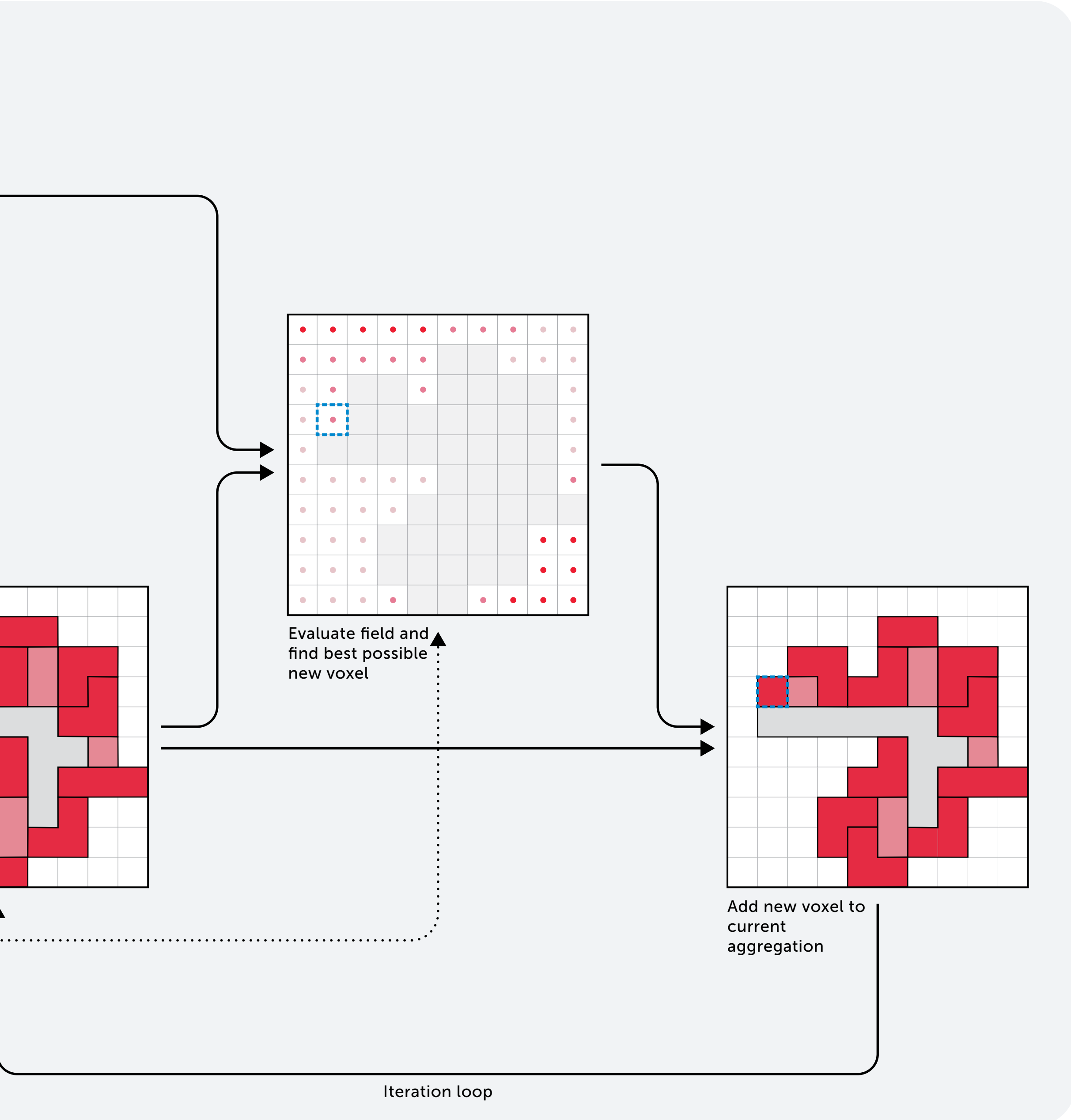






PART AGGREGATION represents the second, and eventually chosen, approach based on a probablistic shape grammar generative technique. The system operates by translating the nodes of a spatial network into spatial types, each containing growth instructions including the topological information, and additively growing in a 3d voxel space through voxel aggregation. This approach also replaces optimization with a process of adaptation, as the structure adapts through gradual growth. While this approach introduced certain constraints such as the restriction to hierarchical tree-like topologies due to computational limitations, it was chosen due


INPUT
TRANSLATION
x meters
x meters
Envelope / Plot
Environment Field
Voxelized Space
P
P
P
Spatial Network with parameters
P
P
P
Spatial Types with parameters
Aggregate in
voxel space

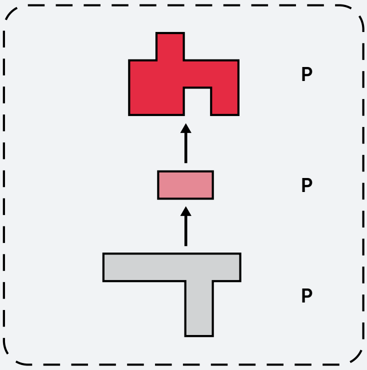


THE AGGREGATOR functions with two key inputs; a spatial network and a defined envelope. The envelope is first voxelized based on a set voxel resolution which generates both the environment and elements for aggregation, as well as the background point field used for evaluations. The spatial network is transformed from a graph to spatial types; a type category represents a node and all its parameters and information on the topology. These types then grow within the voxel grid through aggregation of voxels. At each iteration the algorithm examines the current aggregation and finds potential points into which it can expand. These points are then evaluated as a field for environmental criteria and type requirements which then informs the choice af voxel to add. Once the best voxel is chosen and added the iteration is complete.

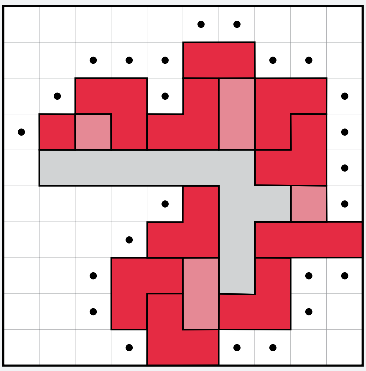
AGGREG

INPUT

VOXEL SEARCH



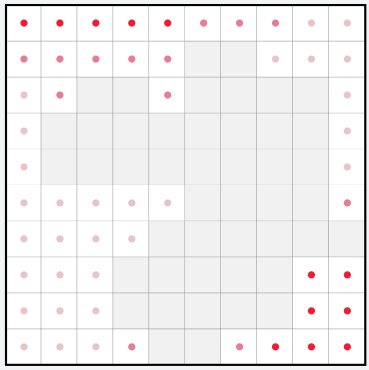
Spatial types



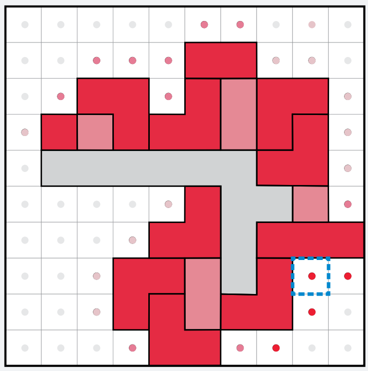
Voxel Search
potential expansion voxel locations

The first segment of the iteration checks the global programme percentage requirements to see which type needs to be expanded this iteration. Next, it extracts from the existing aggregation all possible locations where a voxel of this type could be added; either expand incomplete existing clusters of the same type or parent types which are able to spawn a new subtype of the required type. For this, the defined spatial types containing configuration information are used. The output is a collection of potential points

PRE-CHECK



Environment field



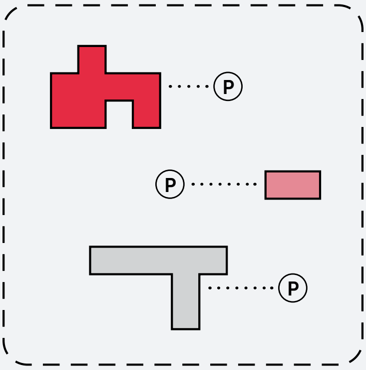
Pre-Check
evaluate potential expansion voxels

Taking the potential expansion points from the first step, the algorithm evaluates each individual point according to the parameters of the type the aggregation is expanding and the environmental conditions at that point in space. This creates a field of evaluated points which can be sorted from best to worst based on performance and as such act as the first guide for the aggregation process towards an optimal adapted solution.

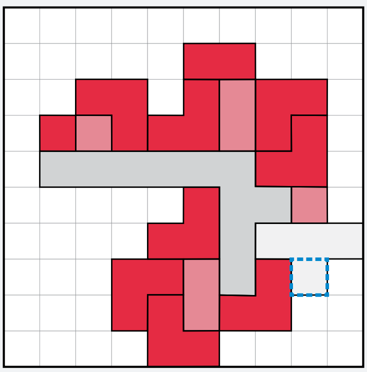
Iteratio

GATION

MAIN CHECK



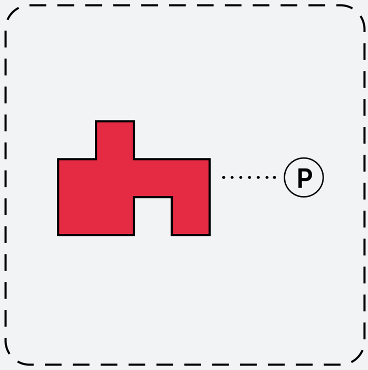
Type parameters



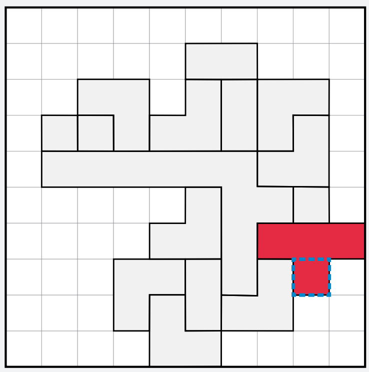
Main Check
add voxel and check existing clusters

In the Main Check the aggregation process attempts to take a (best) point from the evaluated and sorted list and attempts to add it to the existing aggregation. It appends the voxel to the aggregation and checks all existing clusters (not itself) in the aggregation for environmental criteria such as sun, views, privacy, etc. which prevents greedy behaviour. If the criteria for all clusters is still met the voxel is retained and the algorithm moves on, else it repeats the same process with the next best possible point until one can

POST CHECK



Type parameters

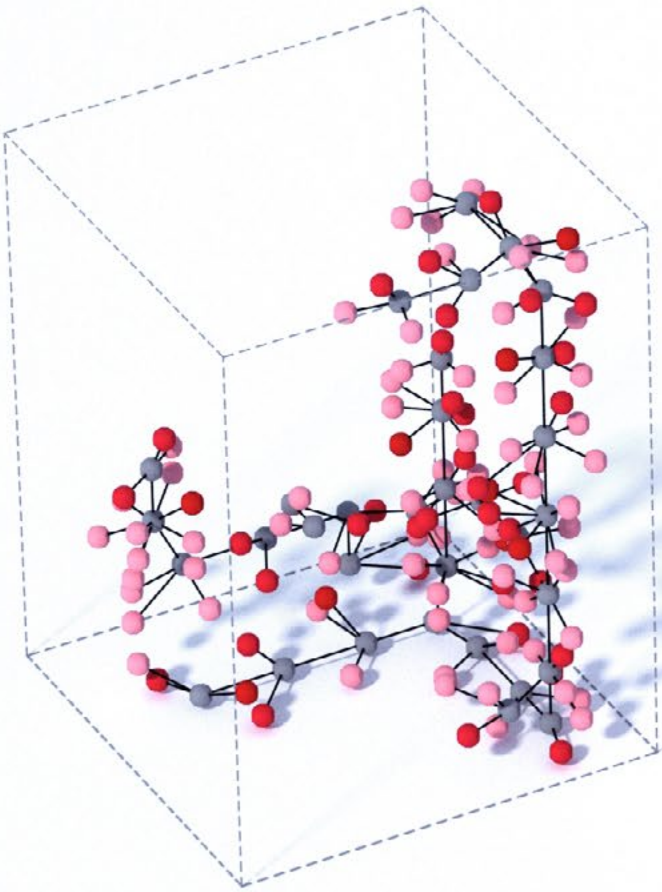


Post Check
check own cluster for requirements

The last step in each iteration is the post-check where each individual cluster is checked for topological criteria (size and number of subclusters), environmental criteria (sun, views, privacy) and structure. This check is performed with a certain delay from the last modification of each cluster which allows time for fulfillment of criteria some of which can not be guaranteed when creating the cluster such as structure and number of subclusters. If a cluster fails any criteria it, along with all of its subclusters, is removed from the aggregation.

OUTPUT

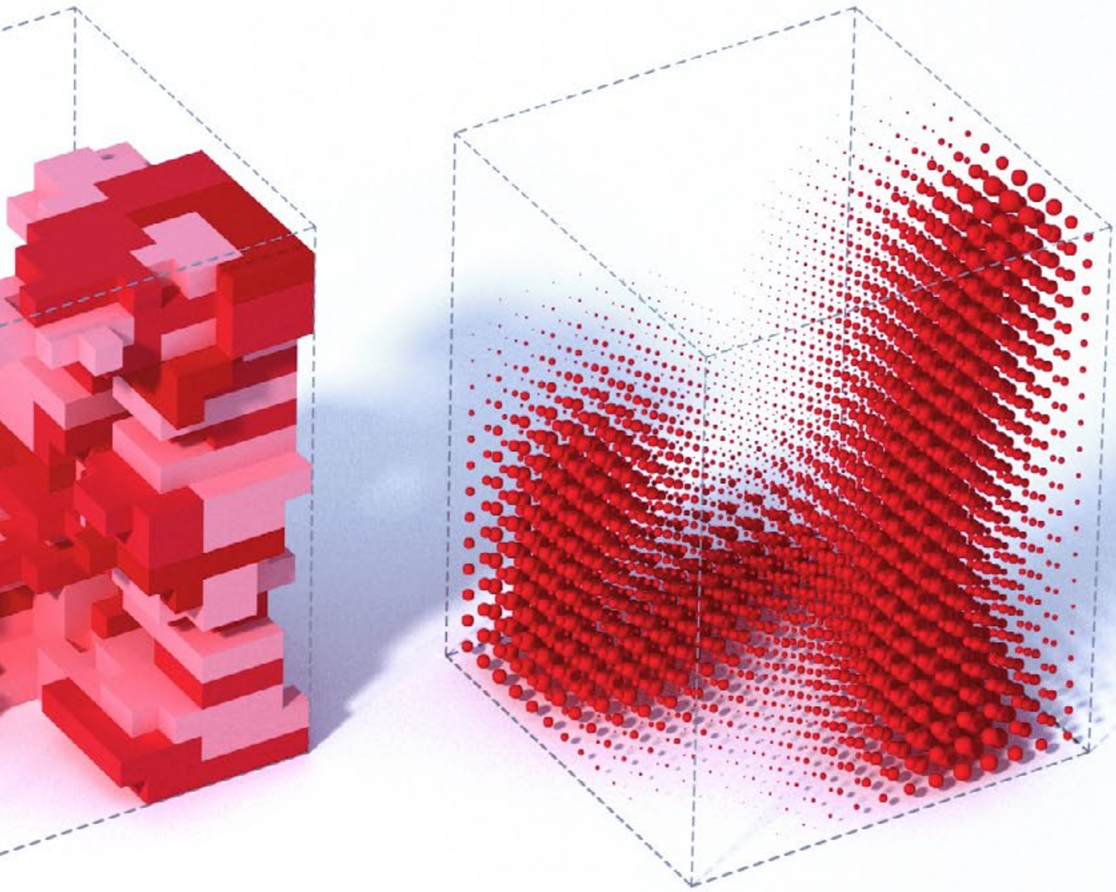
n Loop



Spatial network

Voxel envelope

SCAN FOR AR VIDEO



Environment field

INPUTS

The confiurational algorithm requires a number of input parameters defining not only the configurational (topological) behaviour of the desired spatial composition, but also its spatial aspects and requirements. Parameters are divided in two groups; global simulation parameters that control behaviour on the scale of the entire simulation across all types and local type-specific parameters which mirror all the information contained in the spatial network. Configurational parameters define the types (nodes) and their intercon-

GLOBAL SIMULATION PARAMETERS

ENVELOPE	envelope volume	exclusion volumes	cell dimensions	grid rotation
RANDOMIZATAION	randomization degree	randomization seed		
DELETING	cluster deleting age			
COMPACT LOCAL	compactness multiplier			
COMPACT GLOBAL	compactness multiplier			

LOCAL TYPE - SPECIFIC PARAMETERS

CONFIGURATIONAL PARAMETERS

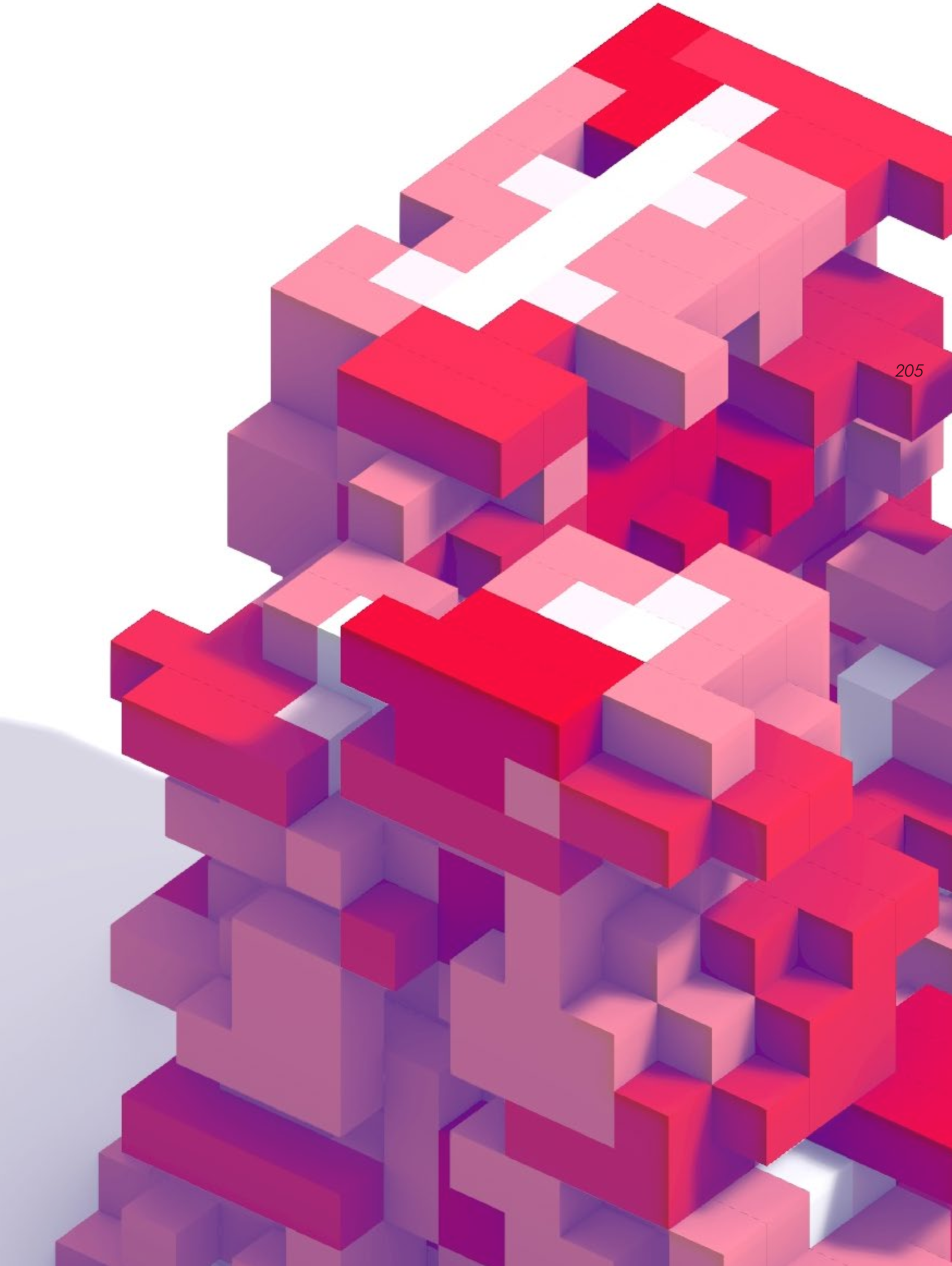
TYPE	type ID	type name	
SUBTYPE	possible subtypes	min. subclusters | #	max. subclusters | #

SPATIAL BEHAVIOUR PARAMETERS

SIZE	cluster size	min. cluster size	total volume percentage
LEVELS	level aggregation	max. number of levels	
GEOMETRY	cell geometry type		
FACADE	cluster facade percentage		
SEARCH TYPE	search behaviour type		
SHAPE	shape behaviour type	shape multiplier	

ENVIRONMENTAL PARAMETERS

SUNLIGHT	min. sun hours	min. % of voxels	field weight	facade angle	
VIEWS	min. view angle	min. distance	min. % of voxels	field weight	facade angle
PRIVACY	min. distance	min. % of facades	field weight		
STRUCTURE	in progress..				



ENVELOPE PARAMETERS

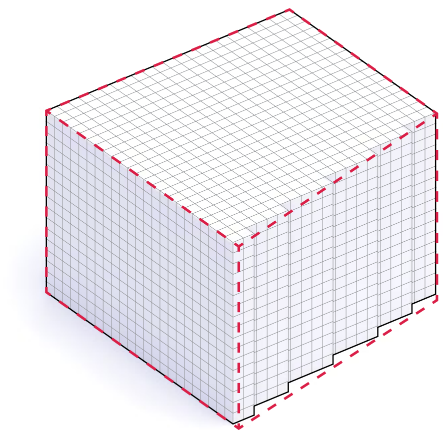
envelope volume | 3d

exclusion volumes | 3d

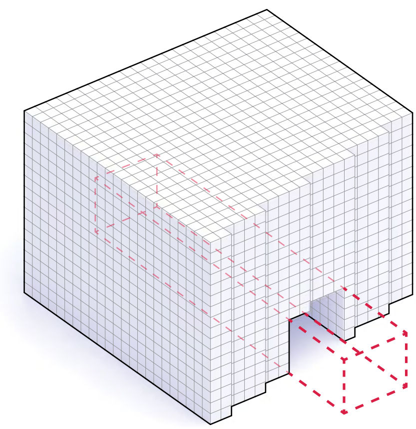
grid rotation | # angle

cell dimensions | # meters

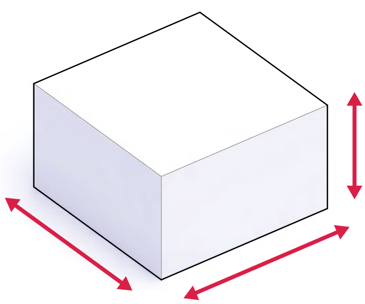
Envelope parameters are crucial for the simulation as they define its area of operation, as well as the base spatial resolution at which the simulation is performed. Envelope volume parameter is a 3d volume which defines the working enviroment of the simulation; the area within which aggregation takes place. This area can be modified through substraction of smaller volumes with the use of the 3d exclusion volumes parameter. Cell dimensions is defined in meters and defines the size of the base voxel in w*d*h format and thus influences the resolution of the entire simulation. This base voxel, along with its rotation angle parameter is used to voxelize the initially defined 3d envelope which also provides the base for the evaluation field; a three dimensional array of points where each represents one specific voxel.



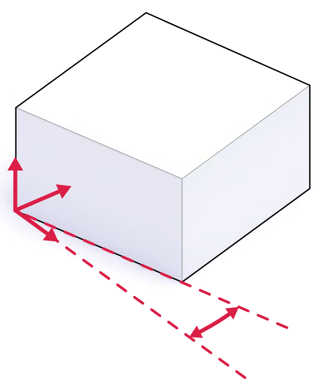
3d envelope volume



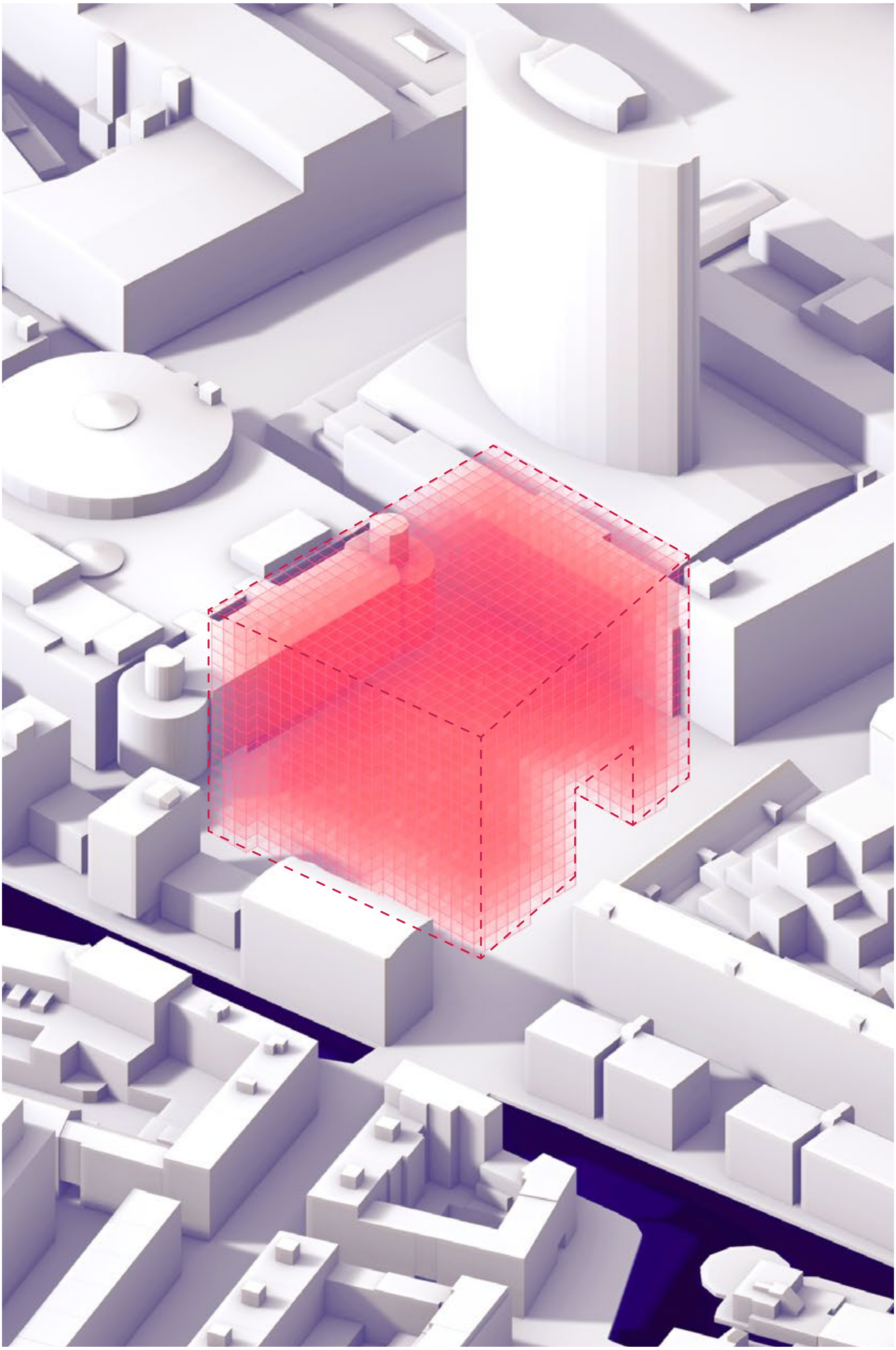
3d exclusion volumes



voxel dimensions



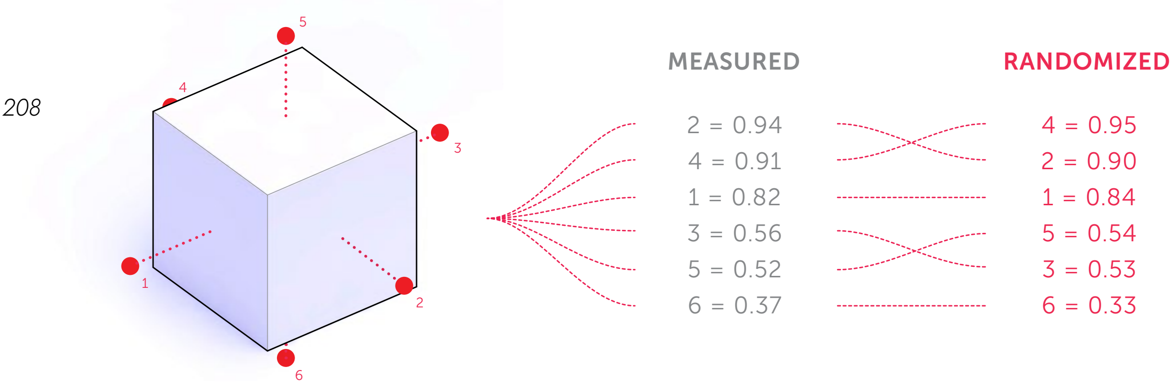
voxel grid orientation angle



RANDOMIZATION PARAMETER

randomization degree | %   randomization seed | #

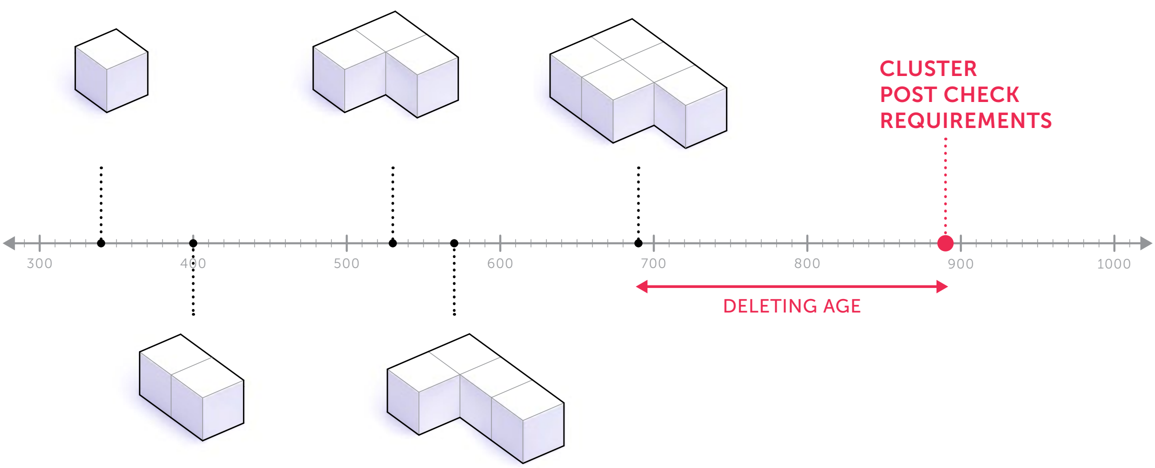
Randomization parameters allow for the choice between a deterministic and a randomized simulation, thus enabling generation of multiple solutions under the same constraints. Randomization degree specifies the randomization percentage of guide field values and ranges from 0 disabling randomization to 1 specifying complete randomness. Randomization seed is a simulation-specific number controlling all subsequent randomness in that specific simulation. By specifying the seed a previously randomly generated simulation can be recreated, while if left unassigned (-1) the seed will be automatically generated. While random behaviour brings valuable diversity of options it comes at a cost of slower and consequently less efficient simulations. When randomization is disabled the simulation is deterministic, always generating the same solution.



DELETING PARAMETER

cluster deleting age | # iterations

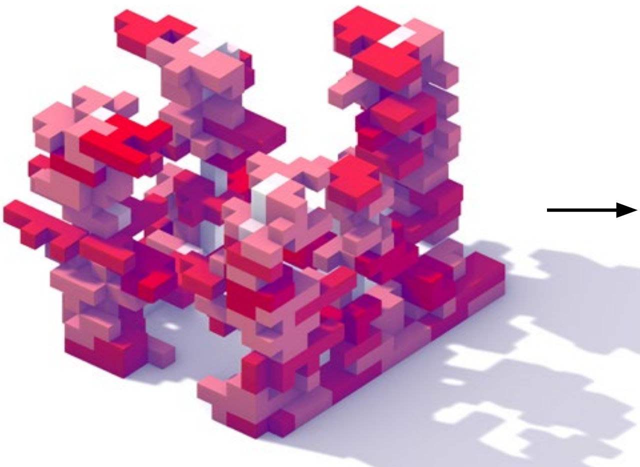
The deleting parameter defines the minumum age in iterations at which a cluster is checked for its topological (size and subclusters), environmental (sun, view, privacy) and structural requirements. The age of a cluster is measured from the iteration at which the cluster was last modified via adding a voxel or adding a subcluster. Low deleting parameter ranges (approx 50) usually lead to better results as clusters are evaluated as soon as possible after their creation which reduces delayed deleting that potentially leads to more fragmented and inefficient spatial compositions.



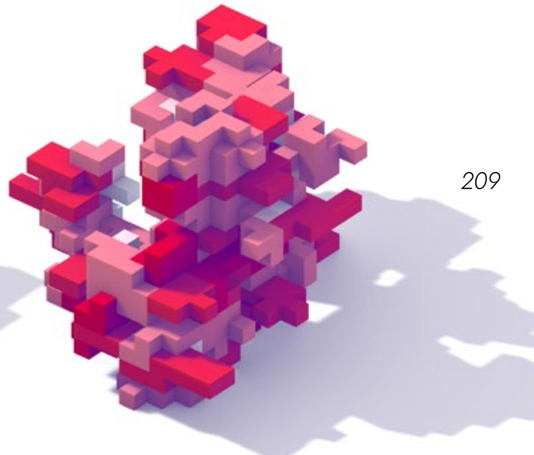
GLOBAL COMPACTNESS

compactness multiplier | %

Global compactness multiplier is a percentage reduction factor between 0 - 100% modifying the guide field values in accordance with a global occupation field; areas which are already densely occupied are preferred. This leads to aggregations less spread out over space and encourages "clumping" behaviour leading to much more compact spatial compositions.



unconstrained aggregation

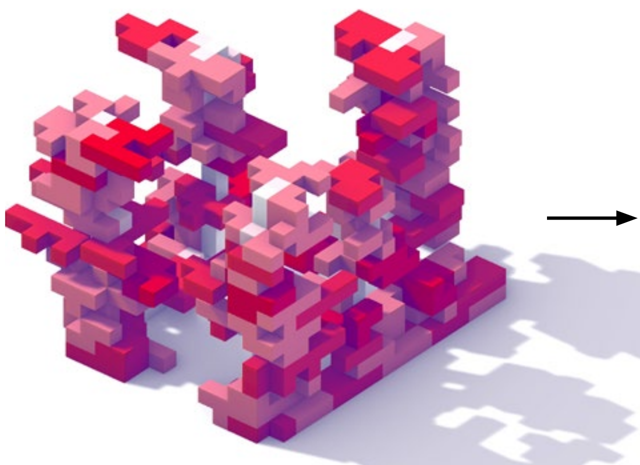


global compactness multiplier

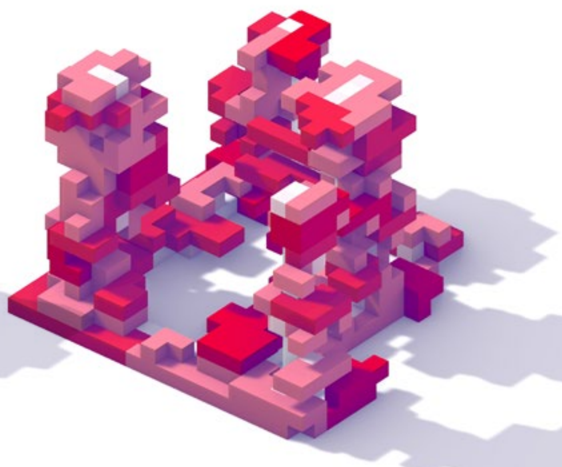
LOCAL COMPACTNESS

compactness multiplier | %

Local compactness multiplier is a percentage reduction factor between 0 - 100% modifying the guide field values in accordance with the number of immediately neighbouring voxels; top, bottom, left, right, front, back. As such, points with a high number of neighbours are assigned a higher percentage value leading to lower reduction and consequently preference. Practically, this behaviour skews aggregation towards locally more compact spatial compositions with a smaller facade to volume ratio.



unconstrained aggregation

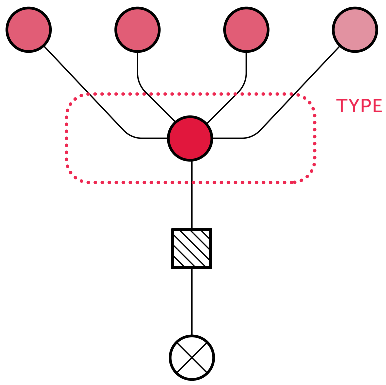


local compactness multiplier

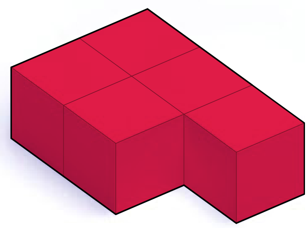
TYPE PARAMETERS

type ID | #   type name

Type parameters is the first type-specific user input with which it is possible to create a new type and assign it a unique ID number and a name. Types are the basis of the simulation and represent unique nodes in a spatial network that describes the desired configuration. Beyond having an ID and name, types have many specific parameters assigned to them that control the way in which they aggregate in the eventual simulation.



allowed aggregation directions

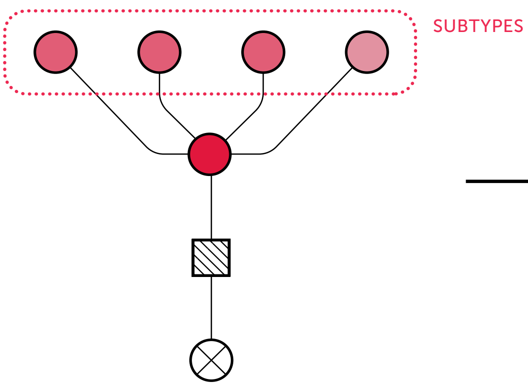


allowed aggregation directions

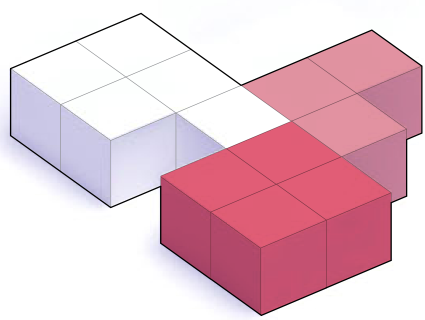
SUBTYPES PARAMETER

possible subtypes | ID   min. subclusters | #   max. subclusters | #

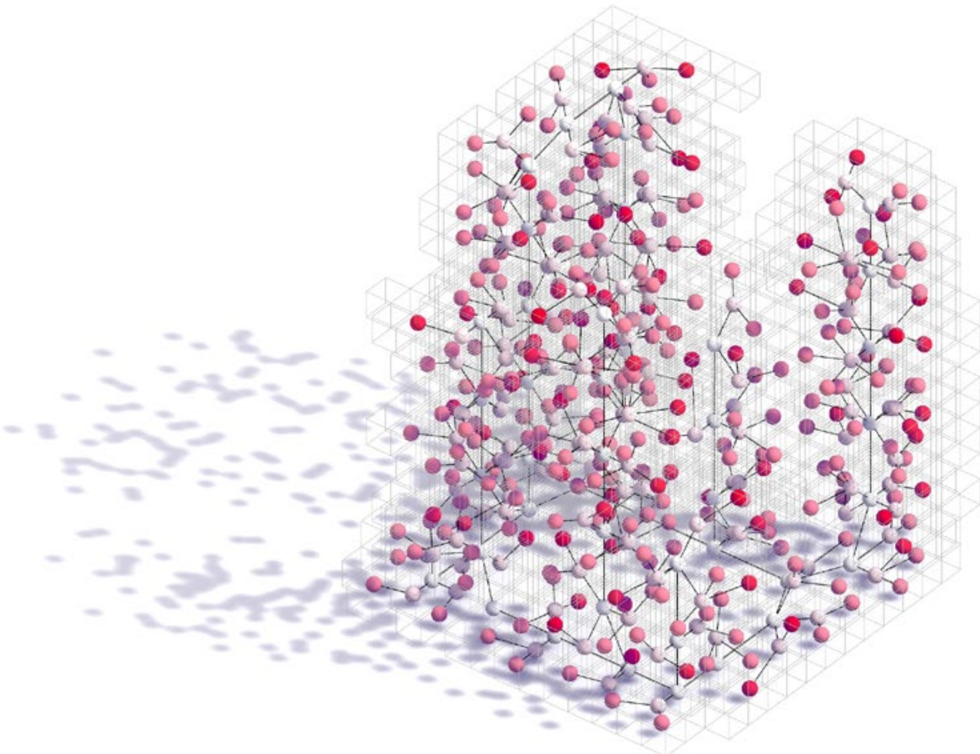
Subtypes parameters define the configurational connections between previously mentioned types and are the equivalent of links in a spatial network. Subtypes specify which other types are allowed to grow from a selected type as well as their number. Max and Min subclusters define the number of subtypes that should/can be connected to a cluster; the maximum number can never be exceeded, while if the minimum is not reached the cluster will be removed. Both parameters can be set either as a single total value per cluster (e.g. min 2 subtypes of A or B) or as multiple values each controlling a specific subtype (e.g. min 1 subtype A and min 2 subtype B).



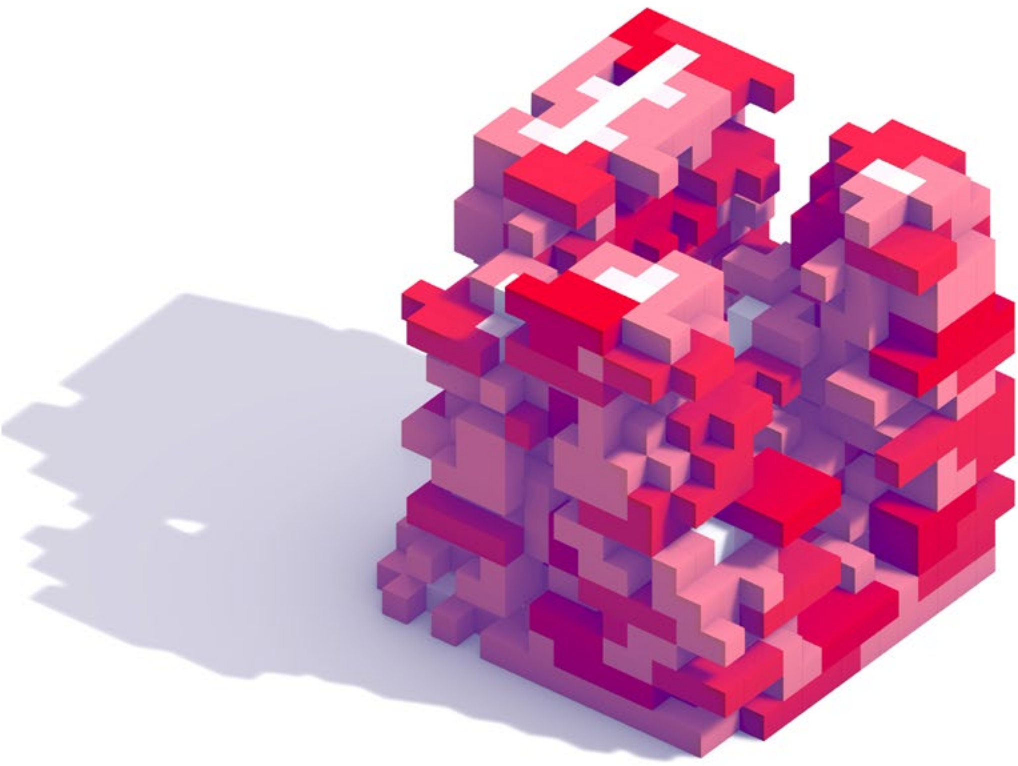
allowed aggregation directions



allowed aggregation directions



aggregation topology resulting from a defined configuration

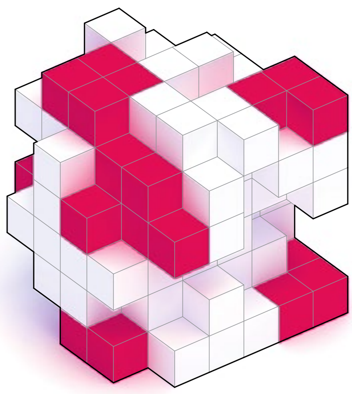


aggregation morphology resulting from the spatialisation of the topology

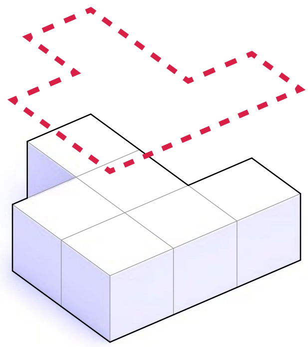
SIZE BEHAVIOUR

cluster size | m2 · min. cluster size | % · total percentage | %

Size parameters control the growth of individual clusters through defining room sizes as well as global programme distribution. Total percentage parameter represents the desired final percentage of a specific type in the entire aggregation. Alternatively it can be defined as 0 for programmes such as circulation leading to their minimum possible footprint. Cluster size is defined in m2 and controls the desired size of a cluster type, while min. cluster size is a minimum percentage of the defined cluster size below which the cluster will be removed if insufficient.



cluster percentage of total volume

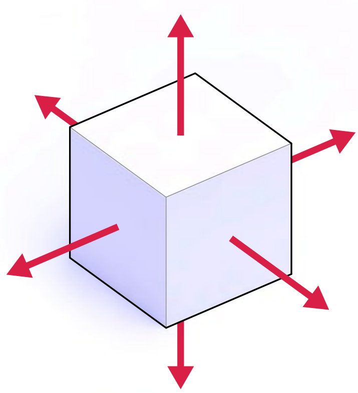


cluster desired and minimum area

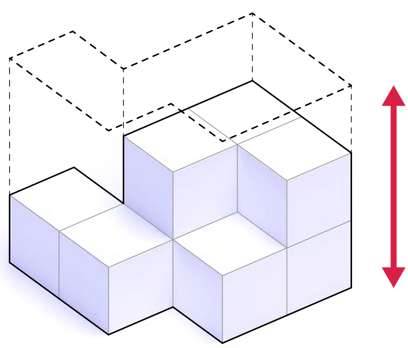
LEVELS BEHAVIOUR

level aggregation | type # · max. number of levels | #

Levels parameters control the direction of cluster aggregation and the maximum number of levels. Level aggregation type is a setting where 0 allows for aggregation in all directions from the initial voxel, 1 only in horizontal directions and 2 only in vertical directions (especially useful for circulation cores). The maximum number of levels controls the max number of voxels stacked vertically in an individual cluster thus allowing for the control of number of floors.



allowed aggregation directions

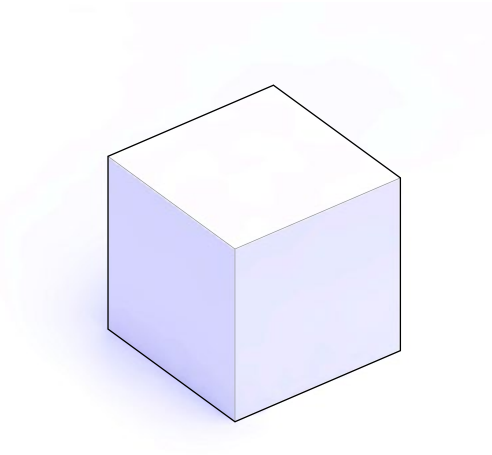


maximum levels per cluster

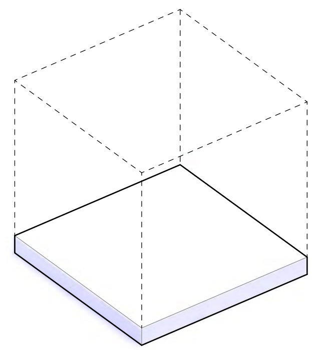
GEOMETRY BEHAVIOUR

cell geometry type | type #

Geometry parameters define the phsical voxel shape of a specific type which is later used from a range of physical sunlight, view, privacy and structure checks. Currently the simulations implement two voxel types; an enclosed interior voxel representing rooms and corridors and an exterior voxel representing terraces and streets. This is subject to later expansion into potential other shapes.



solid / interior cell geometry

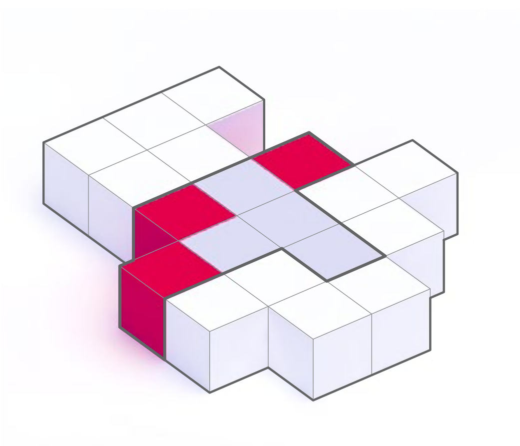


void / exterior cell geometry

FACADE PERCENTAGE BEHAVIOUR

cluster voxel facade percentage | %

Facade percentage parameter controls the minimum required percentage of voxels in a cluster with an exterior facade (pictured red) as opposed to being entirely surrounded by occupied voxels (gray). If this constraint is not met the cluster will be removed.

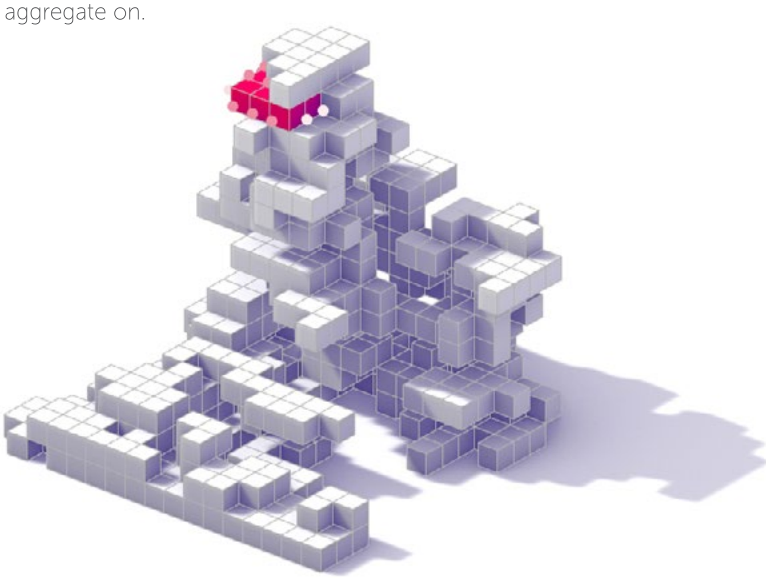


min % of cluster voxels with facade

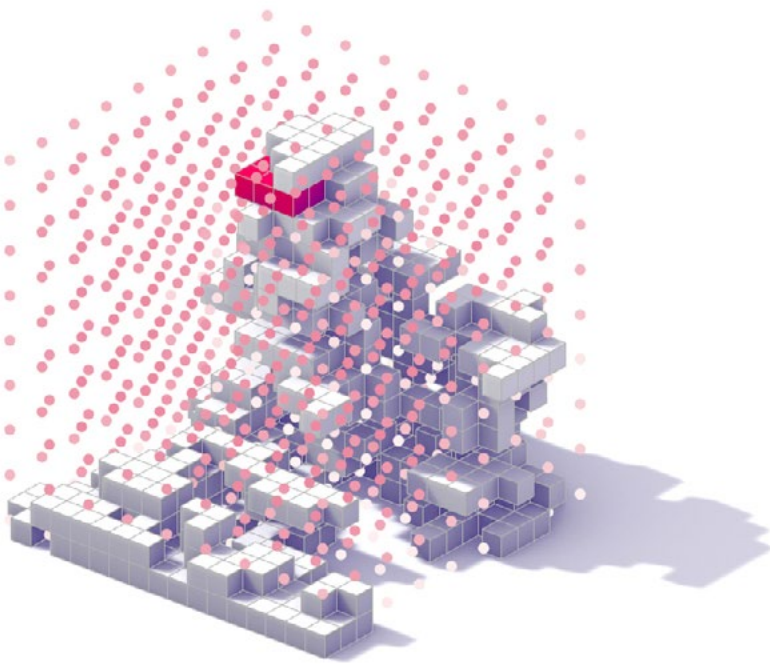
SEARCH BEHAVIOUR

search behaviour type | type # search reach distance | # of voxels

Search behaviour is a type specific parameter controlling the way in which a cluster searches the envelope to find the optimal areas towards which to expand. Local search, defined as 0, mostly governs the behaviour of conventional programme by searching the immediate vicinity of the cluster, evaluating the points and attempting to expand into the best. Global search, defined as 1, predominantly governs the behaviour of circulation and enables it to inspect the entire field in search of unexplored and unoccupied areas with a high evaluation value. This enables circulation types to branch across space and provide a framework for convential programme to aggregate on.



local search | e.g. apartment

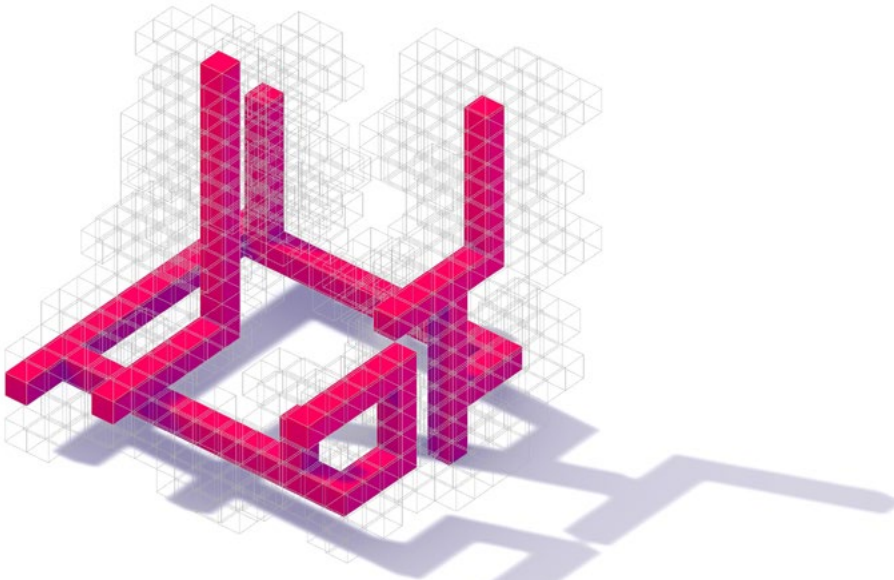


global search | e.g. circulation

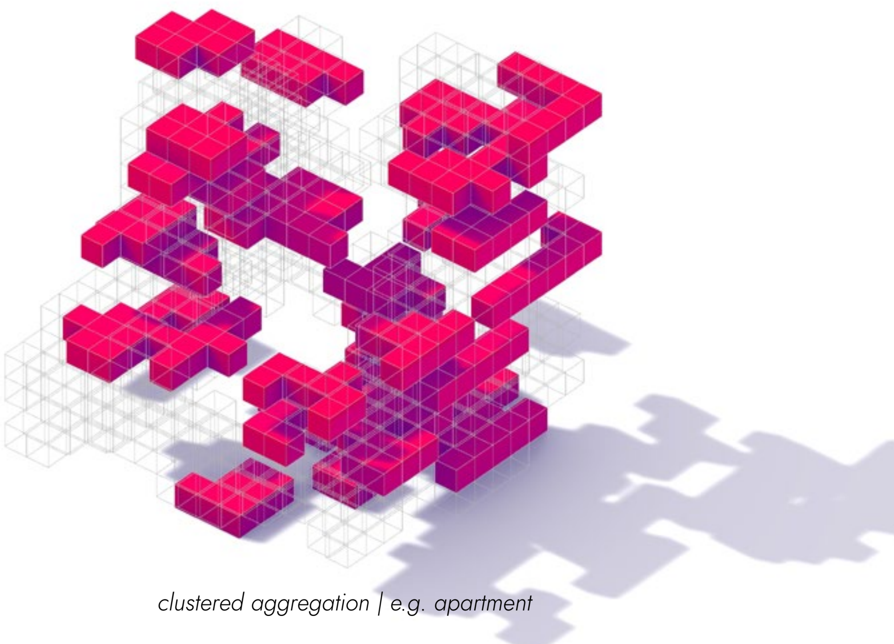
SHAPE BEHAVIOUR

shape behaviour type | type #   shape multiplier | %

Shape behaviour is a type specific parameter allowing for control of the shape of cluster aggregation. Compact aggregation, defined by 0, skews the measured values of potential expansion points by assigning higher values to points closer to the existing cluster voxels. Alternatively, linear aggregation defined by 1 skews point values by assigning higher values to points further away and at the edges of a cluster. The shape multiplier percentage factor controls the strength of the effect of this behaviour on the original measured field values.



linear aggregation | e.g. circulation



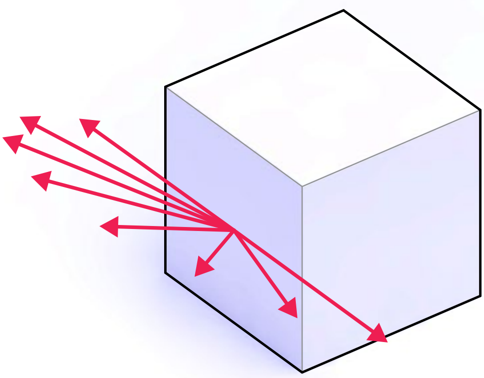
clustered aggregation | e.g. apartment

SUNLIGHT PARAMETER

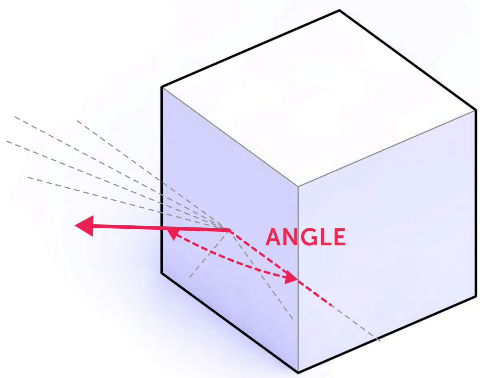
min. sun hours | # hours   min. % of voxels | % or -1   field weight | %

min. facade angle | # angle

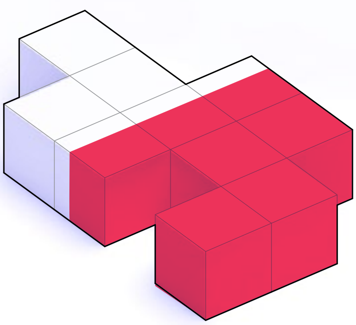
Sunlight parameters control the type-specific cluster requirements for direct sunlight. This is defined as a minimum number of hours per day which can be measured for the cluster as a whole or individually per voxel. In the latter case the minimum can be controlled by the minimum percentage of total voxels in cluster (e.g. a cluster requires a minimum of 5 hours of sunlight in 40% of its voxels). Sunlight access is measured by shooting a ray for each sun hour from the centerpoint of a vertical voxel facade. For sun to be visible from a voxel the ray must be unobstructed by other geometry, while the angle between itself and the facade must be larger than the amount specfied with the min. facade angle parameter. The field weight parameter defines the weighting of sun to other environmental parameters when evaluating the environment field in pre-check stage. Currently the sun simulations are executed with sun vectors from 21.3. in



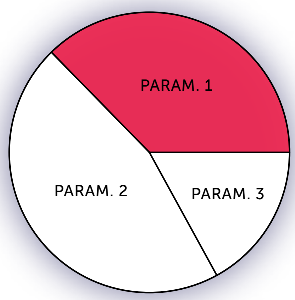
minimum number of sunlight hours per cluster



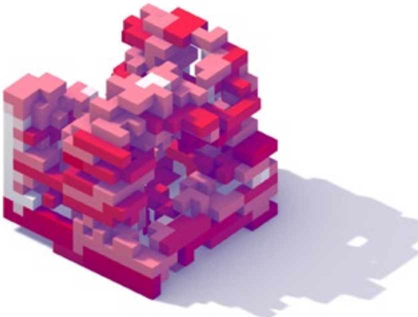
minimum allowed angle from facade plane



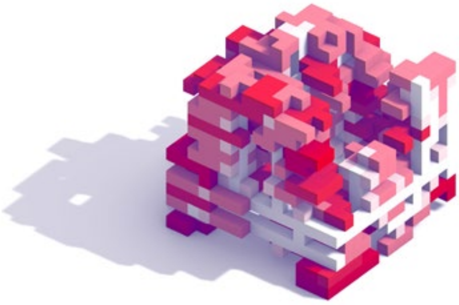
minimum percentage of voxels in cluster to meet criteria OR evaluate cluster as whole (-1)



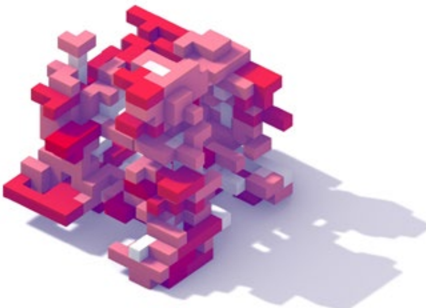
field weight parameter



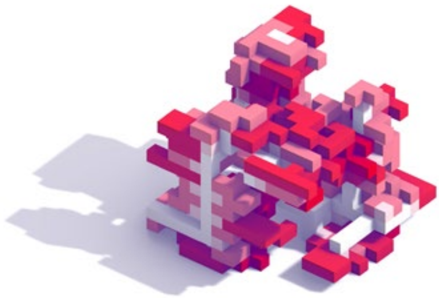
3 hrs | SE



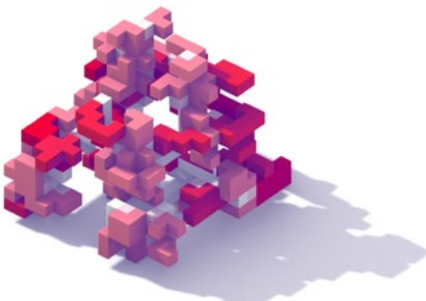
3 hrs | NW



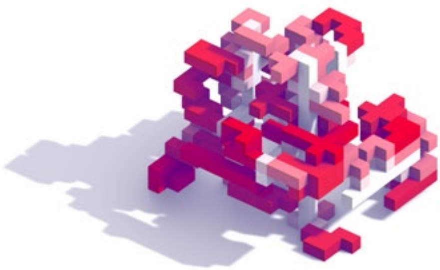
5 hrs | SE



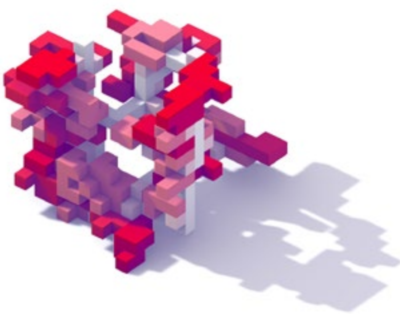
5 hrs | NW



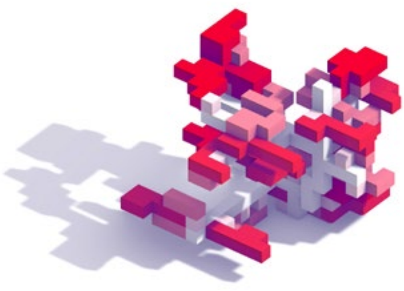
7 hrs | SE



7 hrs | NW



9 hrs | SE



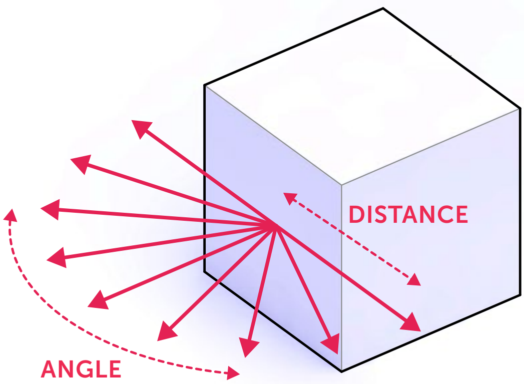
9 hrs | NW

VIEW PARAMETER

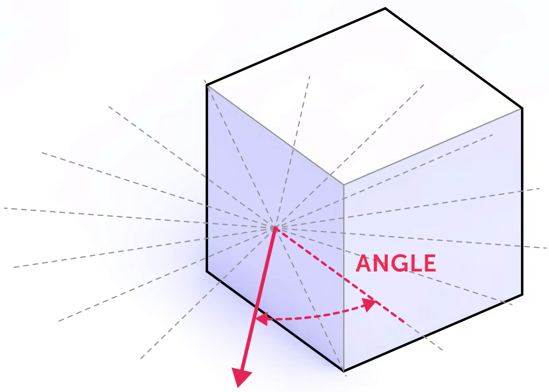
min. view angle | # deg. min. distance | # meters min. % of voxels | % or -1

field weight | % min. facade angle | # angle

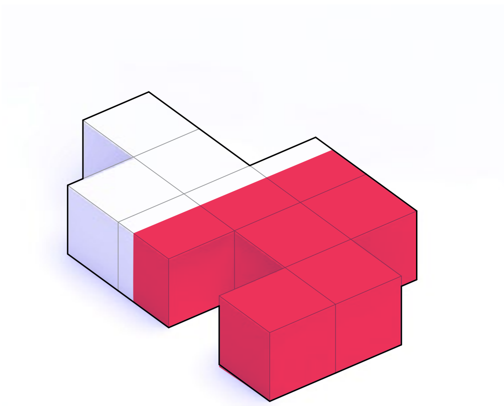
View parameters control the type-specific cluster requirements for surrounding views. Views are defined as a minimum angle and distance which can be measured for the cluster as a whole or individually per voxel. In the latter case the minimum can be controlled by the minimum percentage of total voxels in cluster (e.g. a cluster requires a minimum of 90 degree views at 50 meters in 40% of its voxels). View availability is measured by shooting a ray for each direction from the centerpoint of a vertical voxel facade. For a view to be possible from a voxel the ray must be unobstructed by other geometry for the minimum defined distance, while the angle between itself and the facade must be larger than the amount specfied with the min. facade angle parameter. The field weight parameter defines the weighting of views to other environmental parameters when evaluating the environment field in pre-check stage. Currently, simulations are executed with view vector directions obtained by dividing a circle into 8 directions, each representing a 45 degree view angle. This resolution can easily be increased by increasing the number of subdivisions albeit at the cost of slower performance.



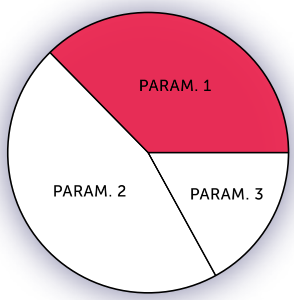
minimum view angle per cluster



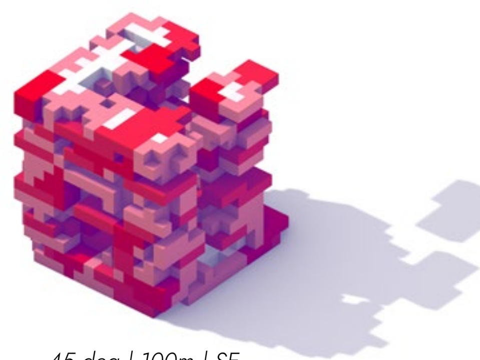
minimum allowed angle from facade plane



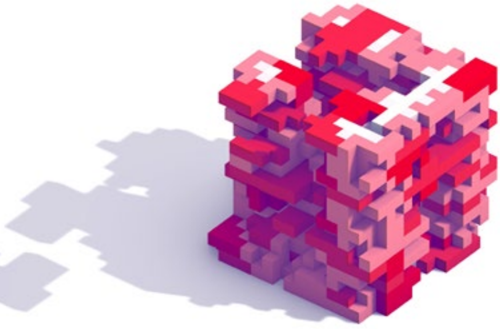
minimum percentage of voxels in cluster to meet criteria OR evaluate cluster as whole (-1)



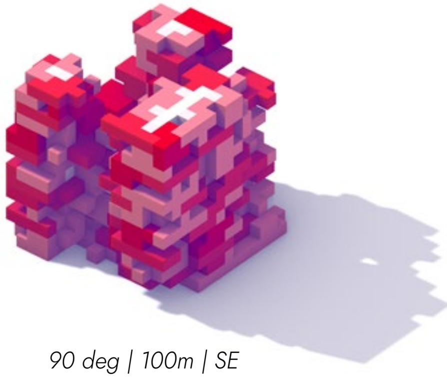
field weight parameter



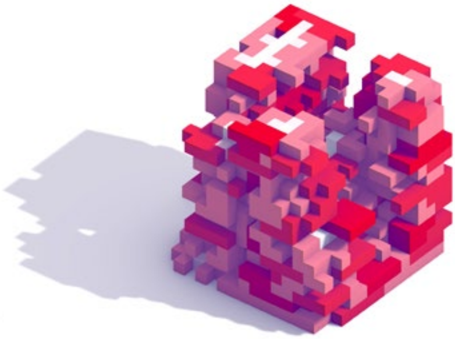
45 deg | 100m | SE



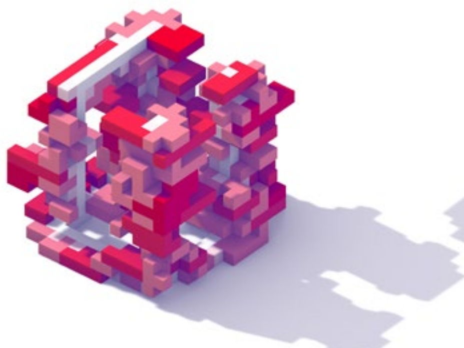
45 deg | 100m | NW



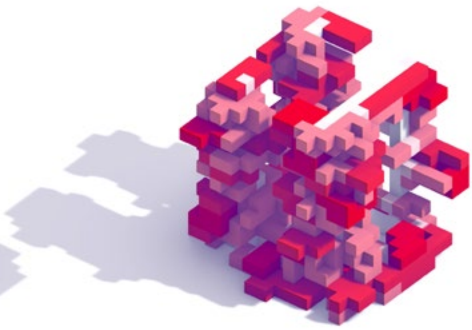
90 deg | 100m | SE



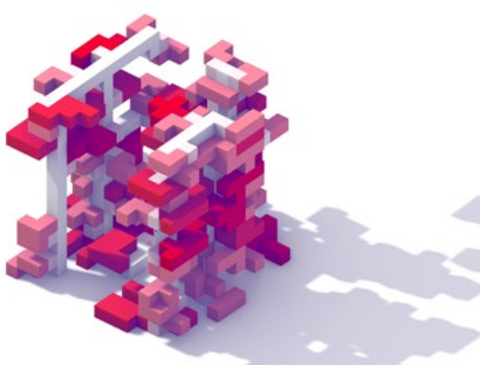
90 deg | 100m | NW



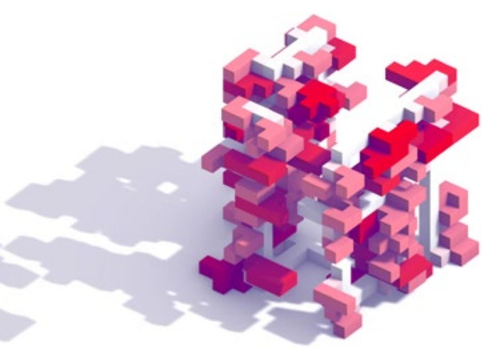
180 deg | 100m | SE



180 deg | 100m | NW



270 deg | 100m | SE

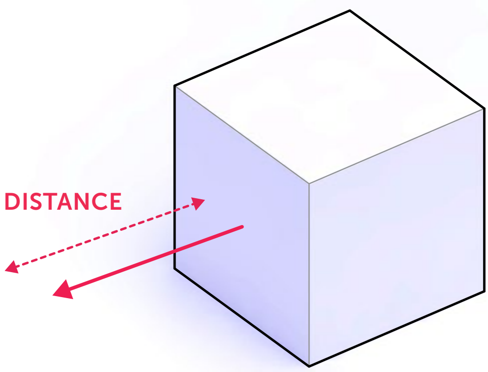


270 deg | 100m | NW

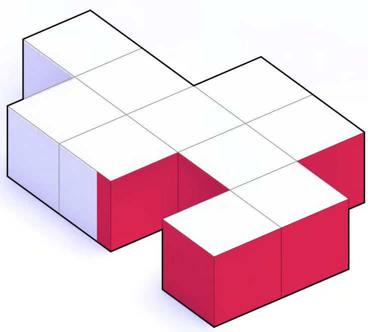
PRIVACY PARAMETER

min. distance | # meters   min. % of facades | %   field weight | %

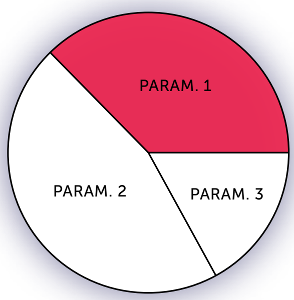
Privacy parameters control the type-specific cluster requirements for visual privacy. Visual privacy is defined as a minimum offset distance in meters from the exterior facades of a cluster and is measured for the cluster as a whole. Privacy is measured by measuring the perpendicular distance from the centerpoint of each vertical voxel facade to the next closest voxel facade. The minimum number of cluster facades that must meet the minimum distance requirement is controlled by the facade percentage parameter. The field weight parameter defines the weighting of visual privacy to other environmental parameters when evaluating the environment field in pre-check stage.



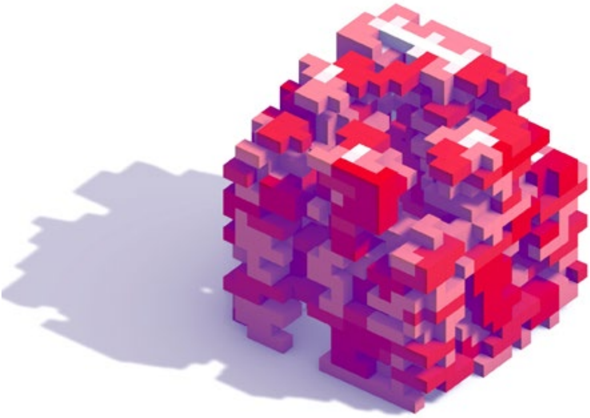
minimum privacy distance



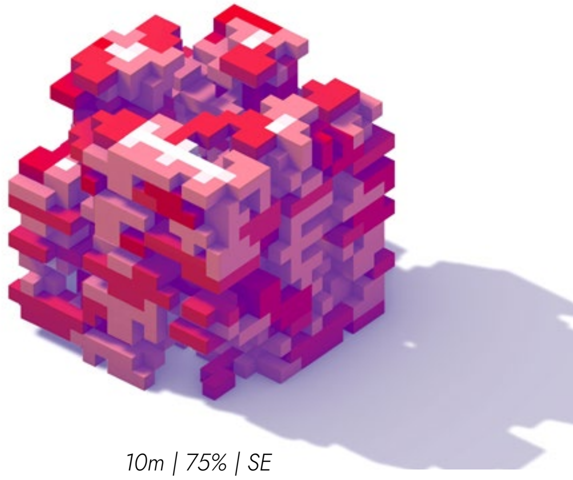
minimum percentage of facades



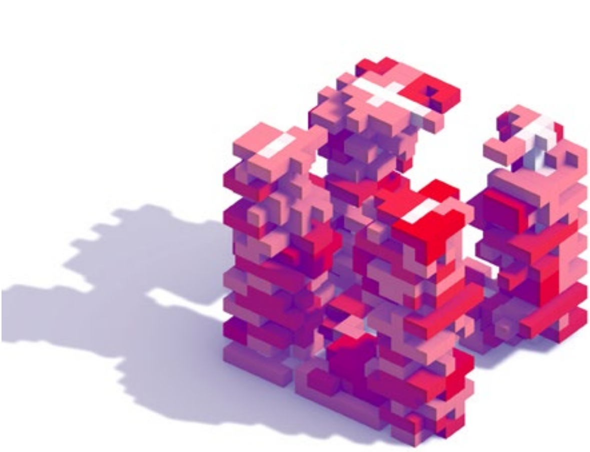
field weight parameter



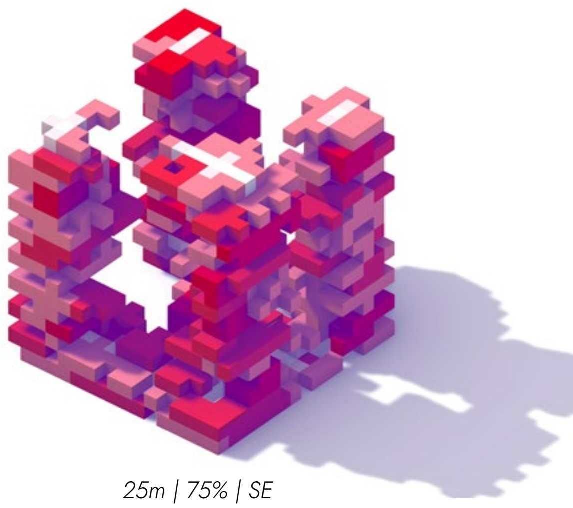
10m | 75% | NW



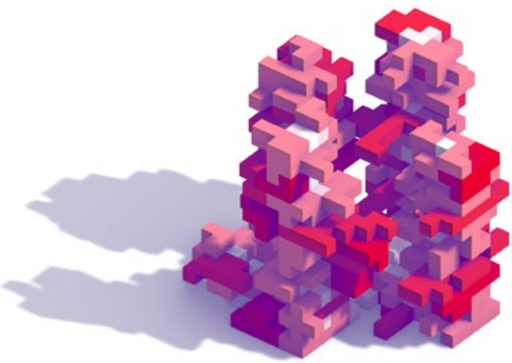
10m | 75% | SE



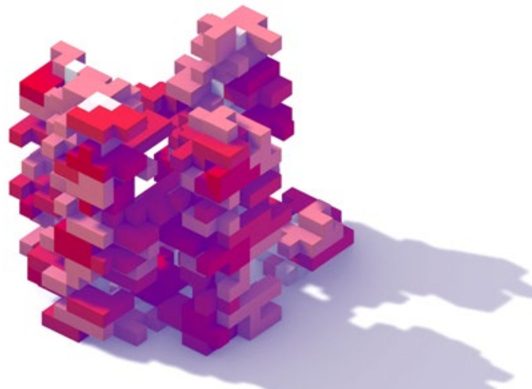
25m | 75% | NW



25m | 75% | SE



50m | 75% | NW

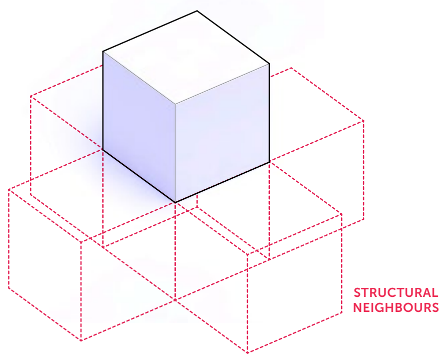


50m | 75% | SE

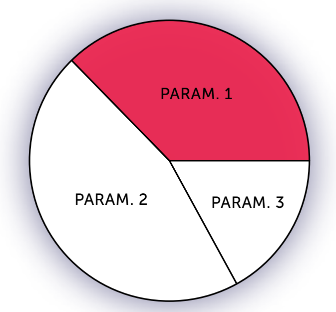
STRUCTURE PARAMETER

min. structure | factor field weight | %

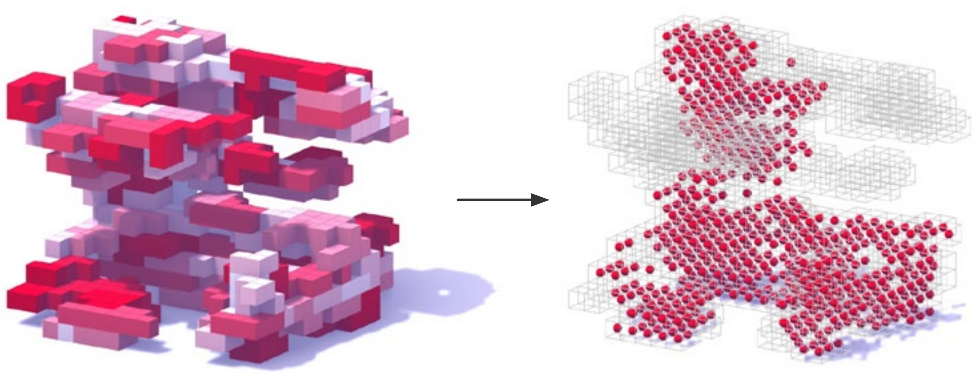
Stuctural parameters control the building statics; can a specific voxel / unit / building physically stand in the place where it's placed and is it feasible to construct? If a cell is structural is calculated via a cellular-automata-like algorithm which, starting from the ground up, examines the structurality states of each of its neighbours from which, based on a set of criteria, the cell's own state is defined. The architect can control the strength of this behaviour by defining a factor from 0 to 1 affecting the minimum requirements of a cell to be structural and the weight which controls weighting of structure to other environmental parameters in the environment field. The influence of structure in the process of morphogenesis cannot be understated. Gravity affects every living and non-living structure and guides their formation. The rudimentary approach applied here has proven to be sufficient to control and generate feasible structures in most cases, but nevertheless presents a major area of potential improvement in the future. Beyond simple towers, slabs and cantilevers, the more complex structural arrangements such as those found in nature, some of which are surely excluded currently as a result of the simplified approach, could hold great potential for new urban form with a drastically different structural and hence spatial disposition.



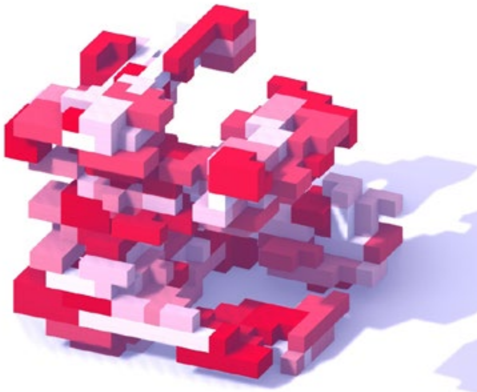
structure rule



field weight parameter

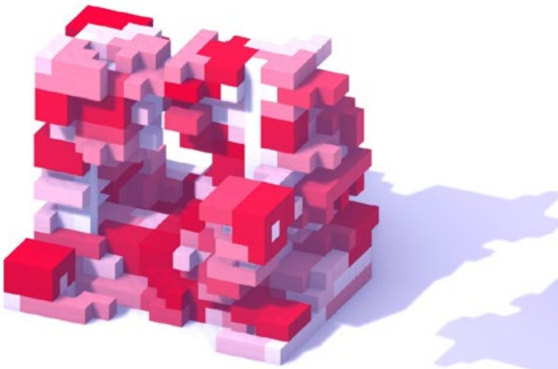


structure calculation principle

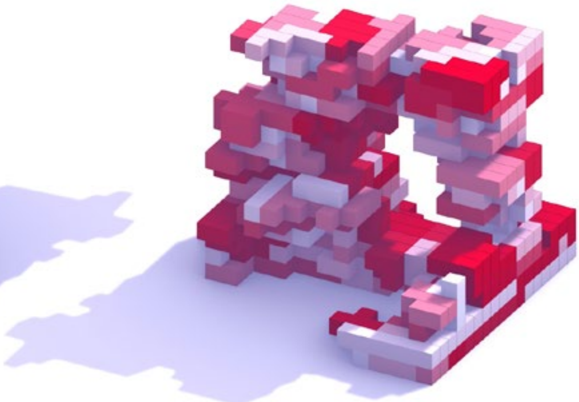


structure factor 0.0 | NW

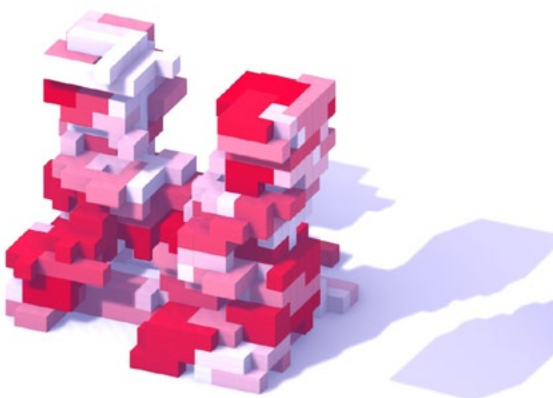
structure factor 0.0 | SE



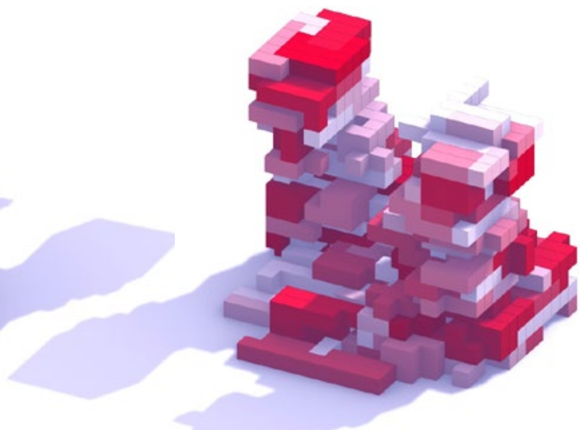
structure factor 0.5 | NW



structure factor 0.5 | SE

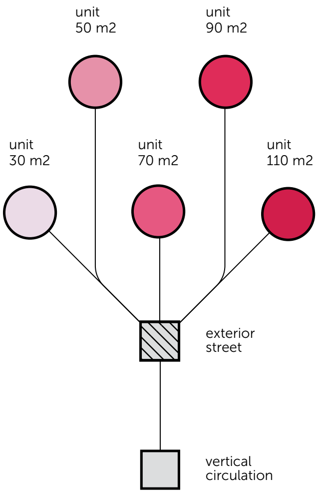


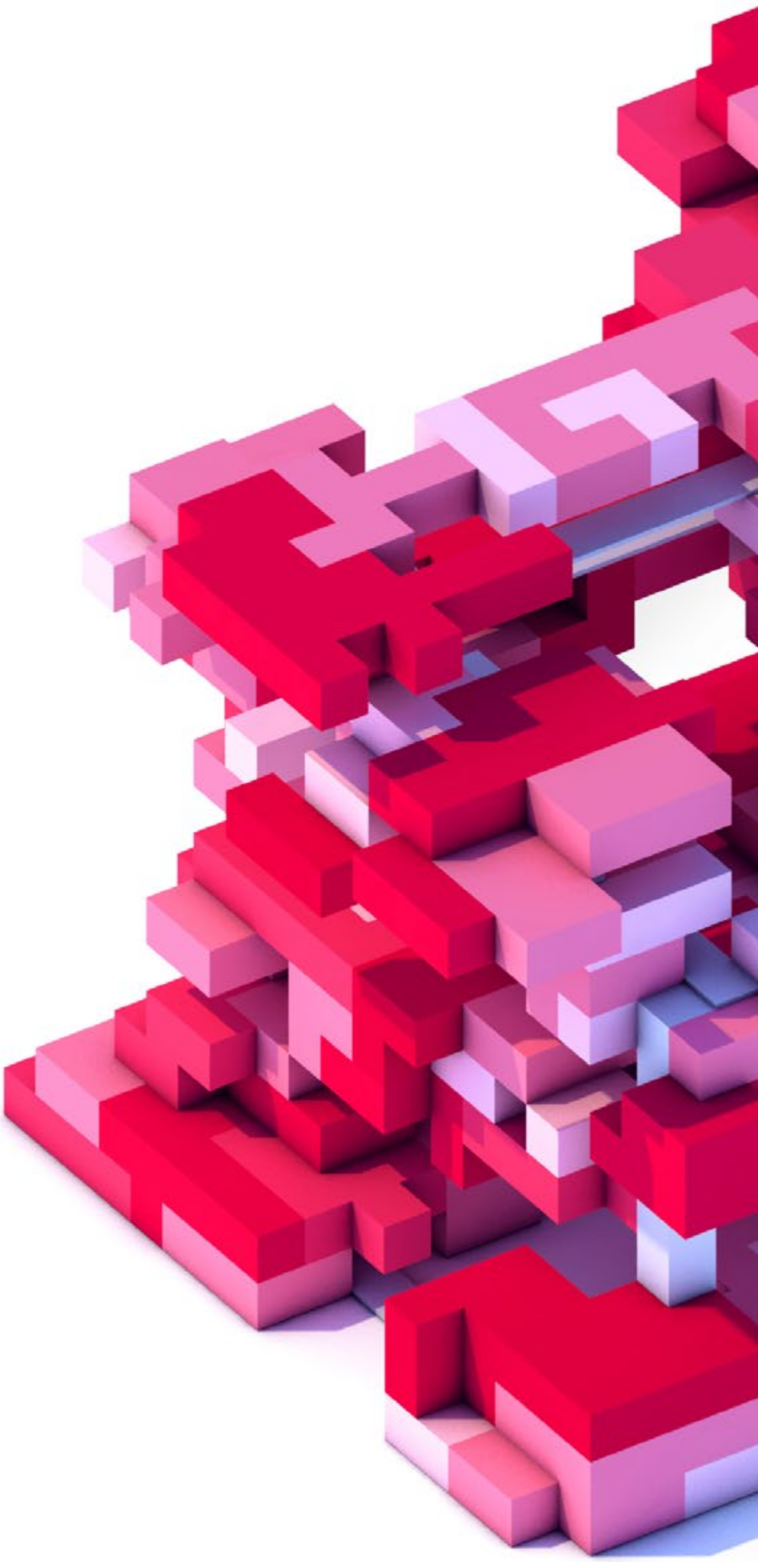
structure factor 1.0 | NW



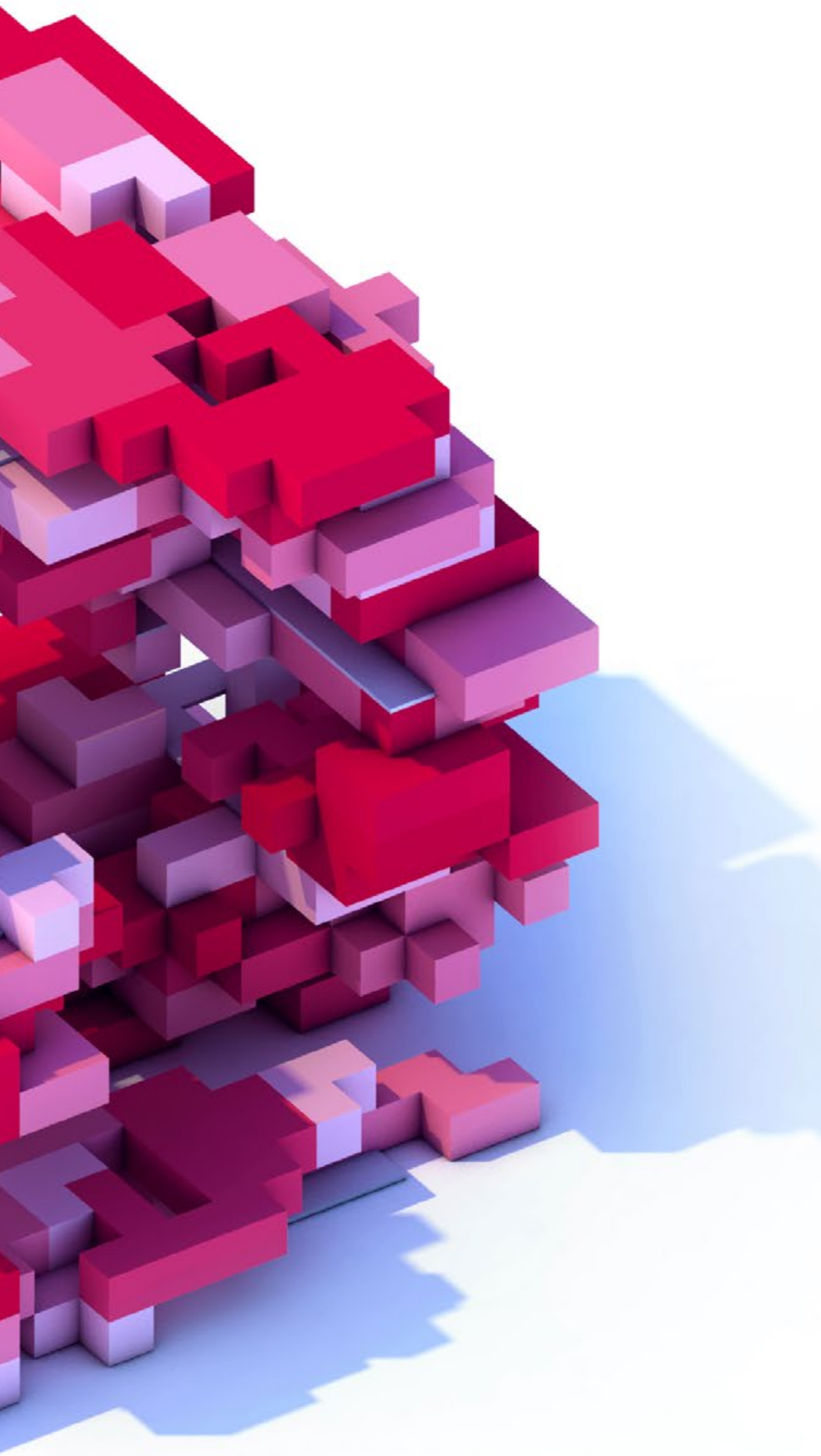
structure factor 1.0 | SE

AGGREGATION PROCESS

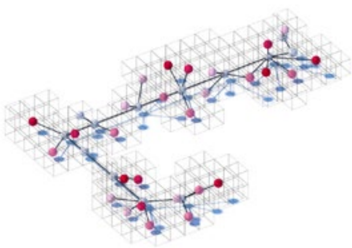




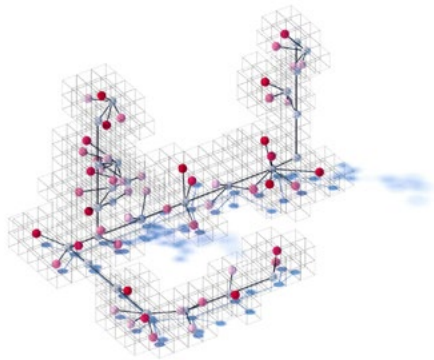
SCAN FOR
AR VIDEO



THE AGGREGATION process by default starts in an empty envelope, although a predefined aggregation as an input is possible. After evaluating the global field for spatial requirements and choosing an optimal start location it begins aggregating. At each iteration the algorithm adds a single voxel based on the requirements of the input configuration and removes voxels that potentially fail due to reasons of size, topology, environmental parameters, etc. As the algorithm grows it consistently keeps track of all the topological connections in the aggregation allowing for both previews during the process. Through this process the main circulations such as cores, corrdors and external streets essentially traverse the envelope for unoccupied areas with environment field values which indicate potential for aggregation of the input programme. As such, these circulation types have priority and are allowed to remove existing voxels in their path, allowing them to reach unoccupied areas, while the programme aggregates and reaggregates around them. Thhoughout the process the number of total voxels usually follows a logarithmic curve, eventually flattening out when no more can be added and the simulation stops. As seen from the aggregation timeline (next page), the final iteration leads to a substantial dip in the number of voxels, which is due to the final check of all clusters for all requirements - topological, environmental and structural - and subsequent removal of all who fail the minimum defined parameters.



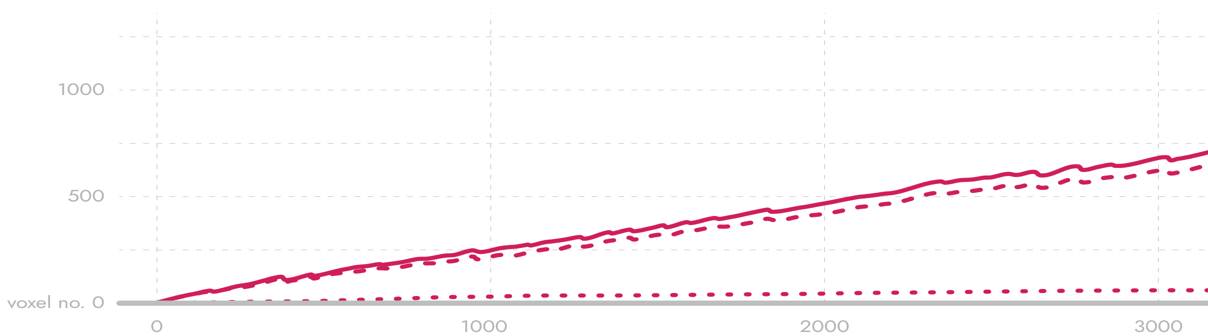
iteration # 500 | topology

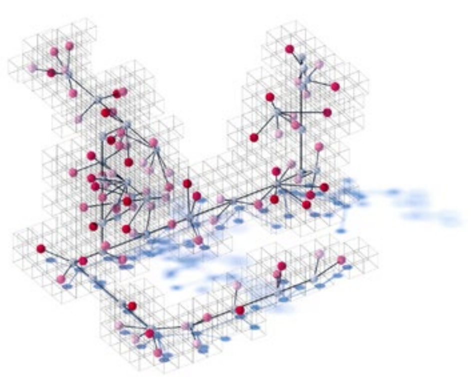


iteration # 1000 | topology

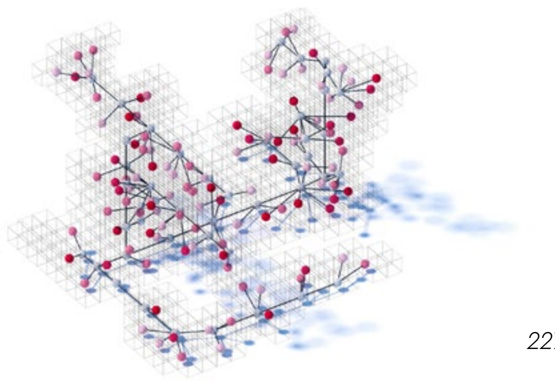
iteration # 500 | volume

iteration # 1000 | volume

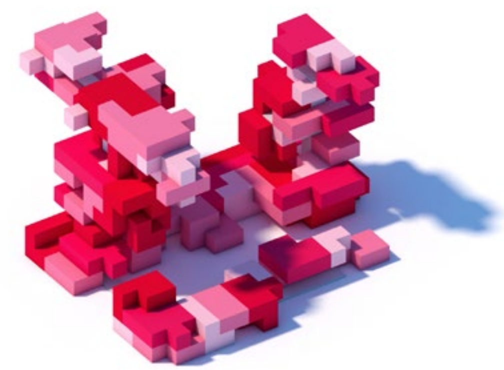




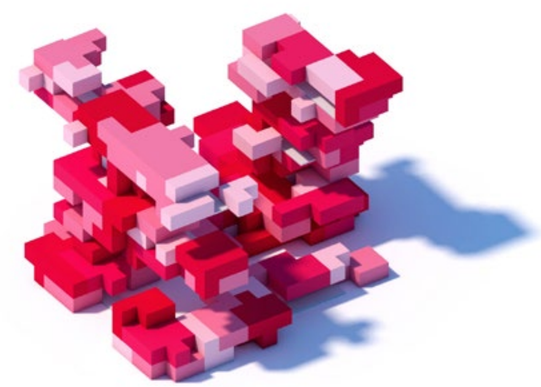
iteration # 1500 | topology



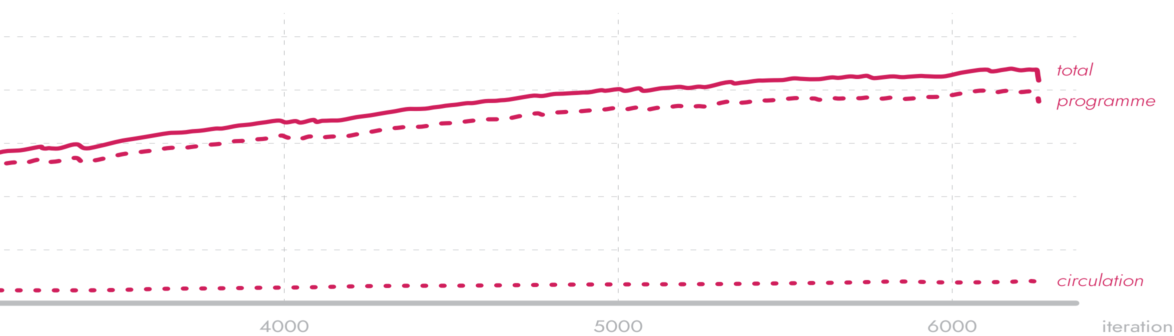
iteration # 2000 | topology

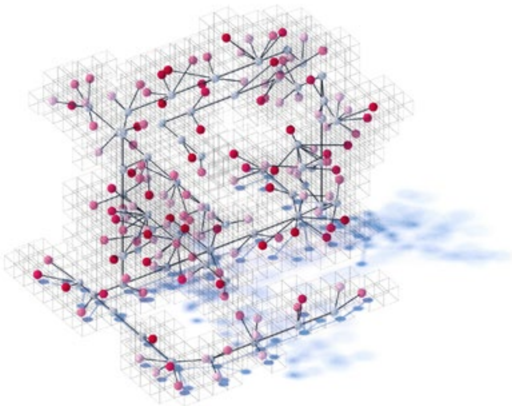


iteration # 1500 | volume

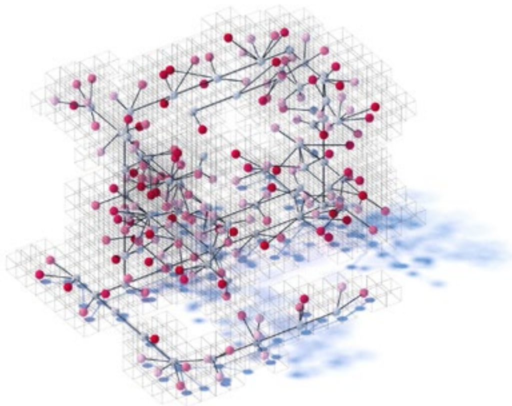


iteration # 2000 | volume

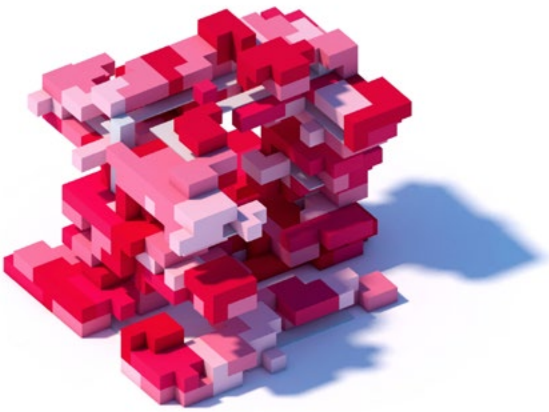




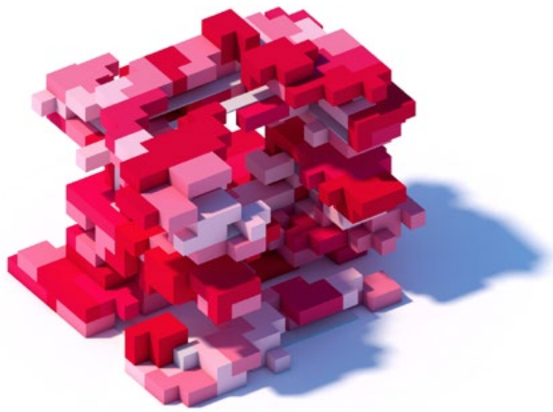
iteration # 3000 | topology



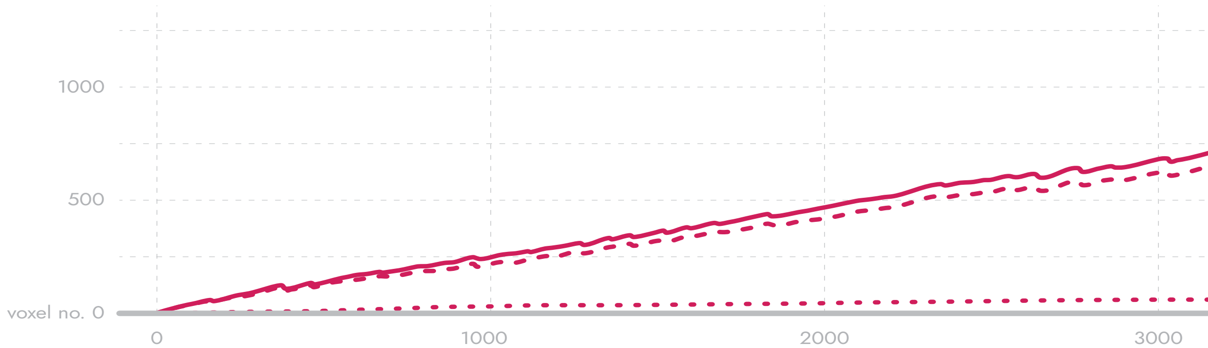
iteration # 4000 | topology

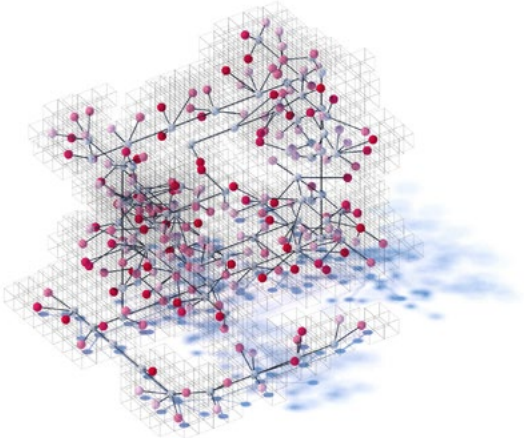


iteration # 3000 | volume

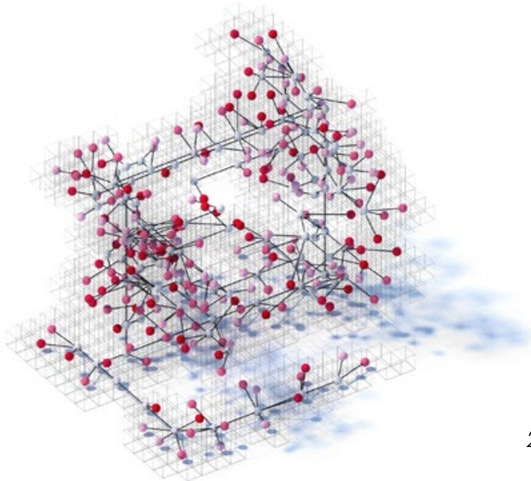


iteration # 4000 | volume

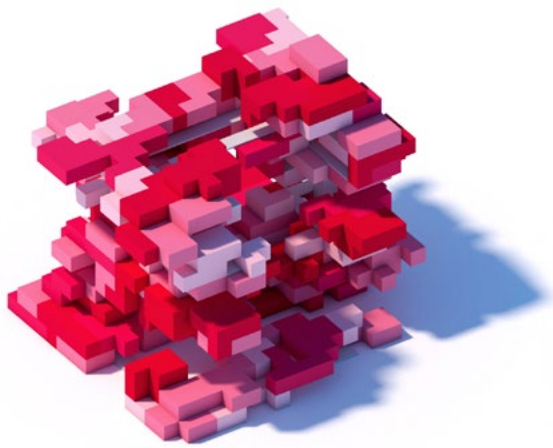




iteration # 5000 | topology

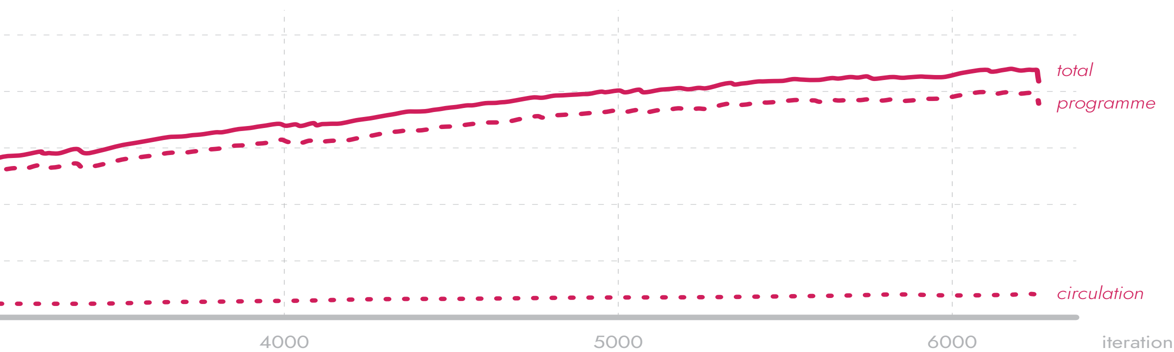


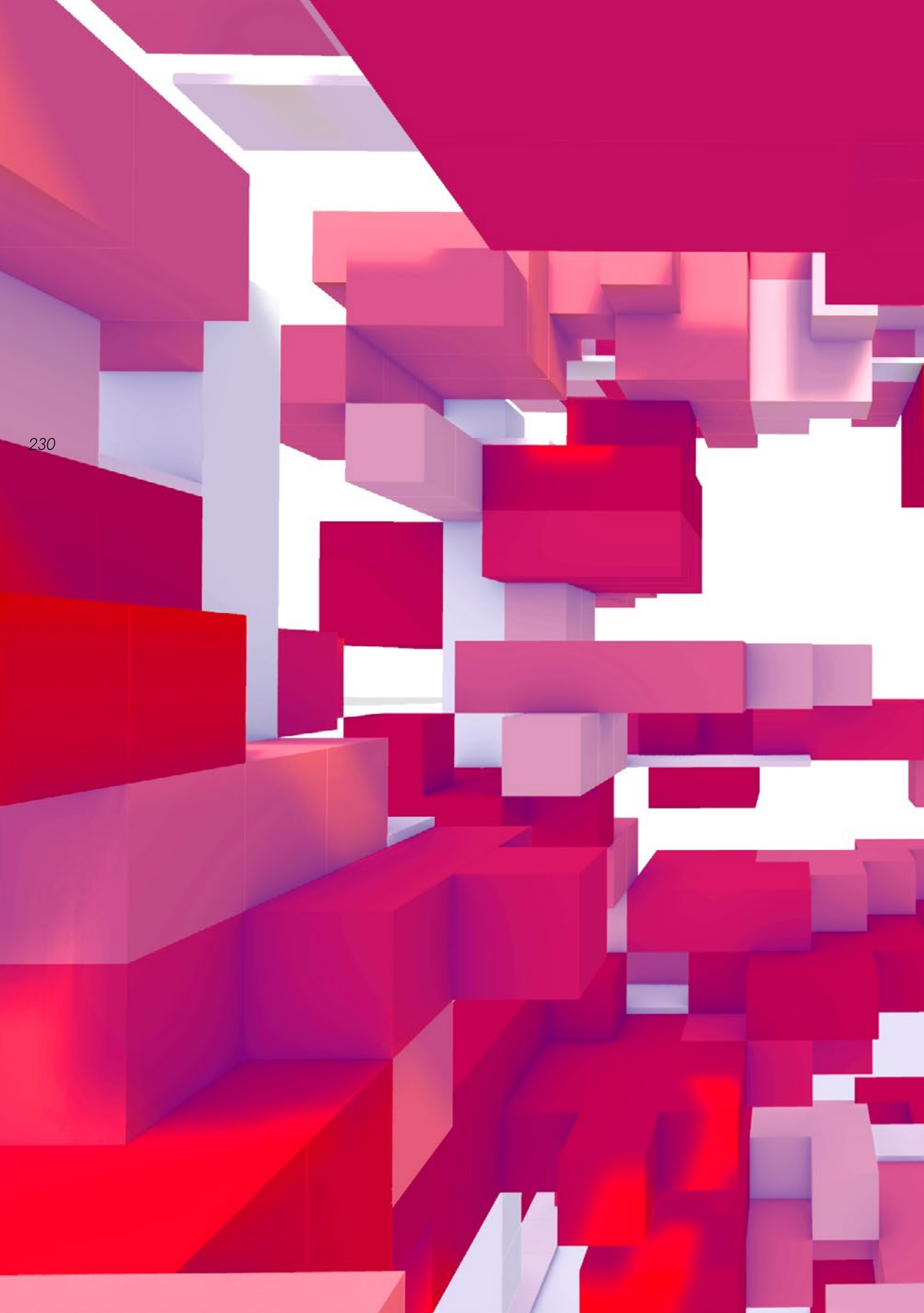
iteration # 6000 | topology

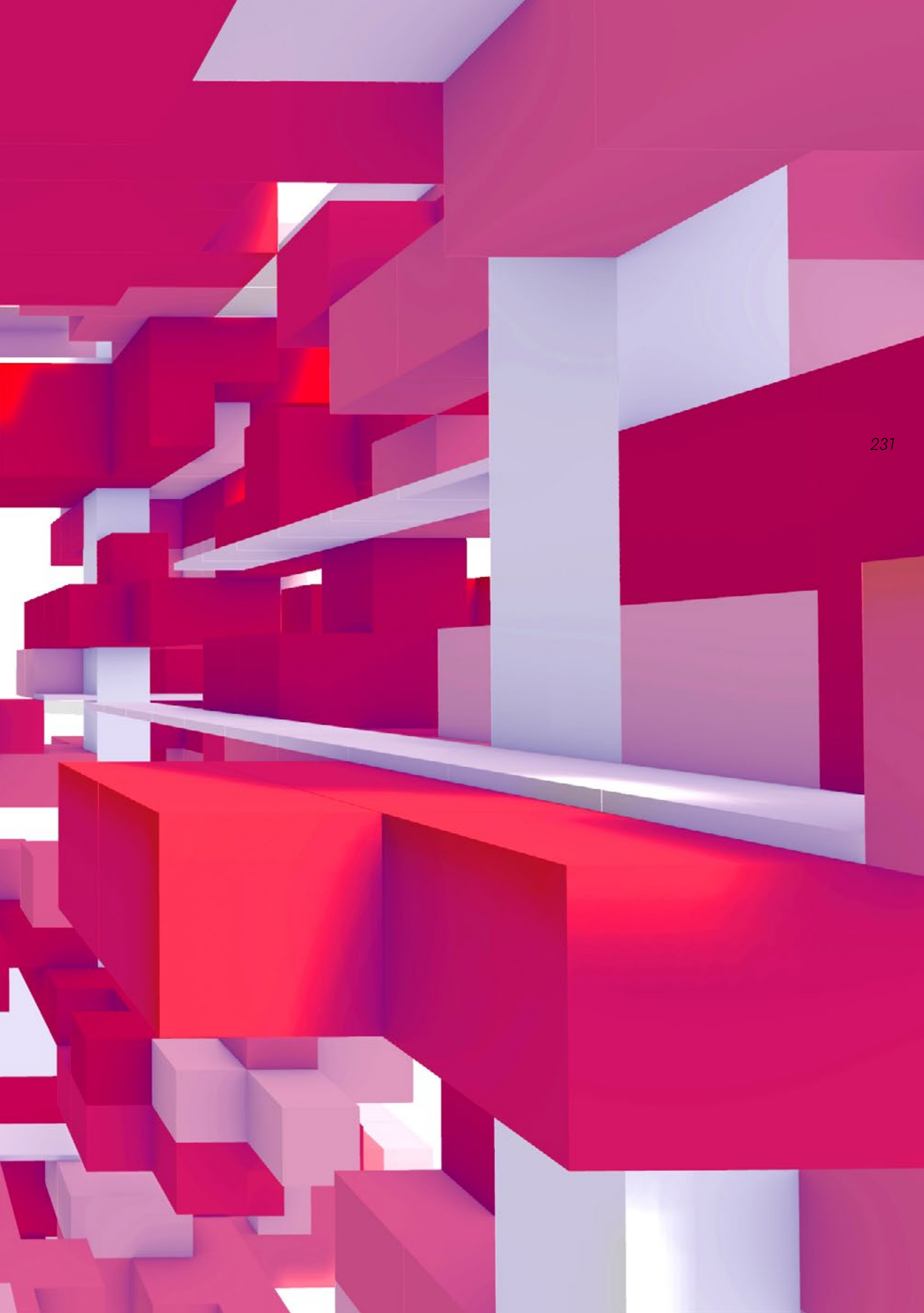


iteration # 5000 | volume

iteration # 6000 | volume

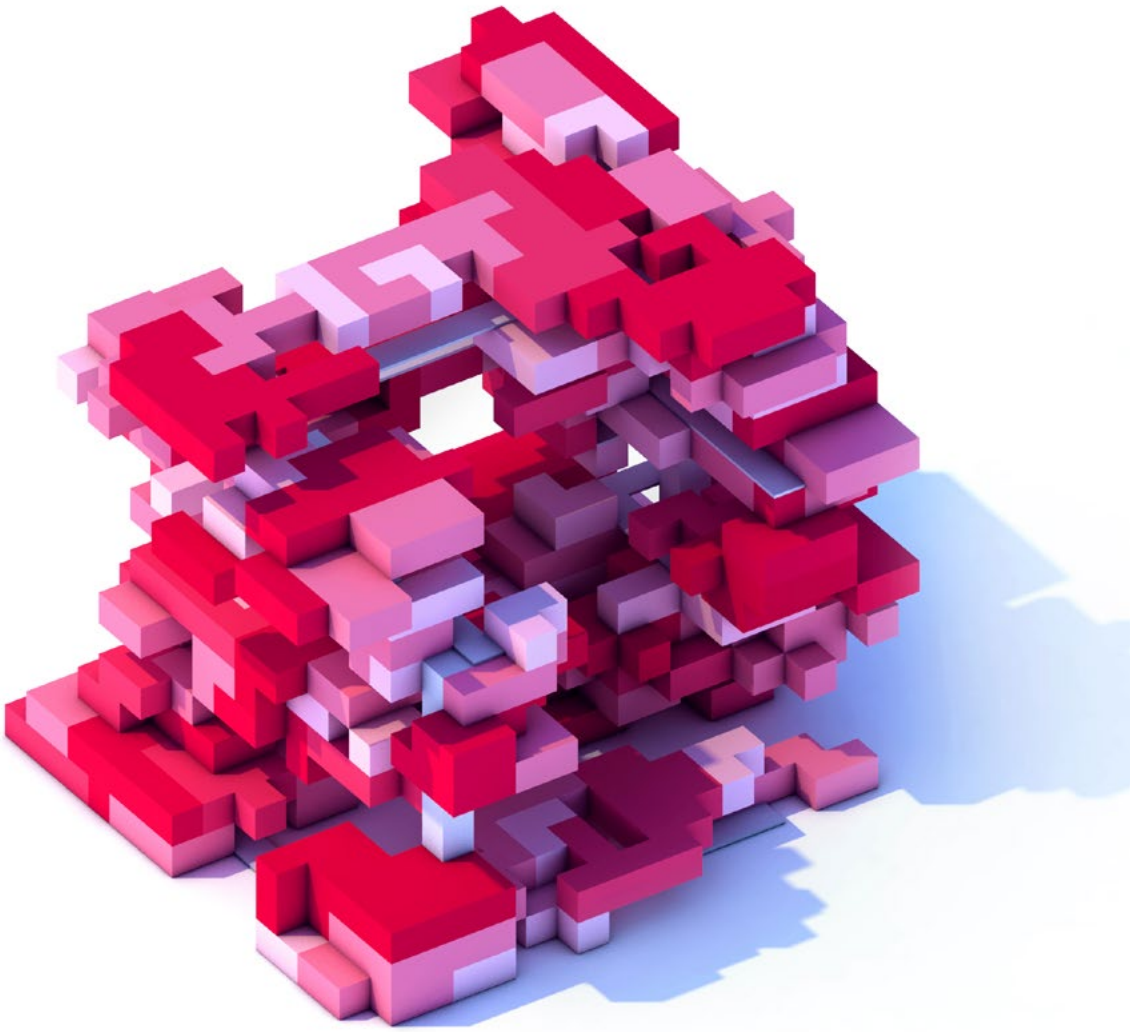




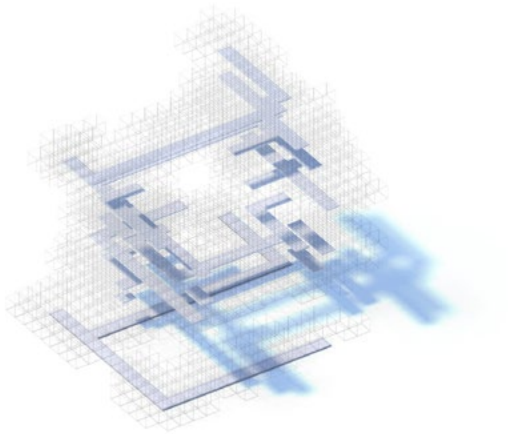


OUTPUT; AGGREGATION

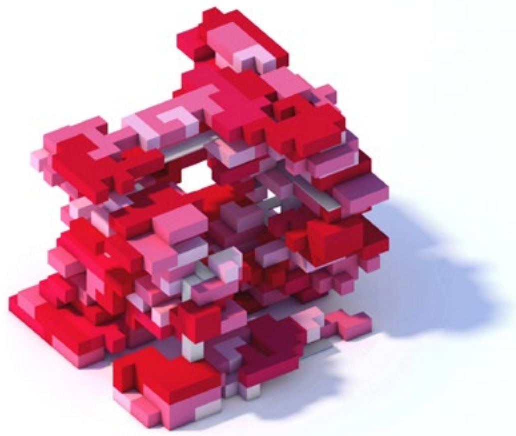
The primary output of the configurational algorithm is a spatial composition constructed from the input cell types and connected in the defined topology. The spatial output enables different previews of the constituent parts of the aggregation, firstly by type of space letting us see the difference between circulation and apartment units, and secondly at different levels of the aggregated topology such as the entire aggregation, a cluster of units connected to the same circulation or individual spaces. These previews enable us to look into how the aggregation functions as well as see the immense diversity that is created in the aggregating process, manifesting itself in a large variety of unit types (page 226). The units can also be further analysed



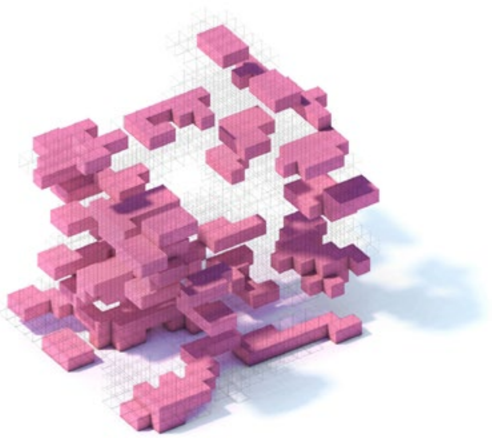
generated spatial composition based on input spatial network



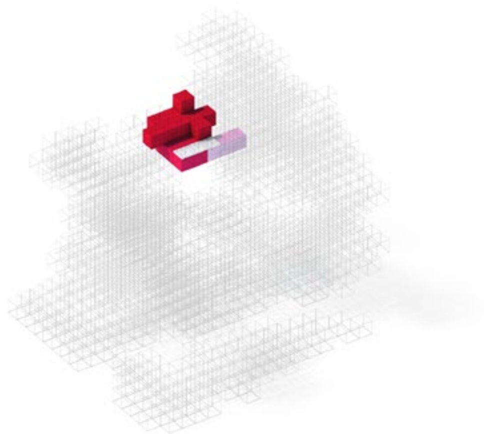
exterior horizontal circulation



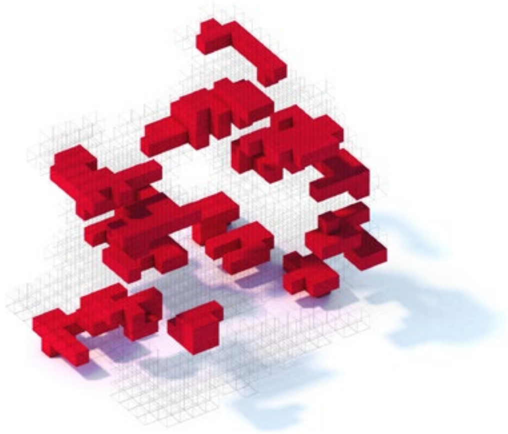
entire aggregation



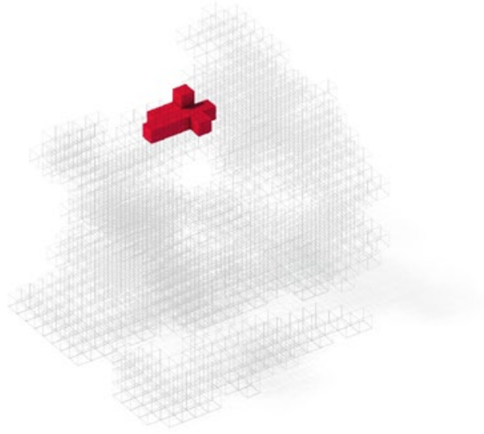
apartment 50m2



cluster of units



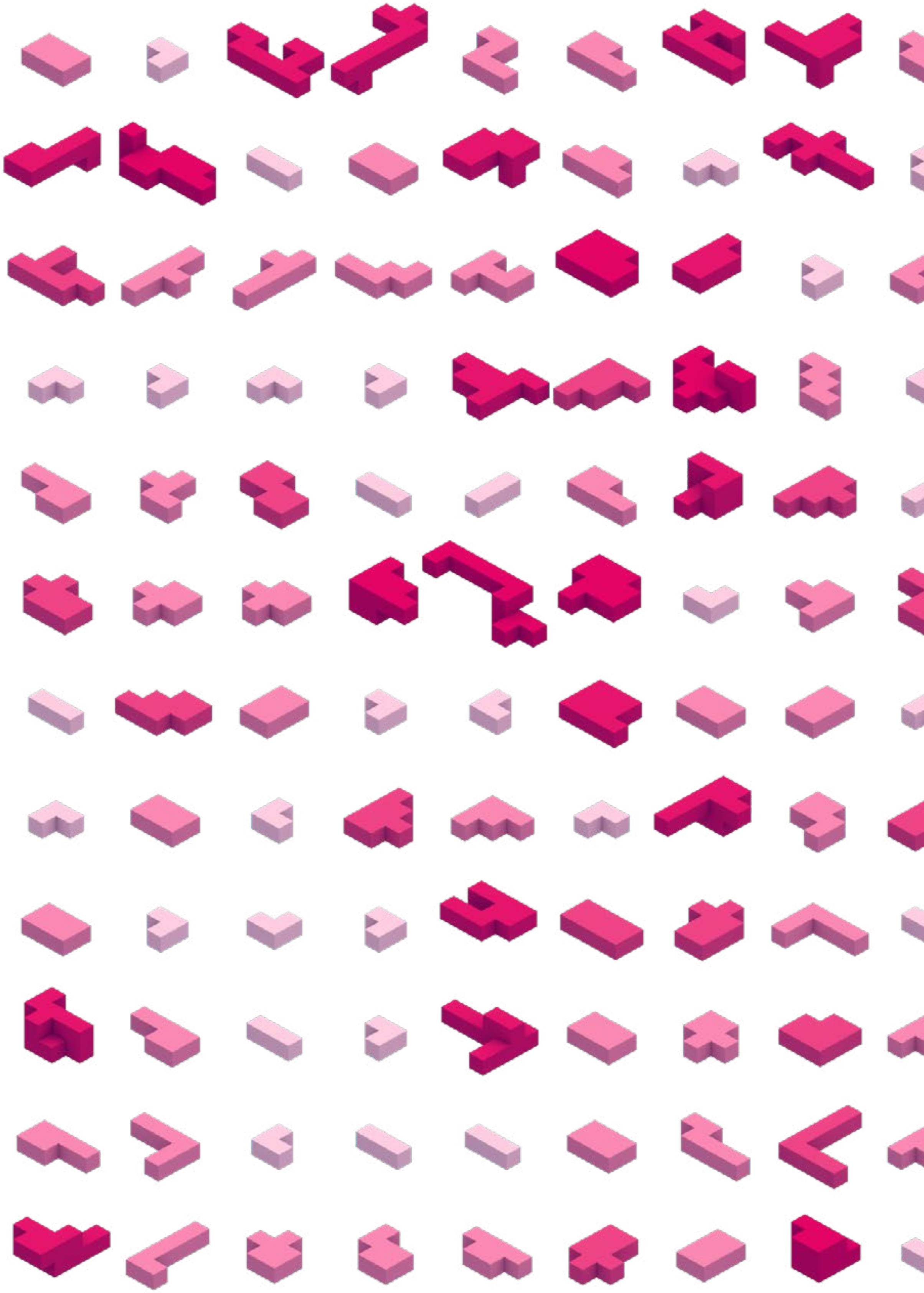
apartment 110m2



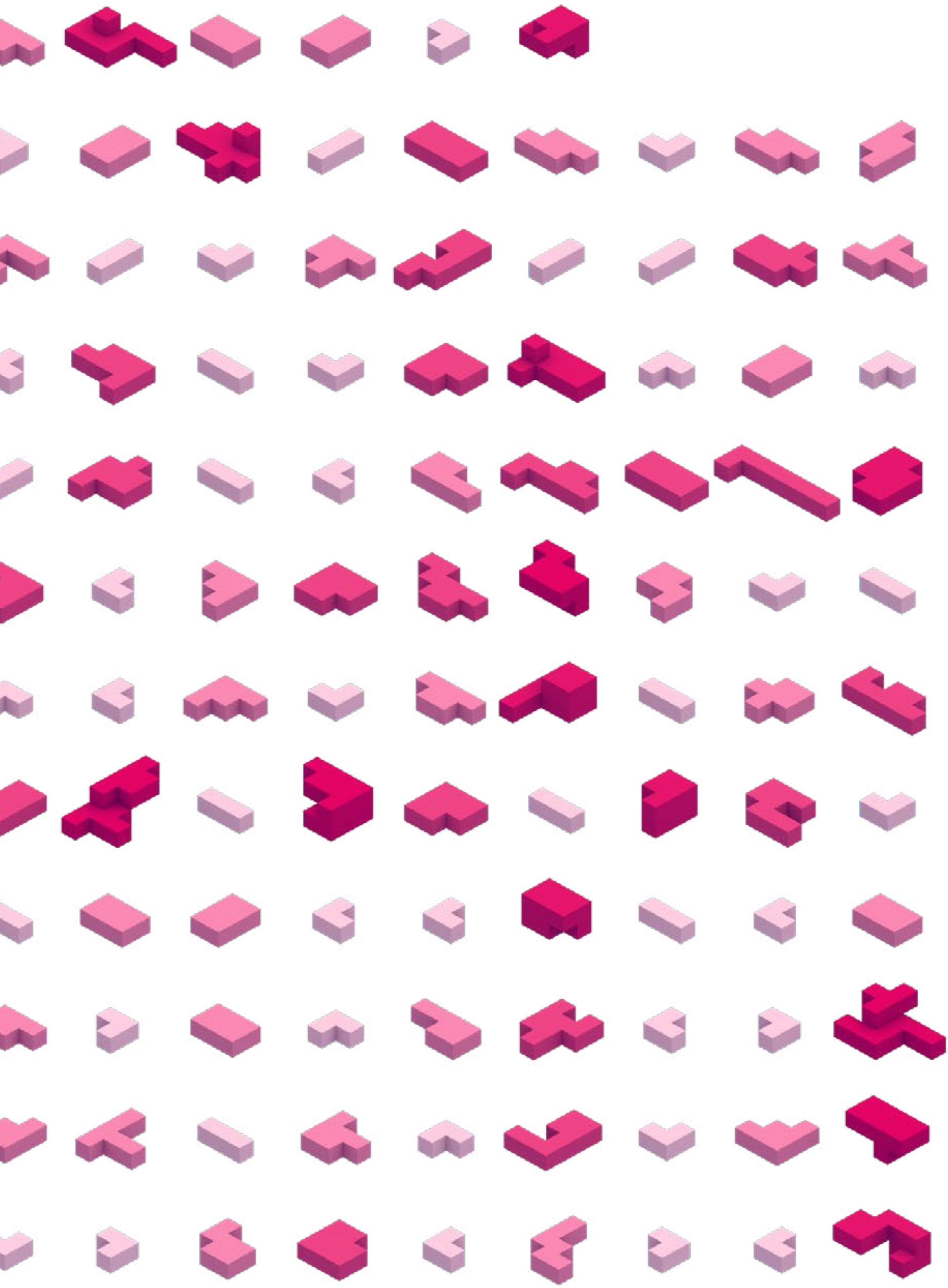
single unit

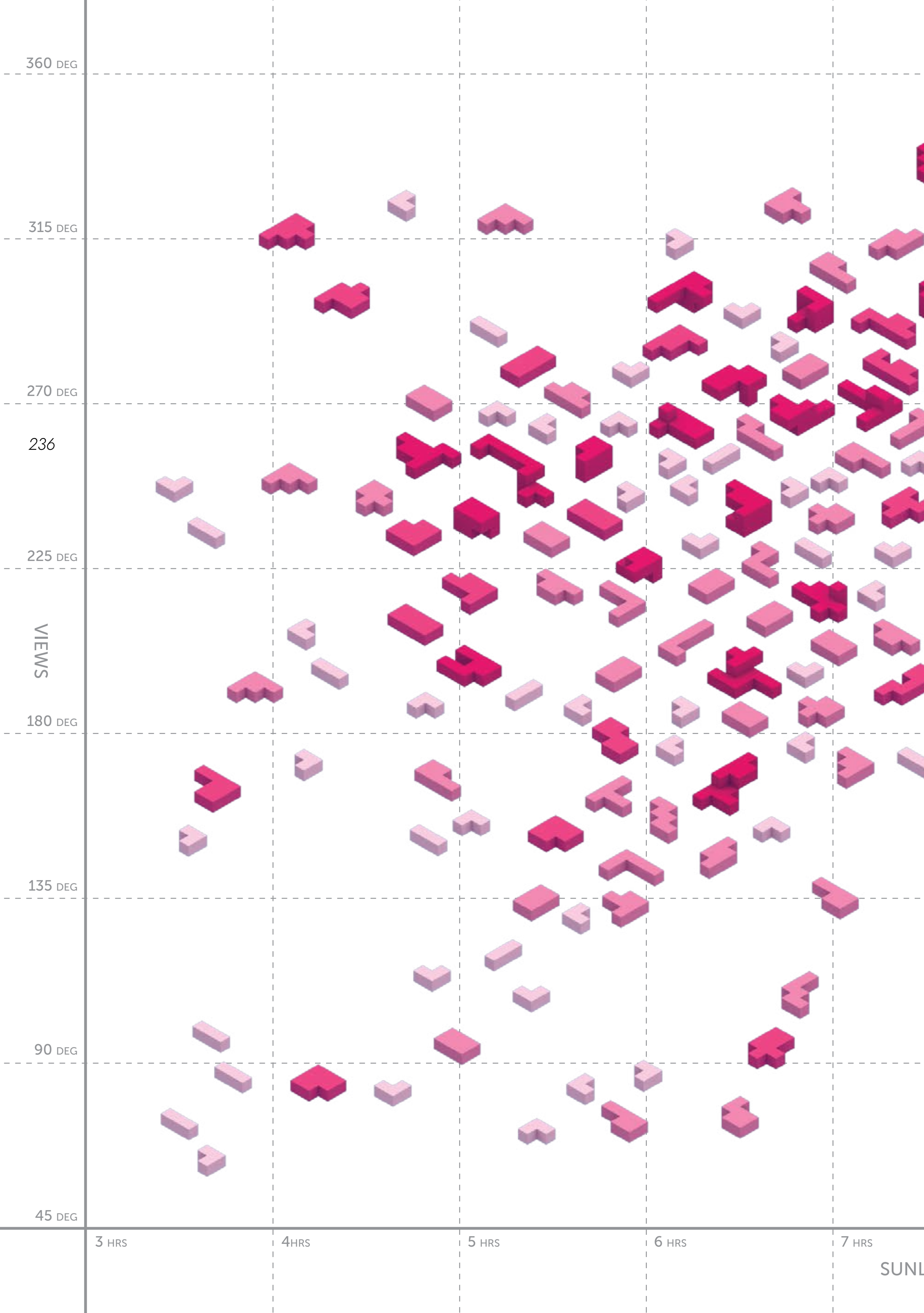
preview by type

preview by scale

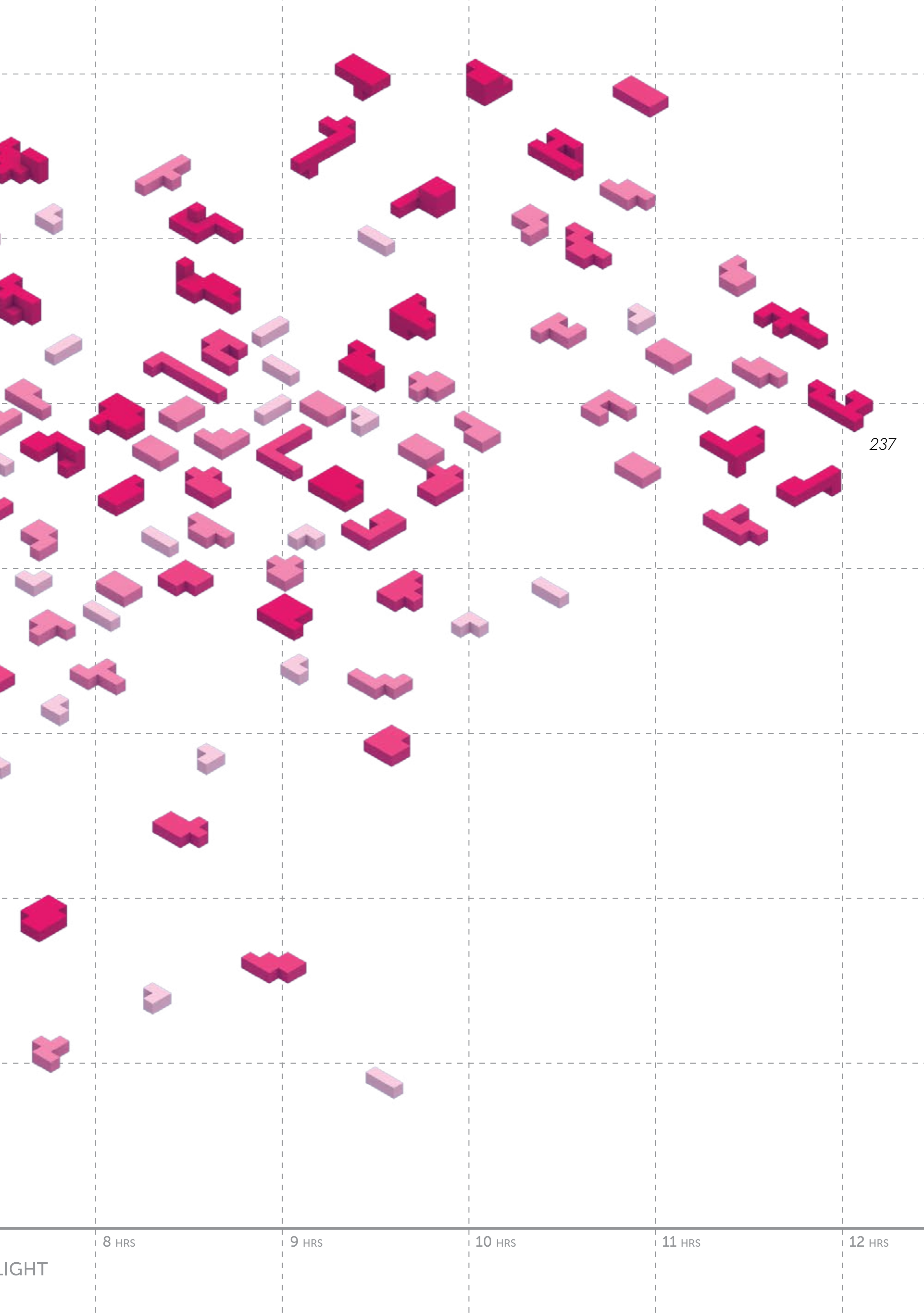


decomposed aggregation into units



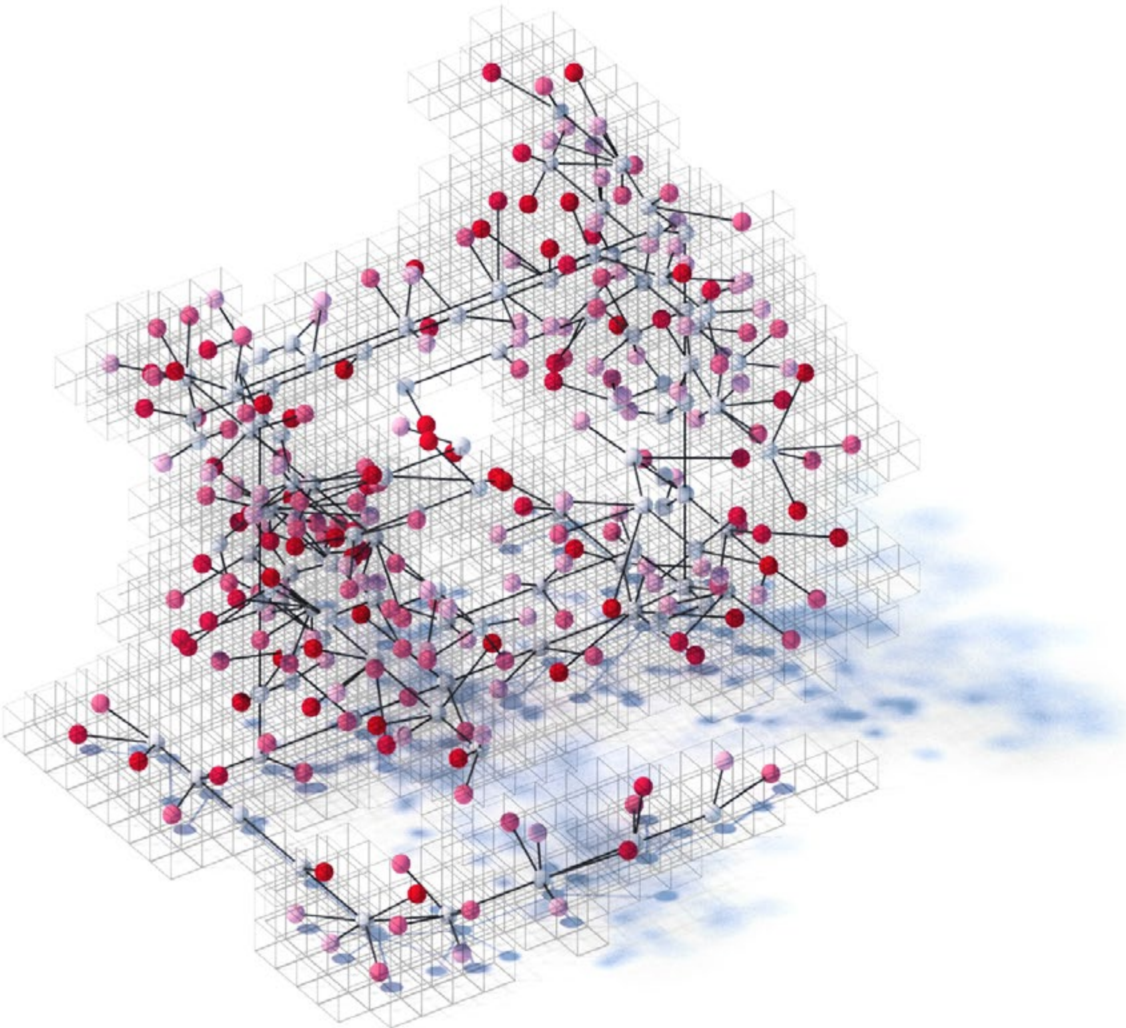

360 DEG
315 DEG
270 DEG
225 DEG
180 DEG
135 DEG
90 DEG
45 DEG
VIEWS
3 HRS
4HRS
5 HRS
6 HRS
7 HRS
SUNL

236

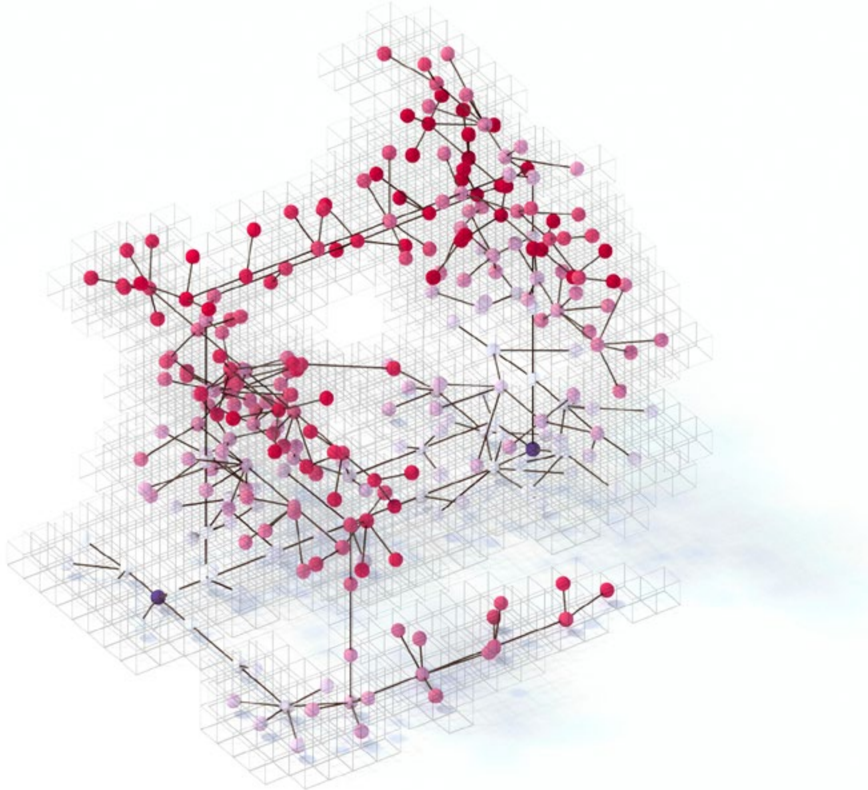

8 HRS
9 HRS
10 HRS
11 HRS
12 HRS
LIGHT

OUTPUT; SPATIAL NETWORK

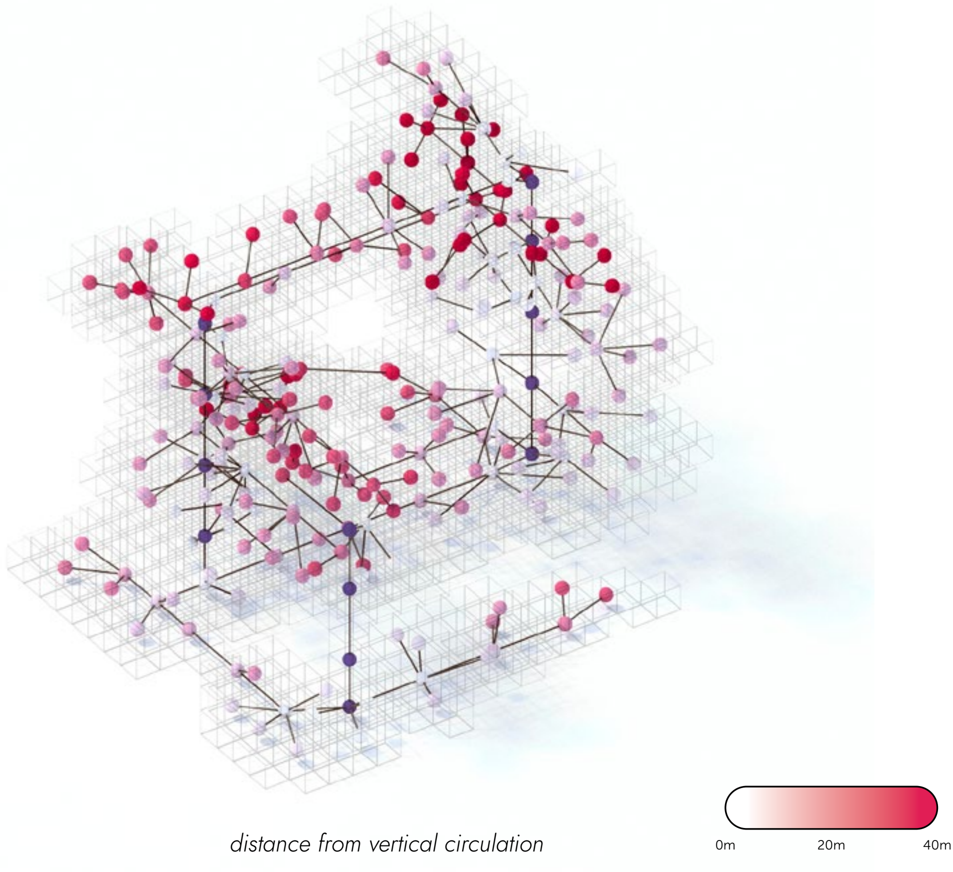
The second output type describes the underlying topology of the generated aggregation and is a direct reflection of the input configuration in the shape of a spatial network. This 3d equivalent of a spatialized spatial network not only connects the result back to its source and allows us to explore the details of how spaces interconnected during aggregation, but crucially enables further analysis of what is effectively a network/graph structure. With further development this could potentially be utilised within the algorithm itself for various applications such as measuring the distances to fire exits and placing them accordingly or placing the programme itself based on the connectivity at a specific node, enabling for example the central positioning of shops and workplaces, while reserving private areas for residential units.



topology of generated spatial composition reflecting the input spatial network



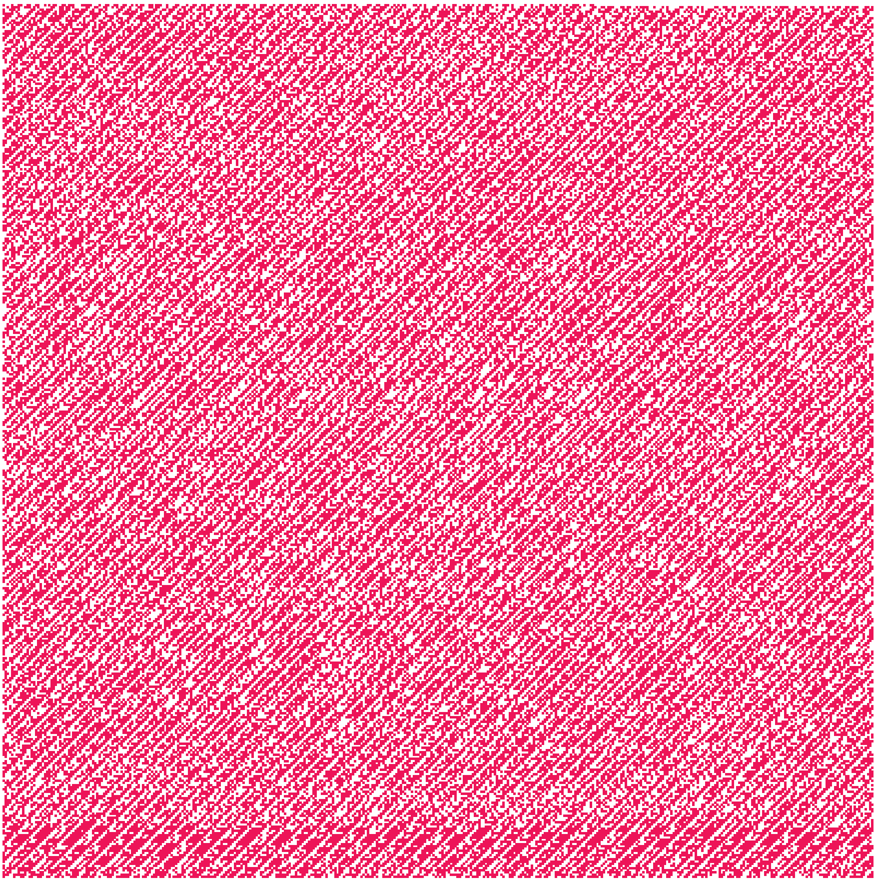
global network centrality from two entrances



distance from vertical circulation

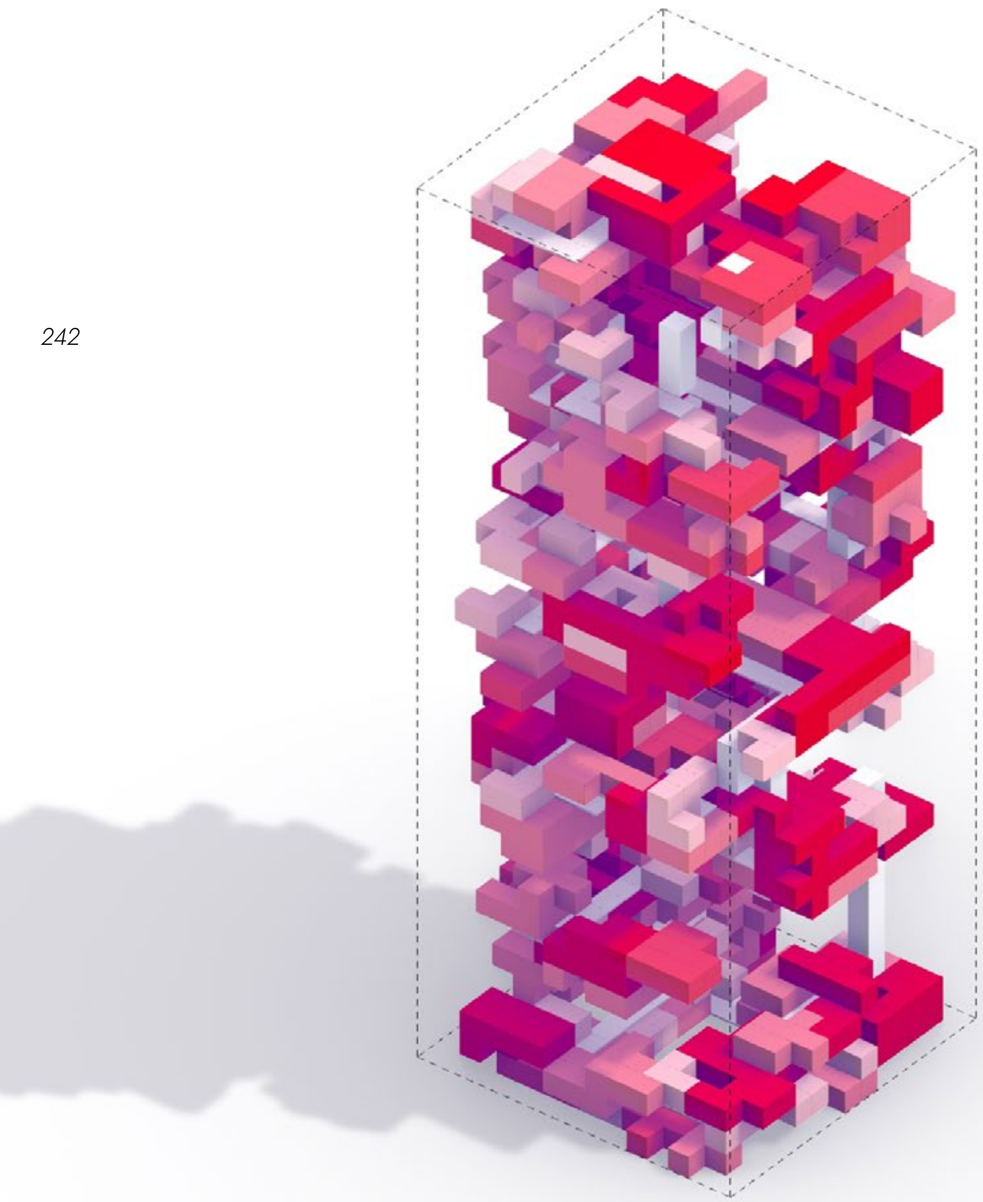
OUTPUT; DNA

The last output of the configurational algorithm is pure data, where all the information about a specific aggregation is contained. This can be encoded in a multiplicity of possible formats to make it visible to the human eye such as in the generated example which encodes 122.420 bits of information containing everything from the input spatial network, the global simulation settings and the final generated output in a graphic qr-code -like format. This is essetinaly the DNA of this specific aggregation visually manifested.



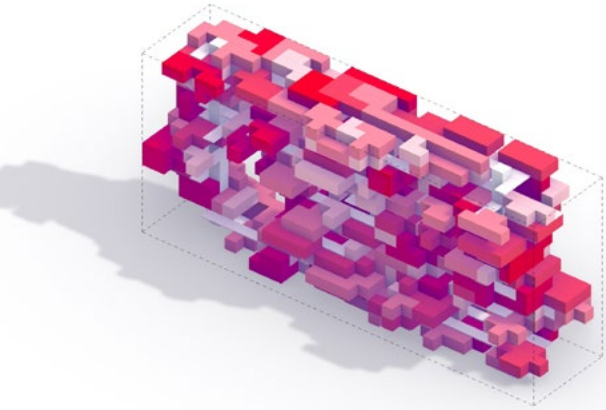
binary representation of the input spatial network and the generated spatial composition

ADAPTIVITY TESTING

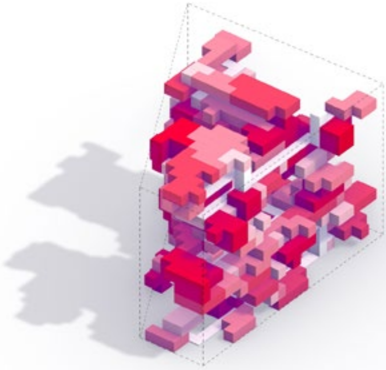


ENVELOPES

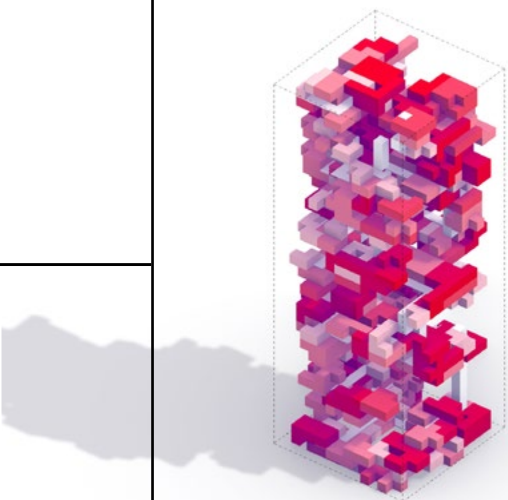
The algorithm is capable of operating with a multiplicity of input envelope shapes broadening its application in different situations. Furthermore, it was proven that every configuration can adapt to any envelope, supporting the argument against fixed urban types and their frozen form. This approach could lead to new formal articulations of already existing spatial configurations.



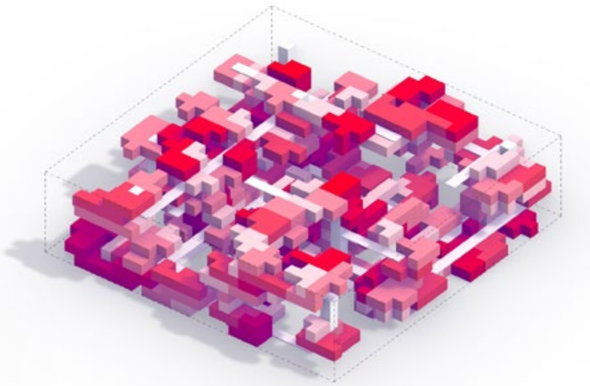
slab envelope



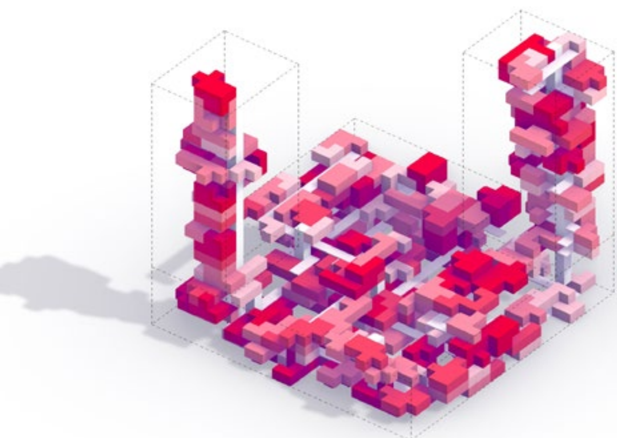
triangle envelope



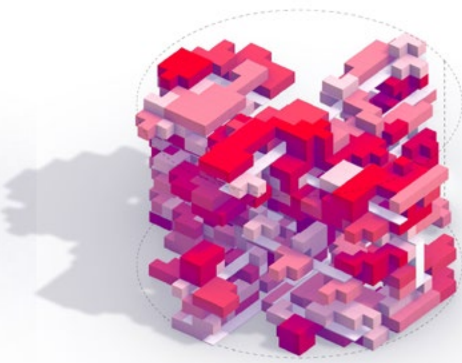
tower envelope



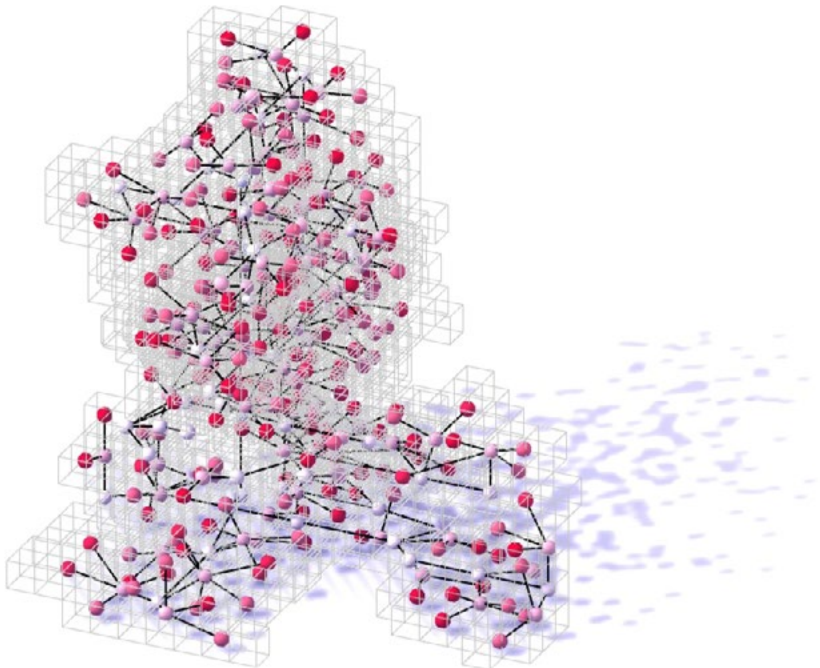
podium envelope

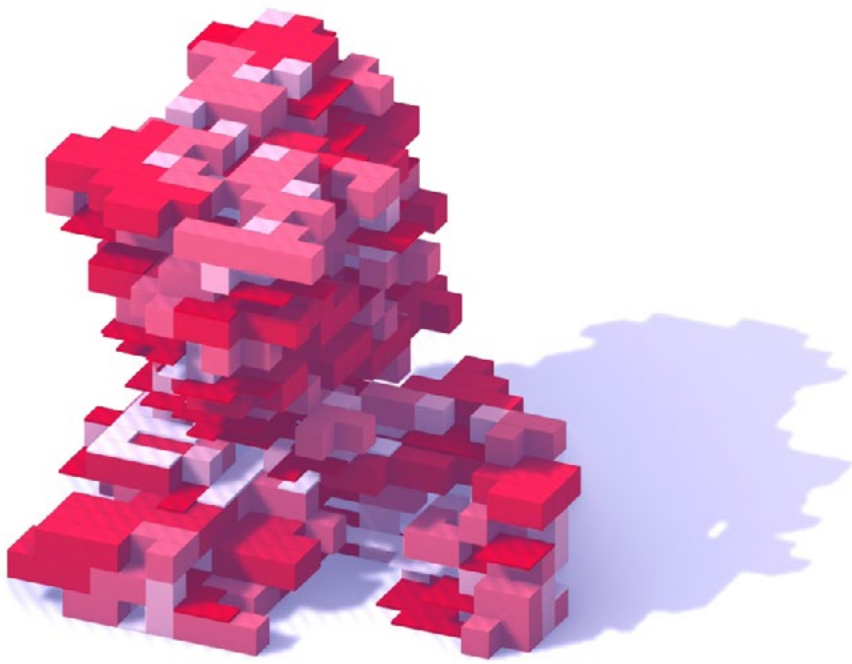


podium tower hybrid envelope



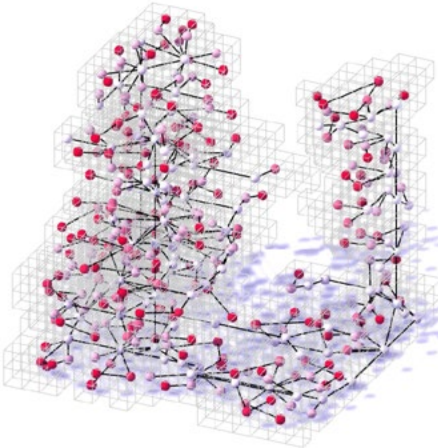
cylinder envelope



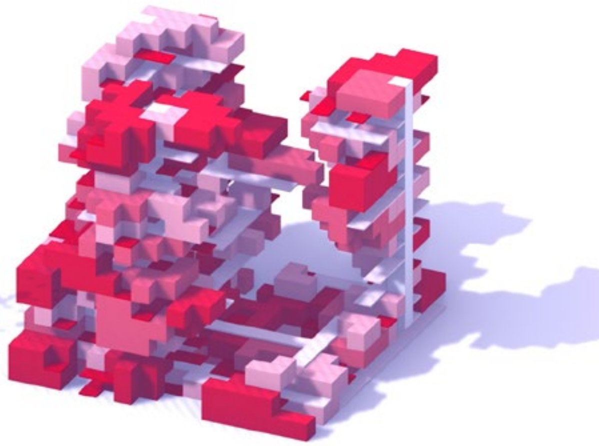


TOPOLOGIES

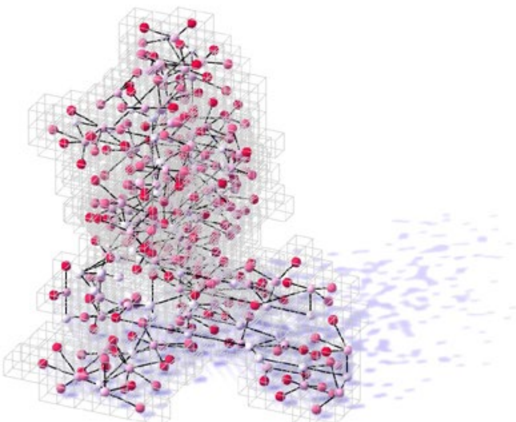
The algorithm was also tested operating with multiple topologies / spatial networks such as the rowhouse, slab or tower. Again, their spatial flexibility is demonstrated by their arrangement in the same envelope; a high-density urban block with the spatial qualities of a courtyard block is suddenly possible? Topological experiments should be further expanded especially with regards to completely new configurations created in response to the perpetually evolving lifestyle trends such as cohousing and working from home.



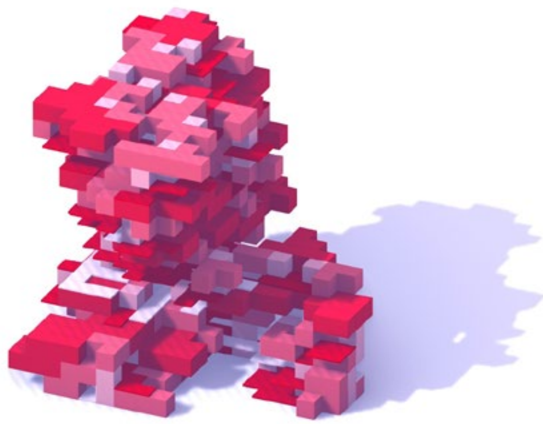
rowhouse - topology



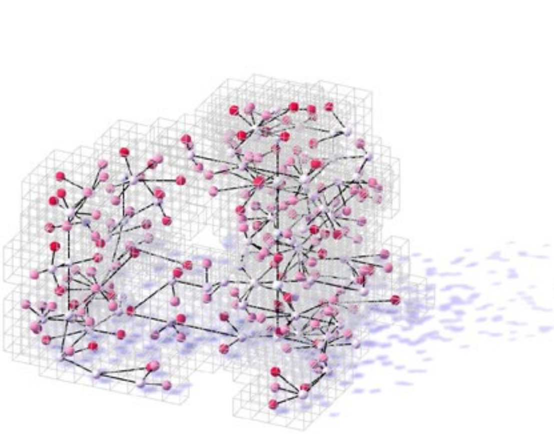
rowhouse - form



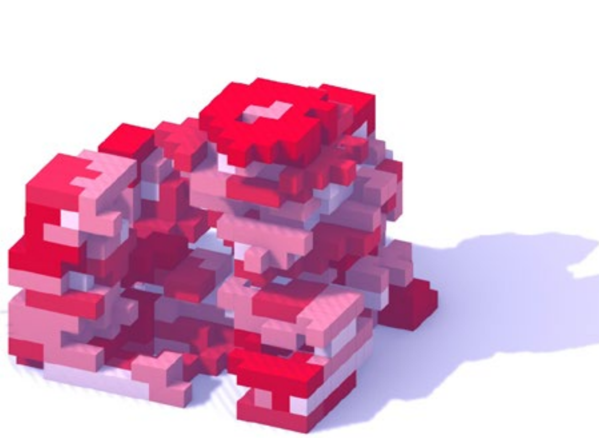
courtyard - topology



courtyard - form



slab - topology



slab - form

12

How does form generated by configuration perform compared to existing urban types?

CONFIGURATIONAL MORPHOLOGIES

Experiments on configurationally generated urban form

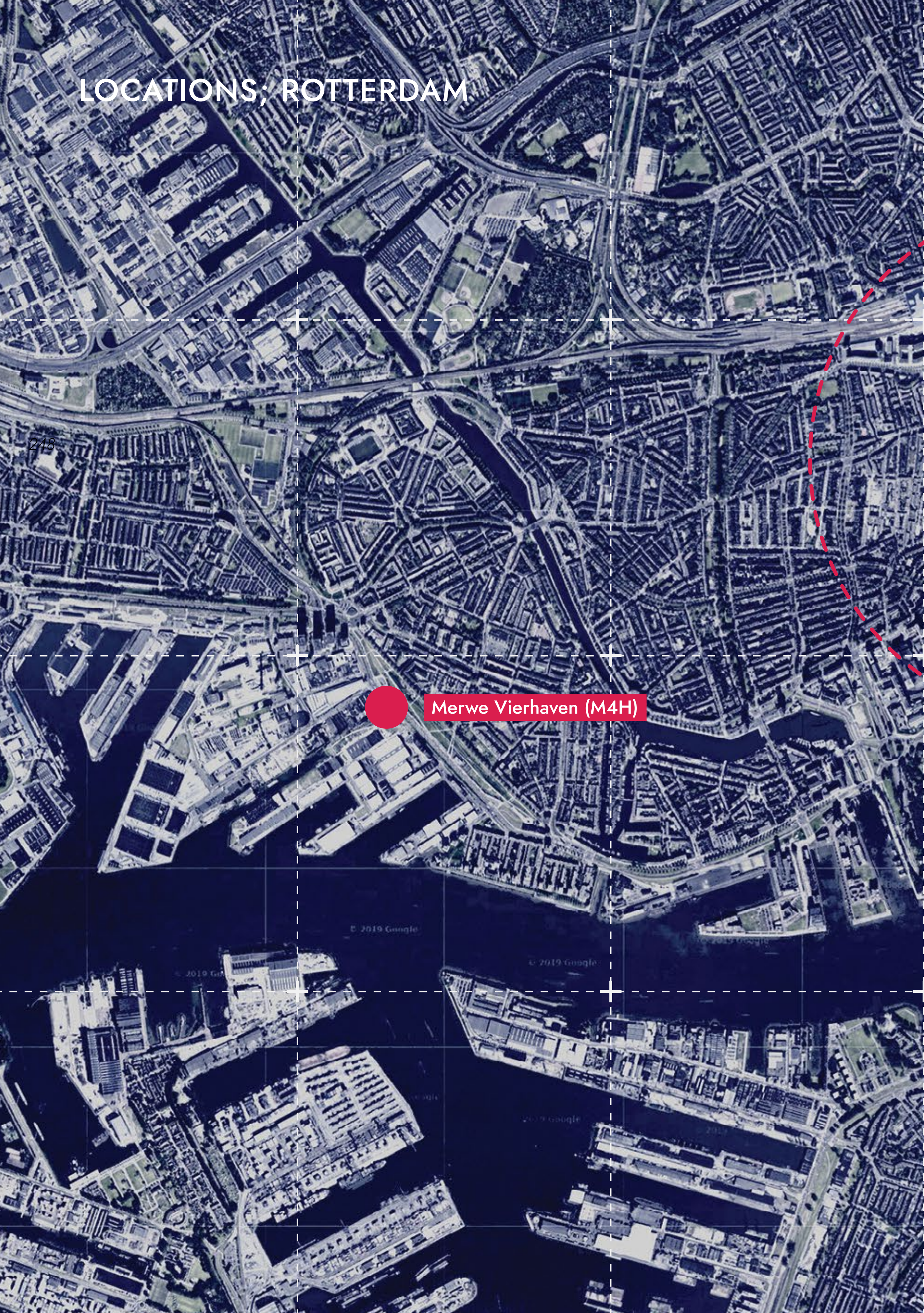
The adaptive nature of spatial compositions generated through a configurational approach holds the promise of improved **performance** compared to established urban types due to its **site-specificity** and **complexity**. These theoretical assumptions are examined using a series of simulations in a controlled setting to establish objective performative differences between typal and configurational form.

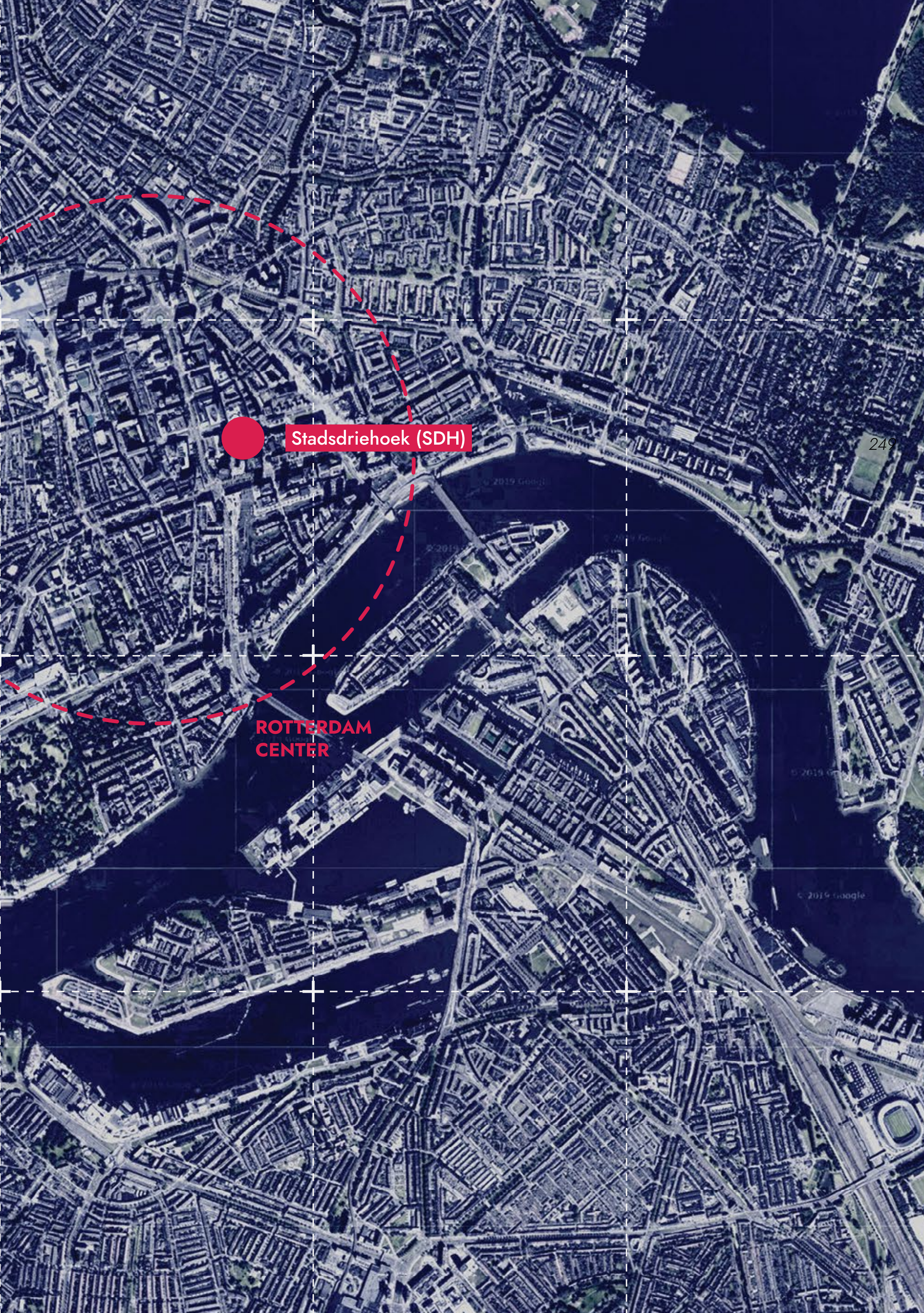
The experiment focuses on four deeply-rooted types - **detached house, rowhouse, courtyard townhouse and slab** - whose dominance in contemporary cities makes them good approximations of the majority of the urban fabric. The performance of each type is subsequently compared to its counterpart configurationally generated based on the original's topology. Parameters used for performance evaluation fall into three groups; **efficiency** parameters of Floor Area Ratio and circulation percentage, **exterior** parameters of Open Space Ratio and percentage of private exterior space and lastly **environment** parameters of sunlight access, view quality and privacy. Furthermore, to ensure the precision of results, the programme used to divide the urban form into units on which evaluation is based had been unified according to the average household size distribution in the Netherlands. All tests are performed on two contrasting locations in Rotterdam. First, a central location of a smaller size and a pronounced context, where hypothetically the adaptive configurational approach should outperform the rigid existing types. Alternatively, the second location on the outskirts of the city with little context and of a much larger size should enable optimal performance of existing types possibly leading to better results.

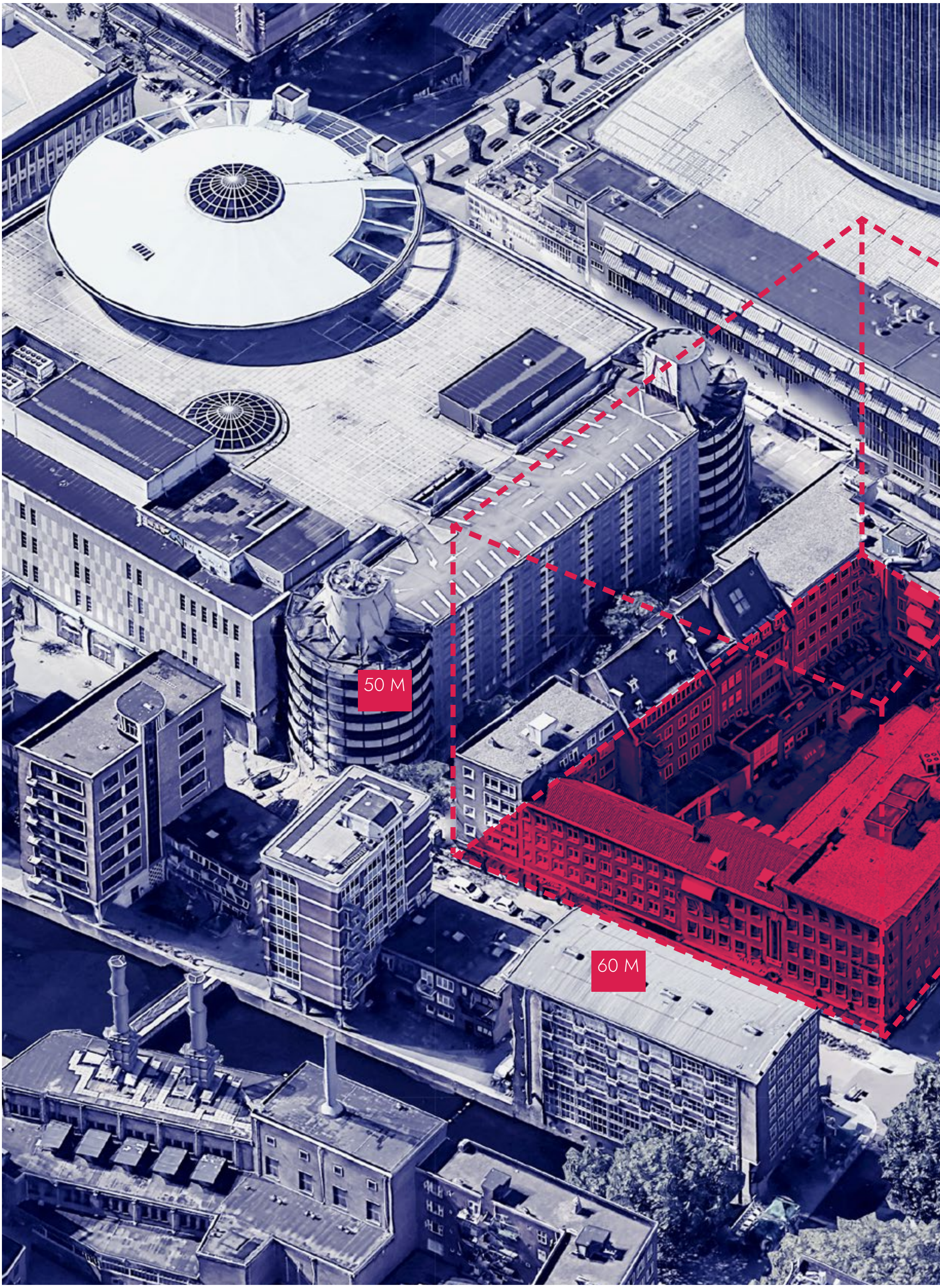
The results of all simulations demonstrate the potential capability of **configurationally generated forms** to perform better in comparison to established **urban types**. The largest improvements in performance were apparent in low-density types like the row house where configurational forms achieved a drastic improvement both in density as well as all environmental parameters. These results imply that established configurations such as the row house could be arranged in different **spatial compositions** better responding to contemporary requirements while maintaining their inherent **socio-spatial** structure. Simultaneously, in case of high-density types like the slab, a symbol of efficiency, the performative gains were much smaller or non-existent with the majority of cases exhibiting a small tradeoff in density in exchange for improved environmental performance. Much as this seems unimportant it holds a crucial implication; due to its adaptivity, configurational form can ensure much greater **equality** of conditions across the entire **urban form**. In this way, we can eliminate outliers such as shaded north-facing apartments or units on lower floors with suboptimal views and ensure the entire **aggregation** performs up to the minimum designated standards.

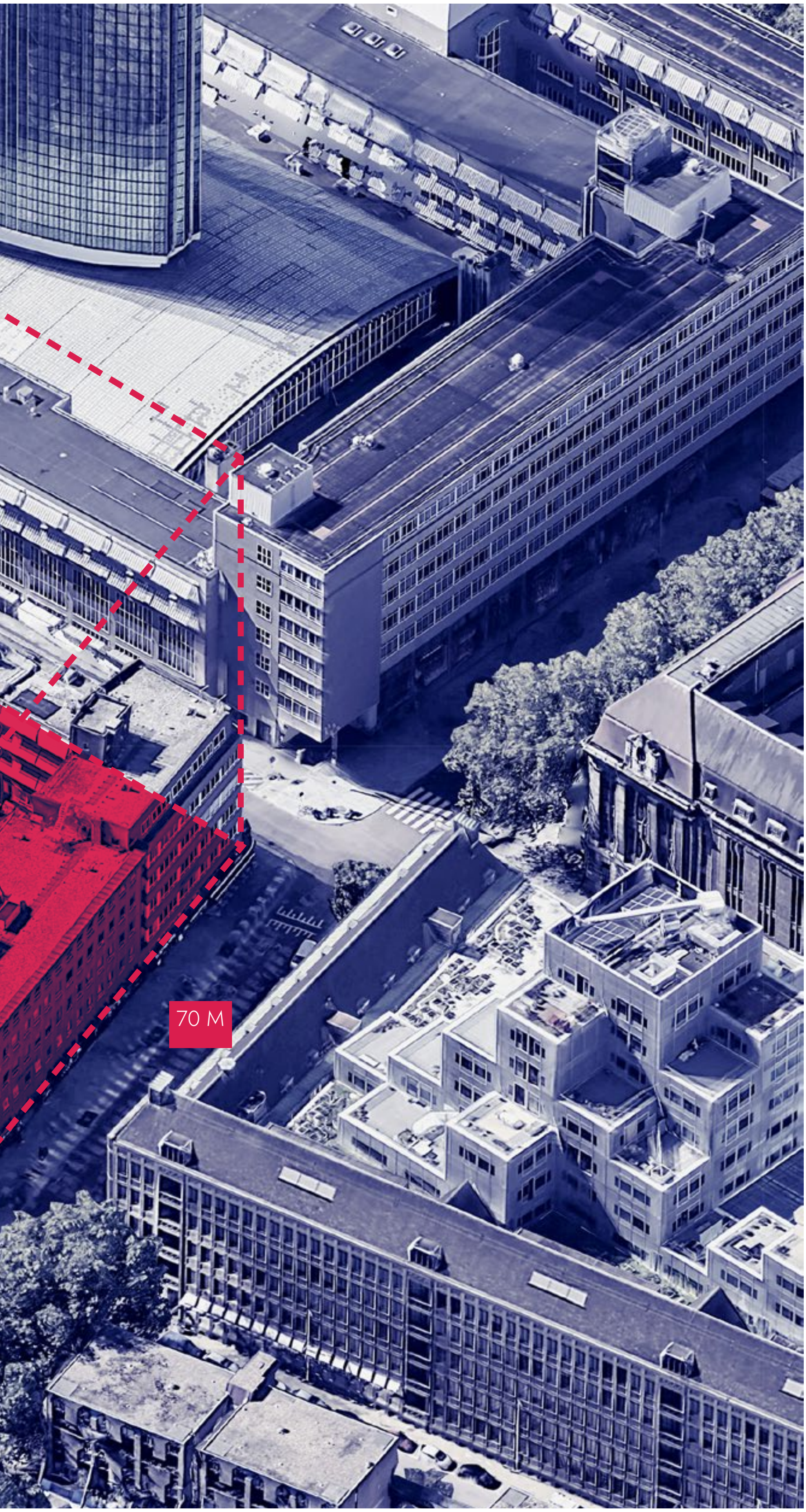
Although admittedly providing a limited sample size evaluated by a small number of parameters and eschewing important others like economic performance, the experiment showcases the potential of configurations to enable new morphological innovation which could lead to hybridisation of existing and creation of new urban forms crucial for the evolution of the future city.

LOCATIONS; ROTTERDAM



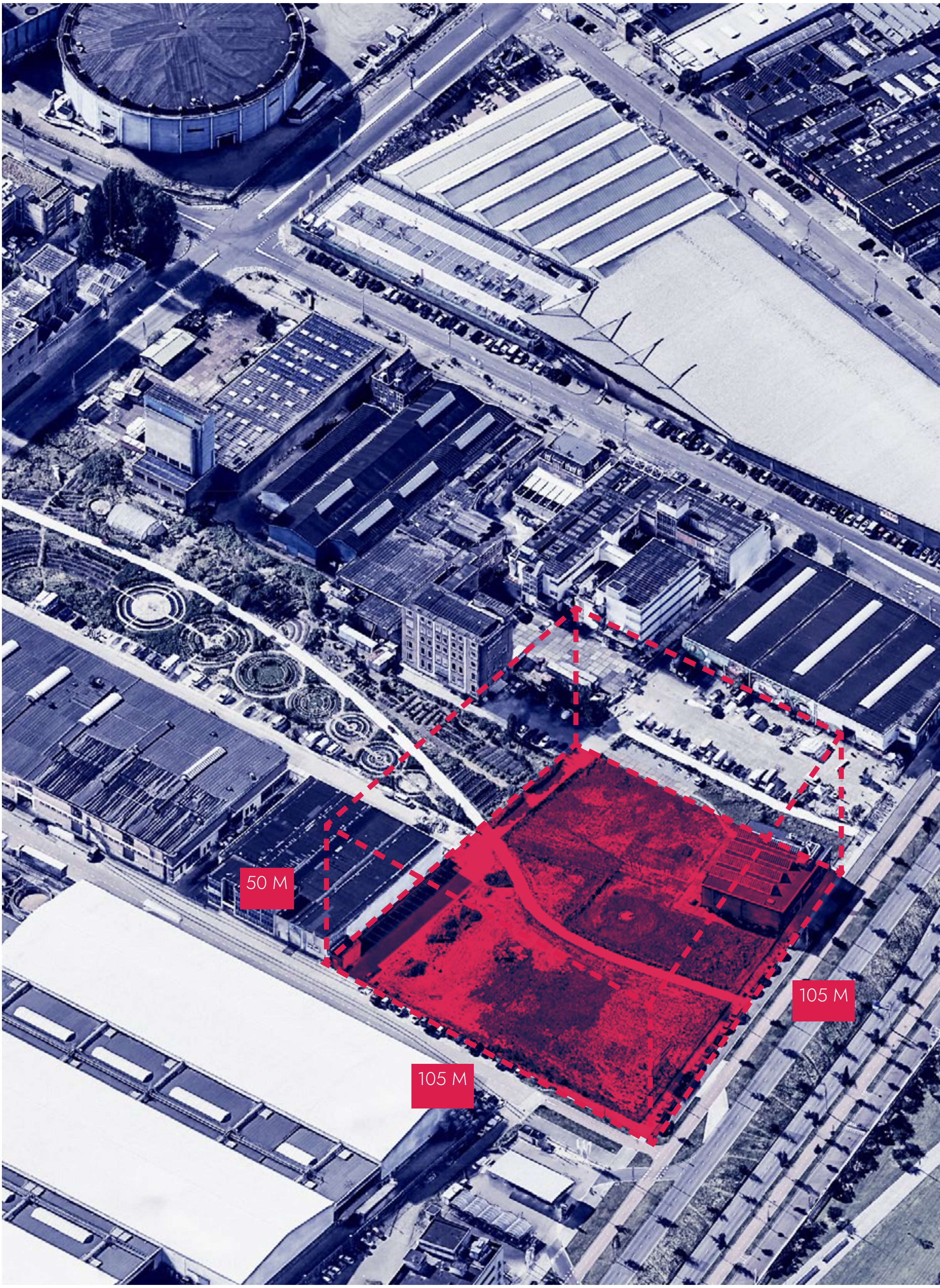

Stadsdriehoek (SDH)
ROTTERDAM CENTER


50 M
60 M



STADSDRIEHOEK is the name of the neighbourhood in central Rotterdam, the location of the first site chosen for analysis. Located in central Rotterdam between the Coolsingel and the old church it is positioned in an extremely difficult spatial context that includes many high buildings such as the World Trade Center, Timmerhuis, the Post tower currently under construction, as well as the large Hudson Bay shopping mall. This high density affects the spatial conditions of the site and calls for an adaptive approach capable of generating urban form that can respond to these spatial constraints. This is one of the primary reasons for the choice of the sites which will allow the direct comparison in performance between existing rigid urban types and their configurationally generated counterparts. The dimensions of the plot equal the existing urban block that is in place, while a 50m vertical limit was chosen to enforce a degree of comparability between all experiments.

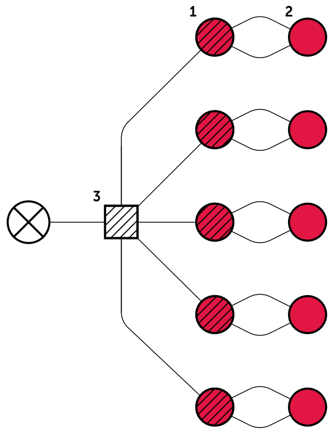
252



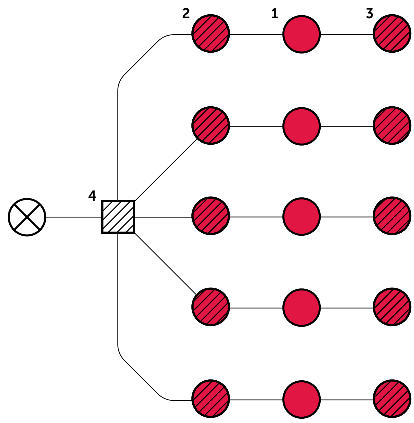
MERWE VIERHAVEN is the second of two chosen sites for the experiment. Located in the east of Rotterdam, almost on the periphery. It is an old port area, currently mostly occupied by big box retail and warehouses, some still in use some repurposed for other programme. The site which was also recently a part of Europan competition, is one of the potential prime locations for the expansion of a city desperately in need of new large housing areas. The choice of this specific site comes down to its spatial characteristics and its size. Opposite from the first site, the lack of substantial context allows for analysis of urban form in an "unconstrained" environment, which should lead to its best performance, especially in the case of existing types of urban form which are incapable of local adaptation. Secondly, the site was chosen for its size; at a 105 * 105m large it is 3-4 times the first site which enables us to test the difference in performance due to scale; how does a type of urban form, existing or generated, perform in large areas where there is enough space for internal logic to emerge? This should emphasise the individual characteristics of types even further and make them more observable.

CONFIGURATIONS

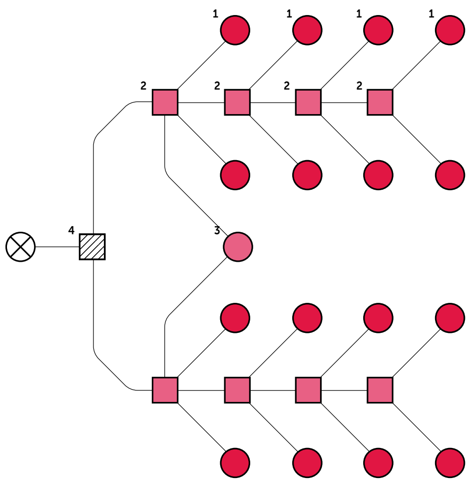
The main intent of the experiment is to compare existing urban types to their configurationally generated counterparts and compare the performances of both. For the experiment four of the most common existing urban types were chosen; detached house, row house, courtyard townhouse and slab. These types were on one hand applied to each site and evaluated and on the other abstracted into spatial networks which were used as the topological input for the aggregation algorithm.



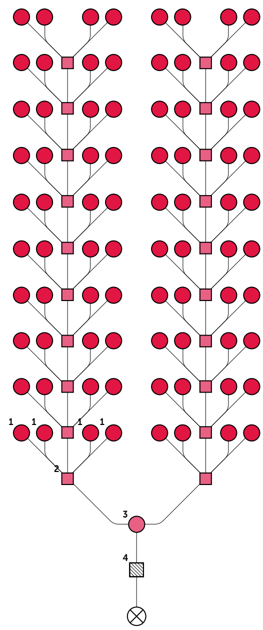
detached house topology



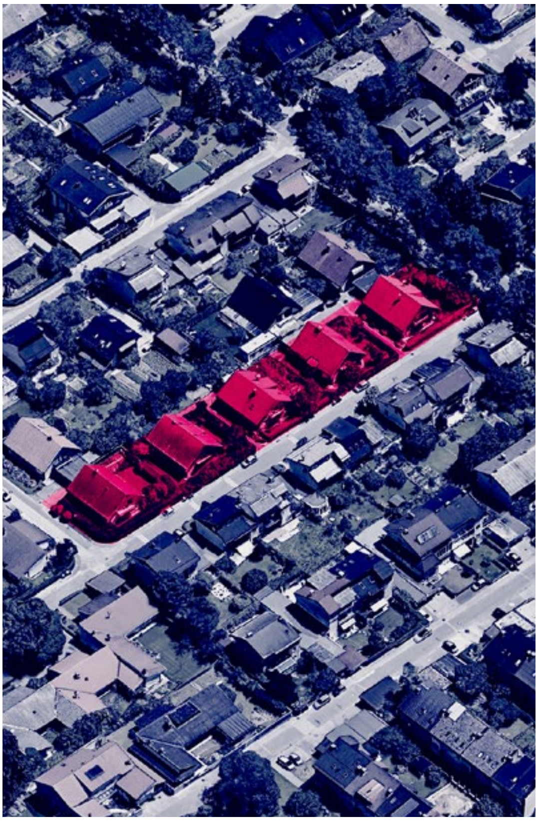
rowhouse topology

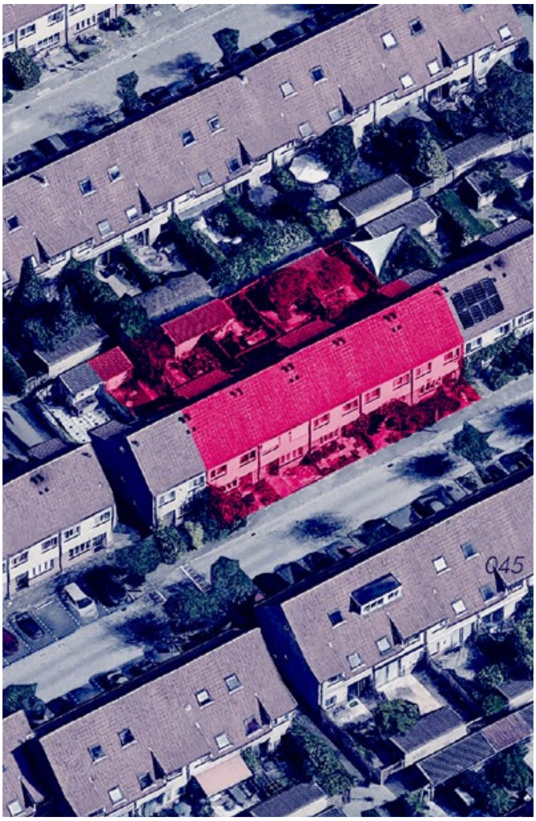


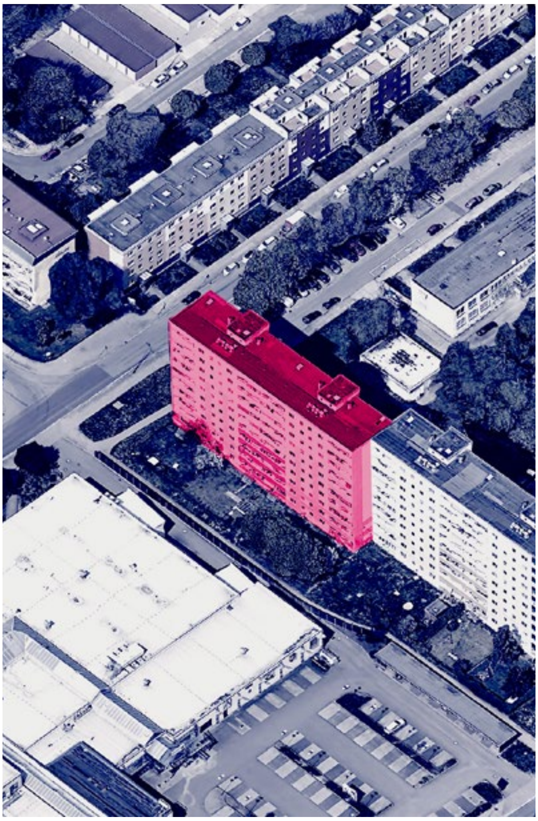
courtyard townhouse topology



slab topology

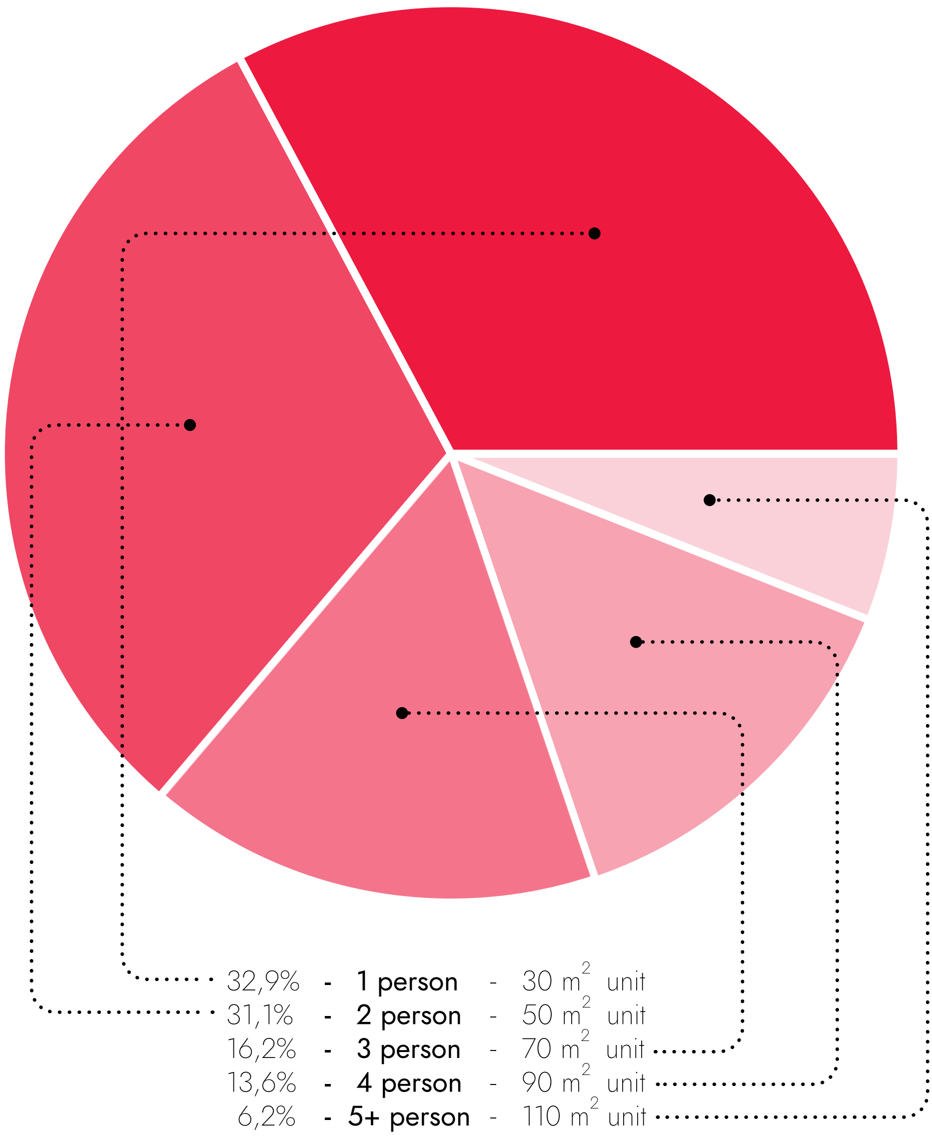



045

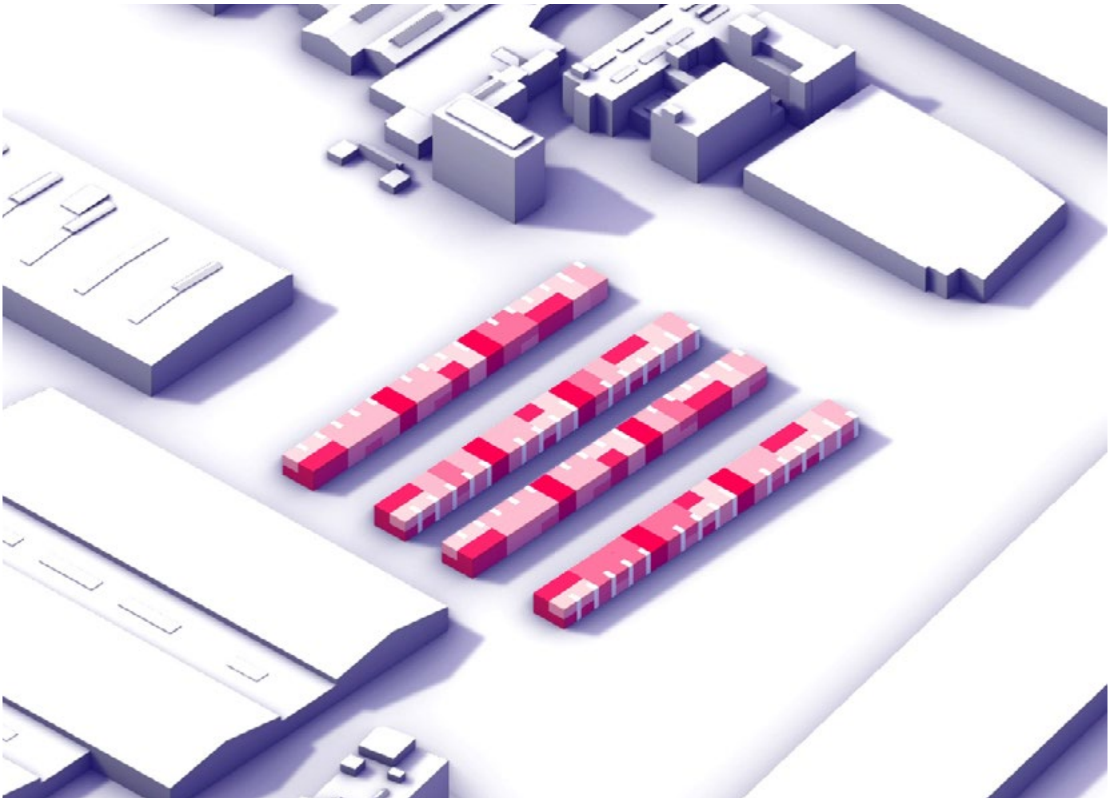


PROGRAMME

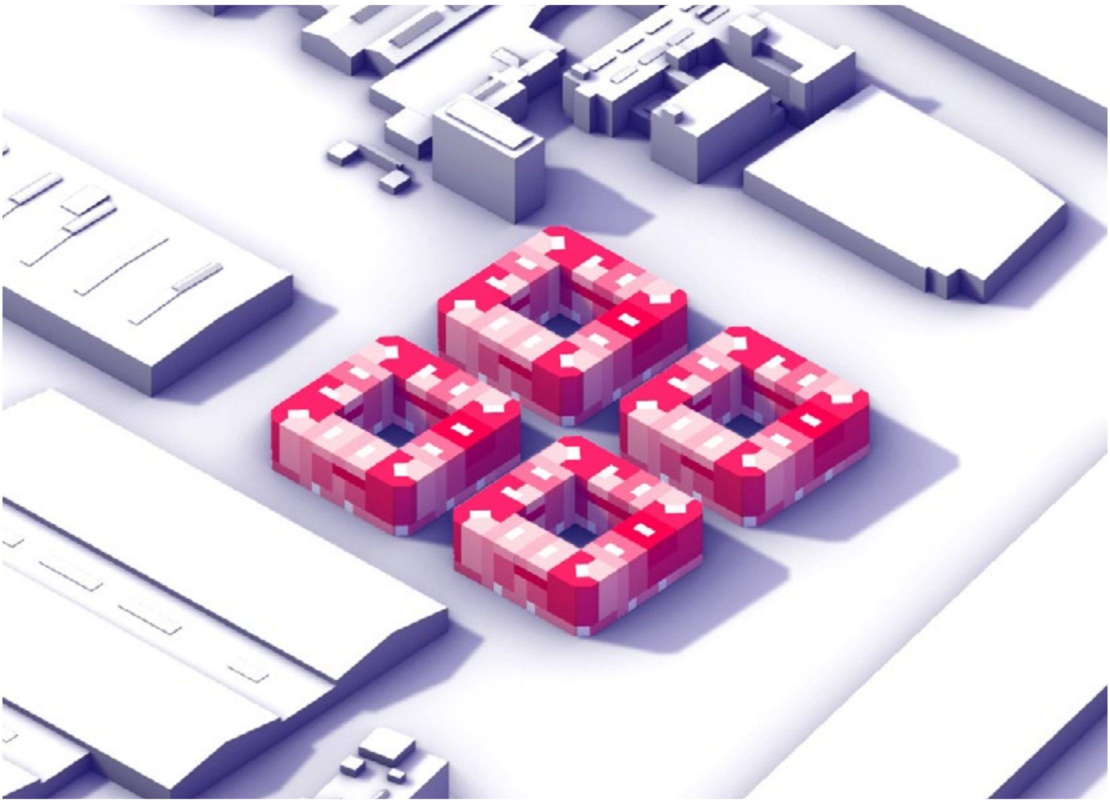
One of the parameters influencing the performance of a certain urban form is the programme contained within; the distribution of space within a volume and their spatial requirements has an important effect on its efficiency. As a result, in order to make the different types and variations comparable to each other, the programme needs to be uniform throughout all experiments. Due to the fact that this thesis focuses on generic urban tissue the most appropriate test programme was residential. Furthermore, because unit size often also has great effect on the performance of urban form, the programme was designed to correspond to the demographic composition of the Netherlands, where household size statistics inform the distrubution of required units by size. This standardized programme is then applied to generated morphologies as an input, as well as to existing urban types which are deployed on each site in their traditional form with a developer-like approach.



Netherlands household size distribution

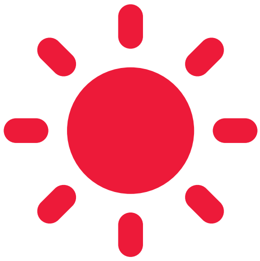


unit size distribution, rowhouse type, M4H



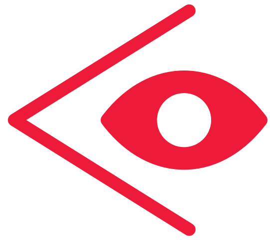
unit size distribution, courtyard type, M4H

EVALUATION PARAMETERS



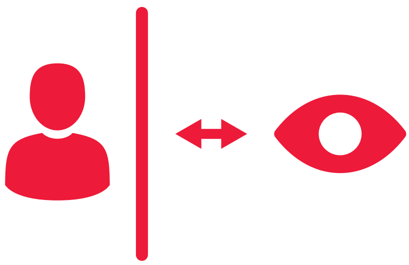
SUNLIGHT
hours / unit / day

The average number of sunlight hours on a set date (21.3.) per unit (apartment) per day.



VIEWS
view angle / unit

The average angle of views at a set minimum distance (50m) per unit (apartment).



PRIVACY
distance / unit

The average offset distance in meters of a unit from other nearby units to ensure visual privacy.

EXTERIOR SPACE
Open Space Ratio % | units with access %

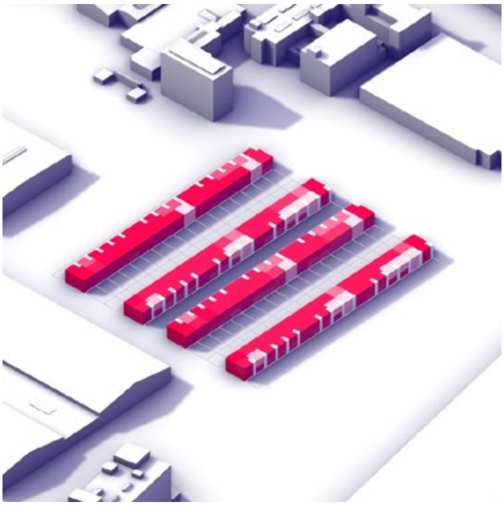
The percentage ratio of units with access to an external terrace and the ratio between total external spaces and the total gross built area.

DENSITY
Floor Area Ratio %

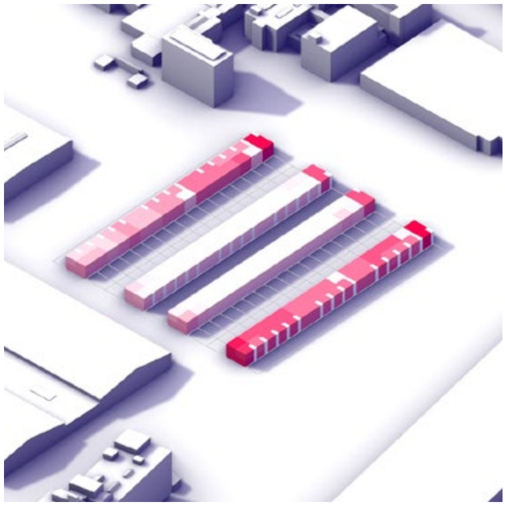
The ratio between the total built gross floor area in square meters and the area of the plot.

CIRCULATION
total circulation area %

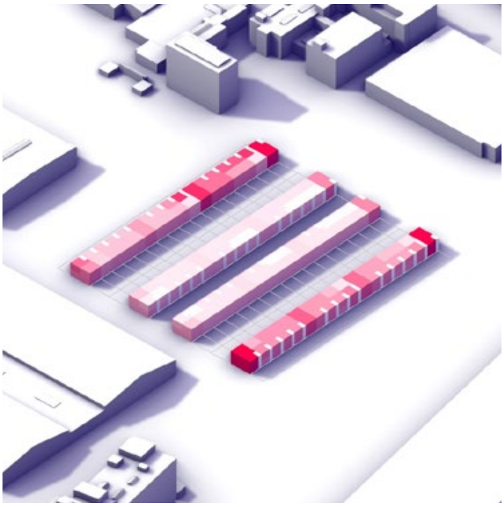
The ratio between the total area intended for circulation and the total built gross floor area.



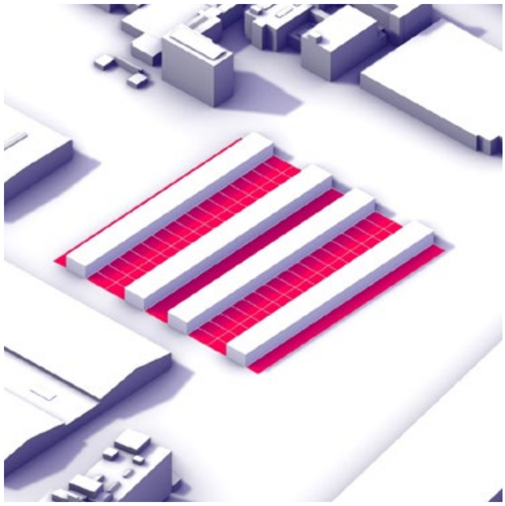
sunlight, row house, M4H



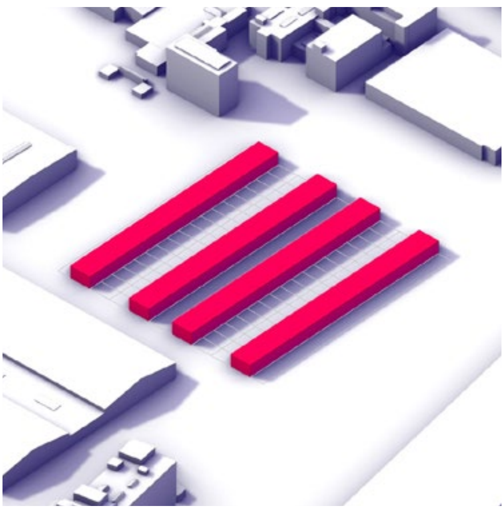
views, row house, M4H



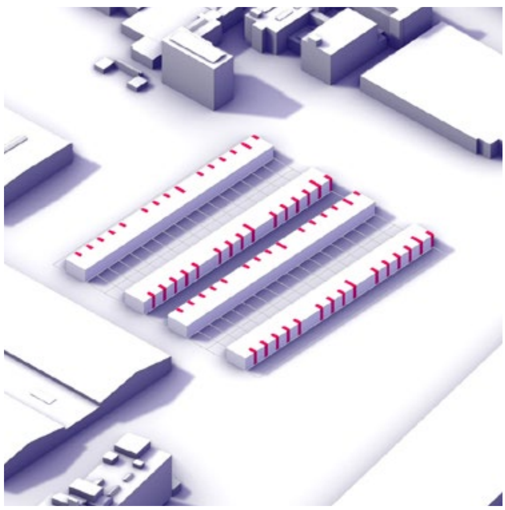
privacy, row house, M4H



open space ratio, row house, M4H

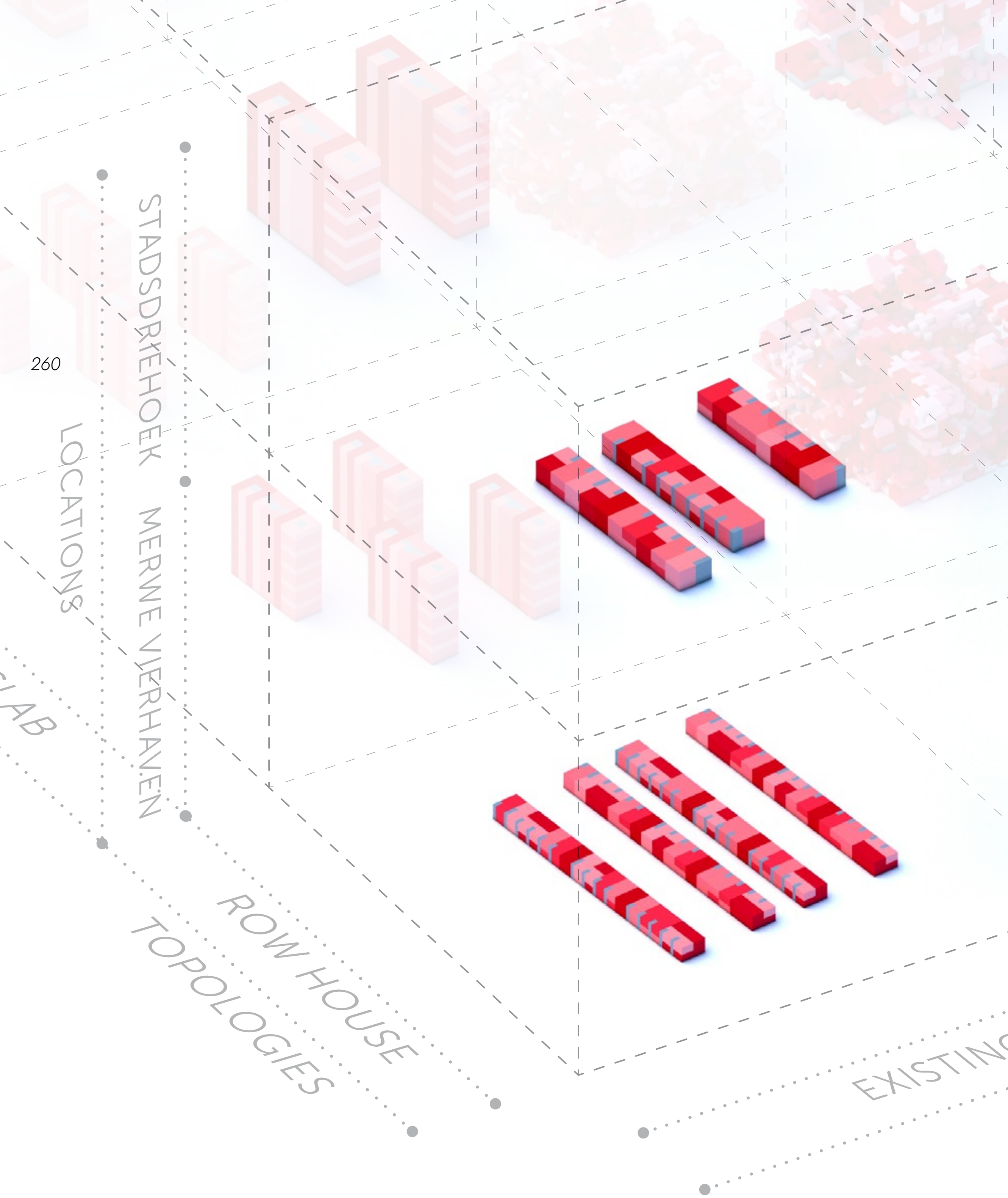


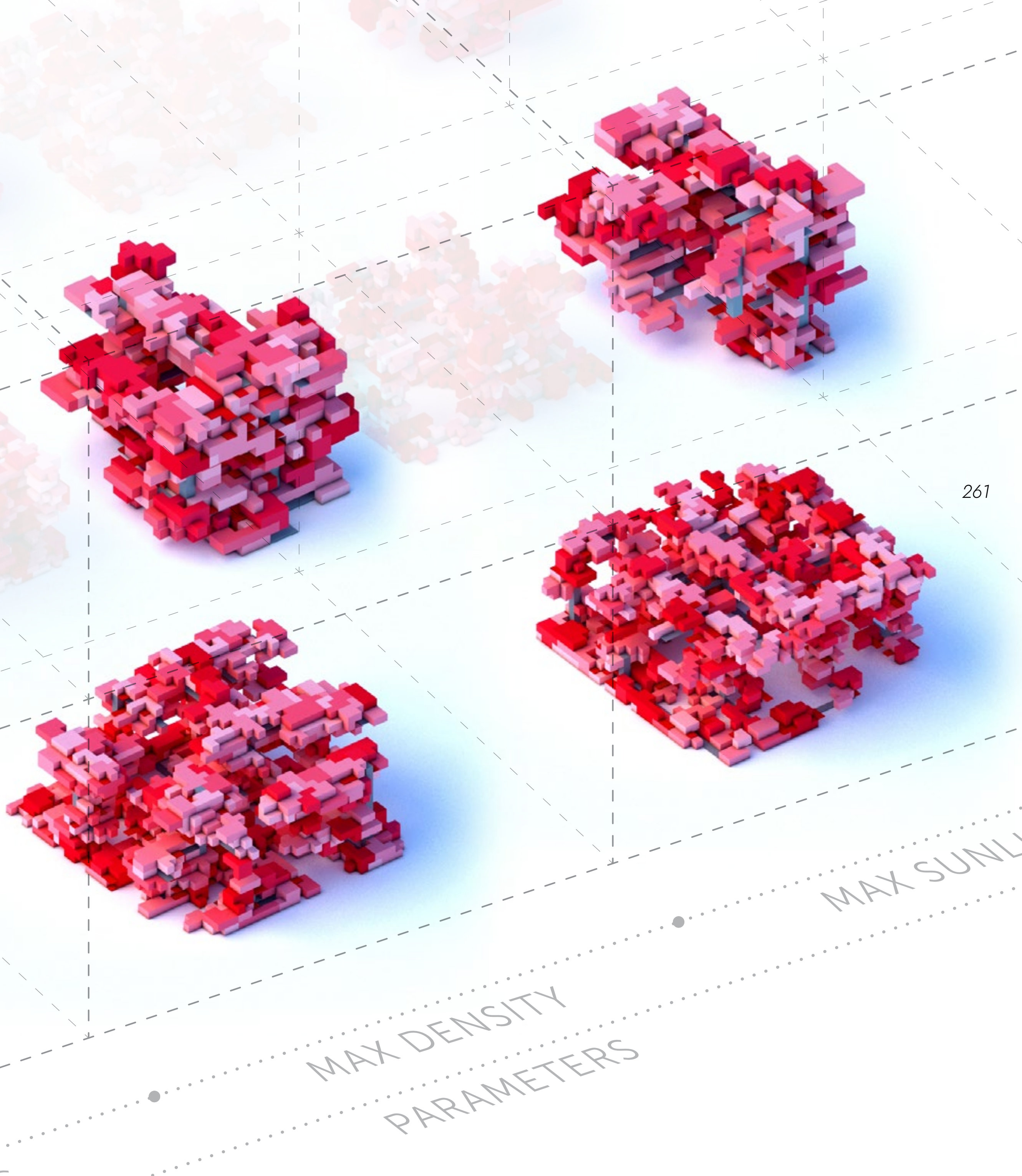
density, row house, M4H



circulation, row house, M4H

EXPERIMENT

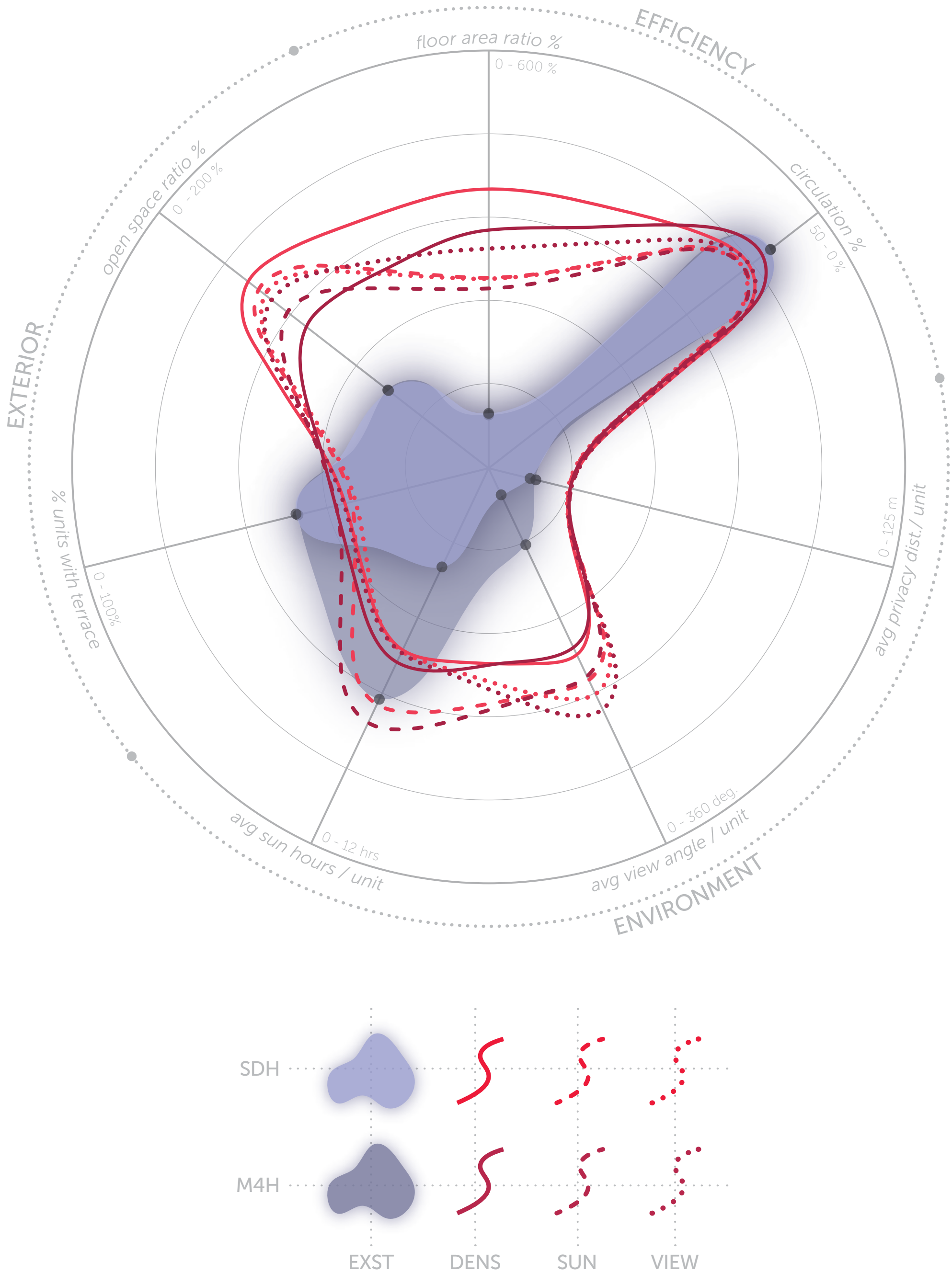

STADSDRIEHOEK
MERWE VIERHAVEN
LOCATIONS
SLAB
ROW HOUSE
TOPOLOGIES
EXISTING

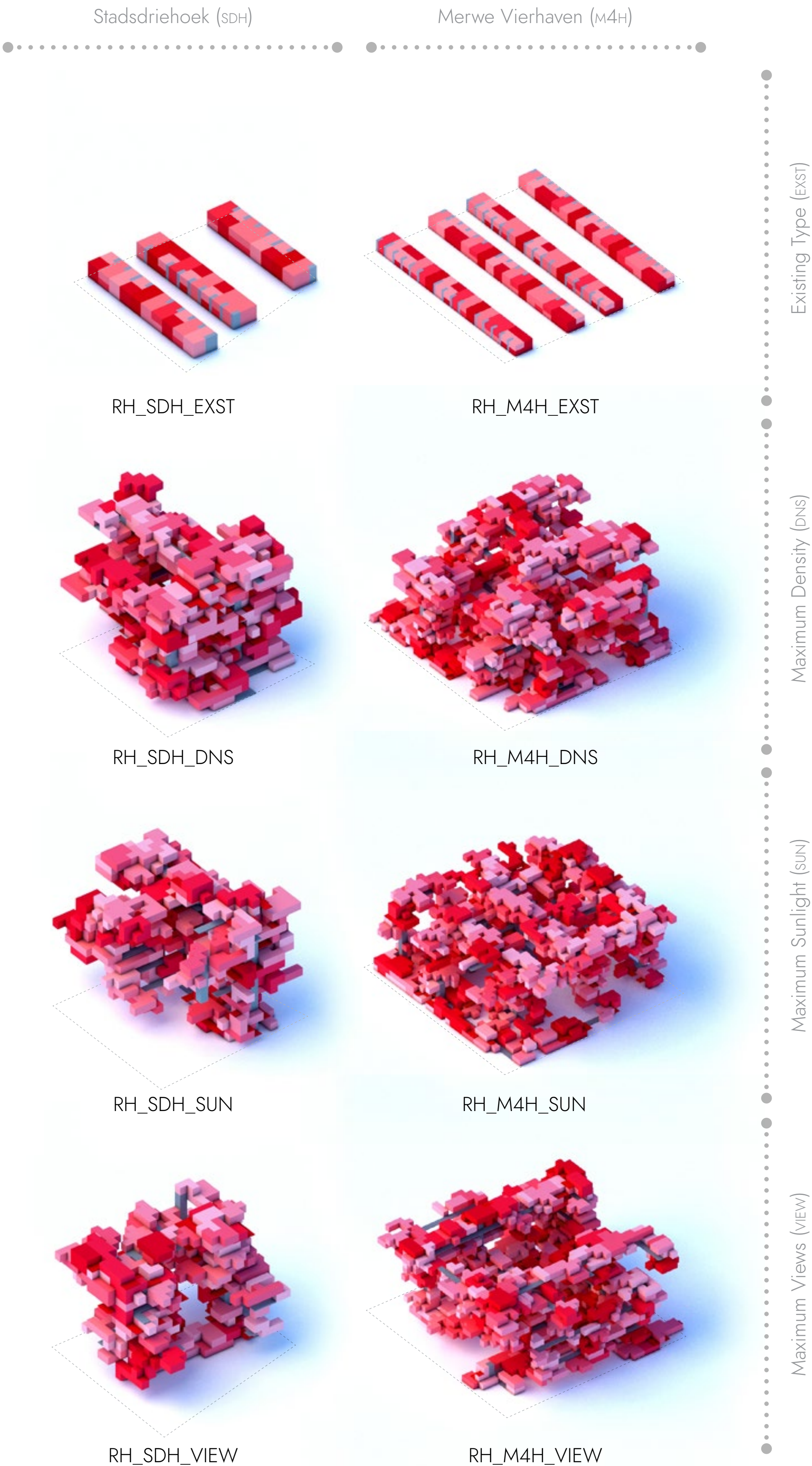


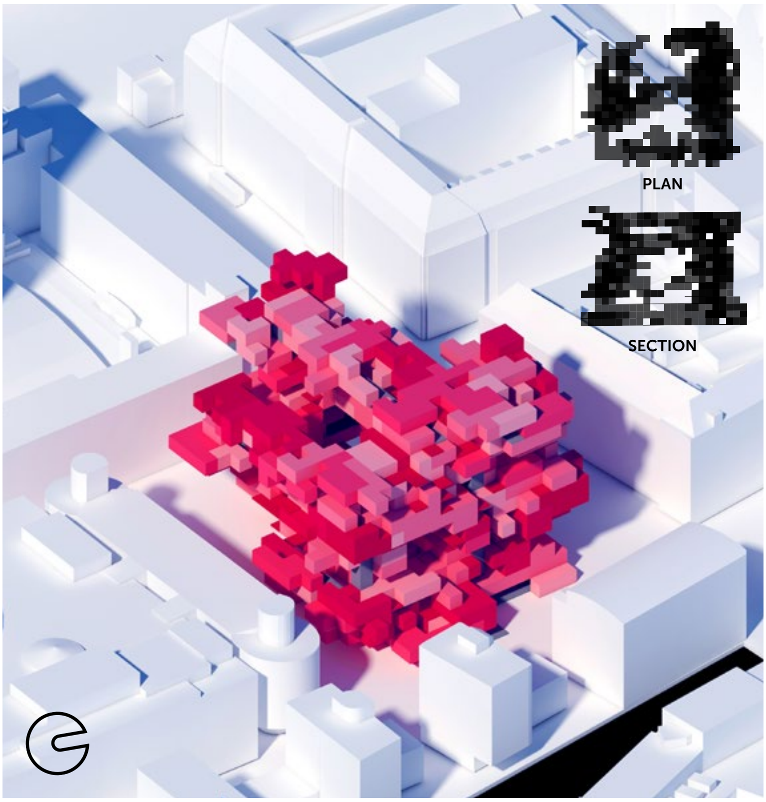
THE MATRIX of morphologies is a result of all the possible experiment permutations between the defined topologies, locations and minimu parameters. Each of the four chosen topologies was applied to each of the two locations; first in the form of existing urban types, and the three alternative variants generated by the configurational algorithm, each geared to maximise one of the chosen parameters; density, sunlight or views. Each iteration was then evaluated based on the predefined evaluation criteria and compared against each other for performance differences.

ROW HOUSE TOPOLOGY (RH)

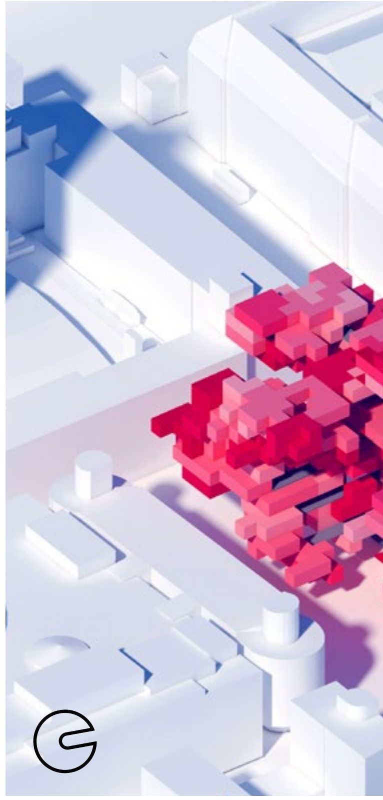
The results of the row house topology demonstrate the potential performance gains enabled by utilizing a computational configurational design approach to modify existing urban types to fit contemporary conditions that require higher density and spatial quality. Comparing the performance on both sites we see that, as expected, existing urban types perfomed better in terms of environmental parameters on the M4H location, a result of a lack of context and lower need for adaptation. In contrast, the generated spatial compositions performed very similarly on both sites, pointing towards the adaptive capabilities of the algorithm which strives to fulfill requirements within the constraints of the location.



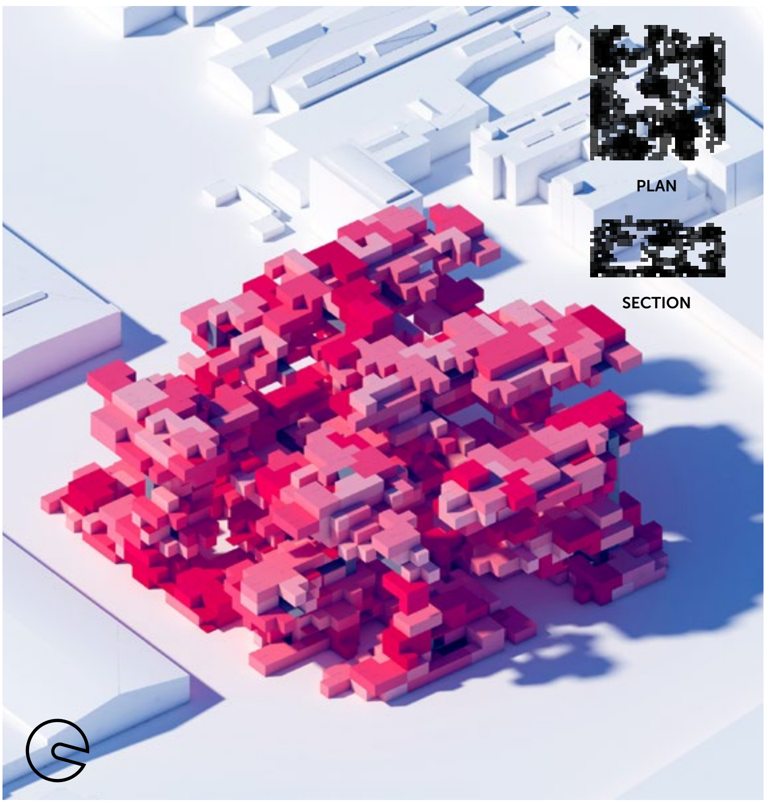

Stadsdriehoek (SDH)
Merwe Vierhaven (M4H)
Existing Type (EXST)
Maximum Density (DNS)
Maximum Sunlight (SUN)
Maximum Views (VIEW)
RH_SDH_EXST
RH_M4H_EXST
RH_SDH_DNS
RH_M4H_DNS
RH_SDH_SUN
RH_M4H_SUN
RH_SDH_VIEW
RH_M4H_VIEW



RH_SDH_DNS

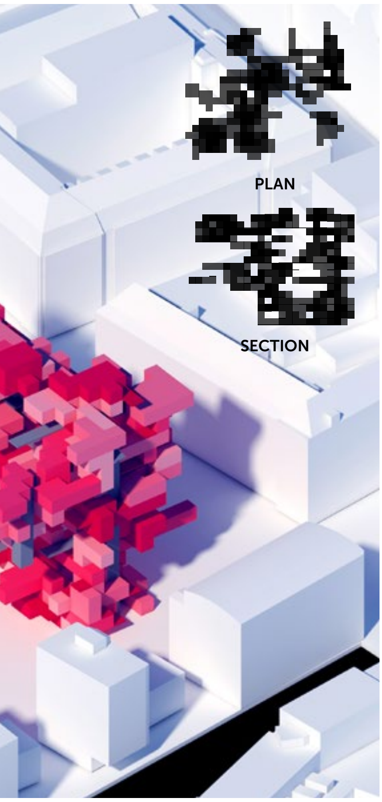


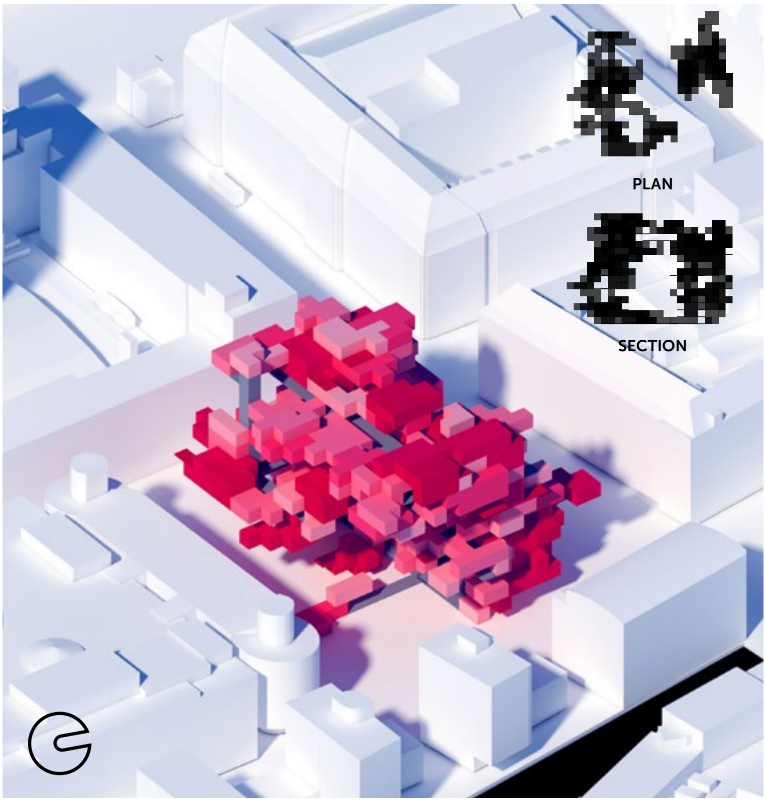
RH_SDH_SUN



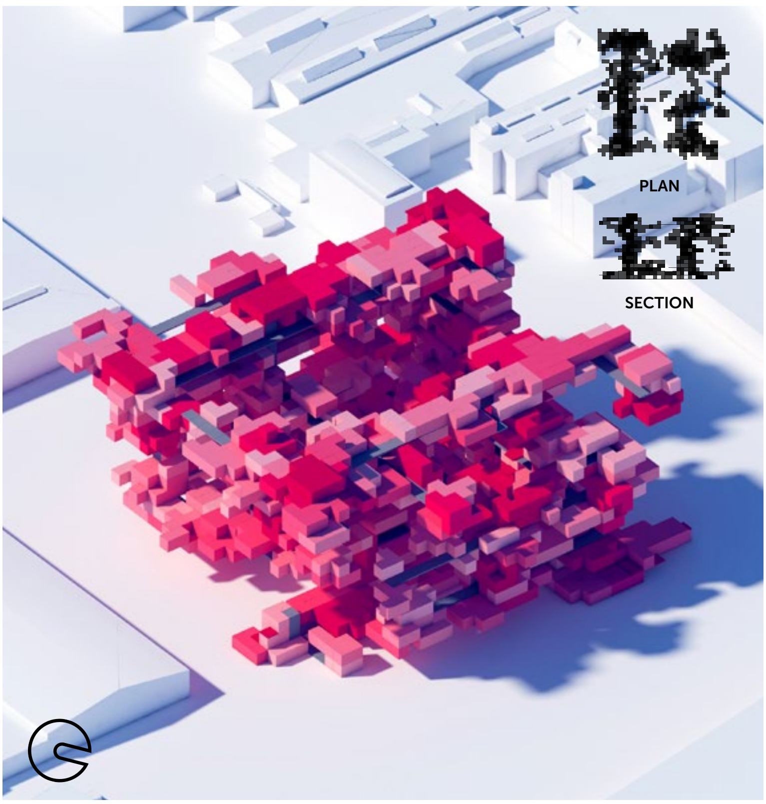
RH_M4H_DNS

RH_M4H_SUN





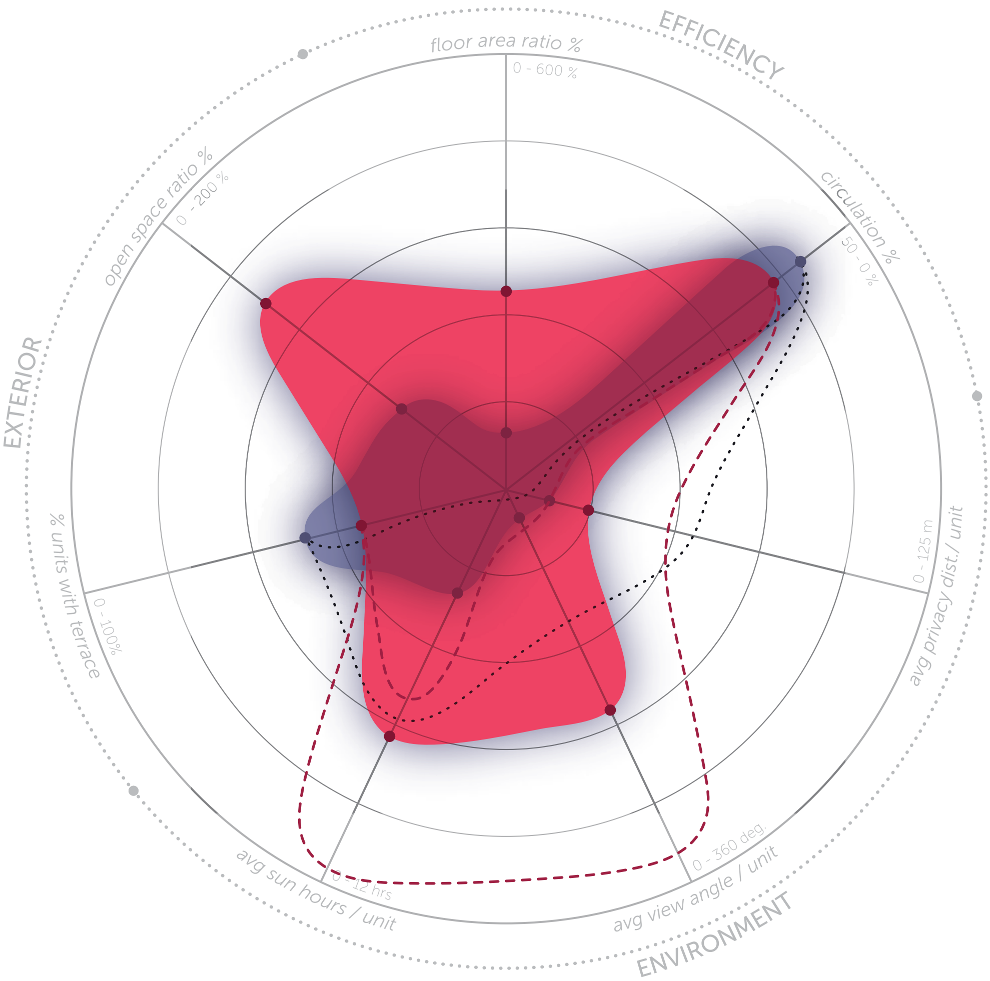
RH_SDH_VIEW



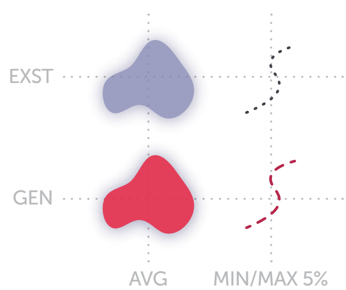
RH_M4H_VIEW

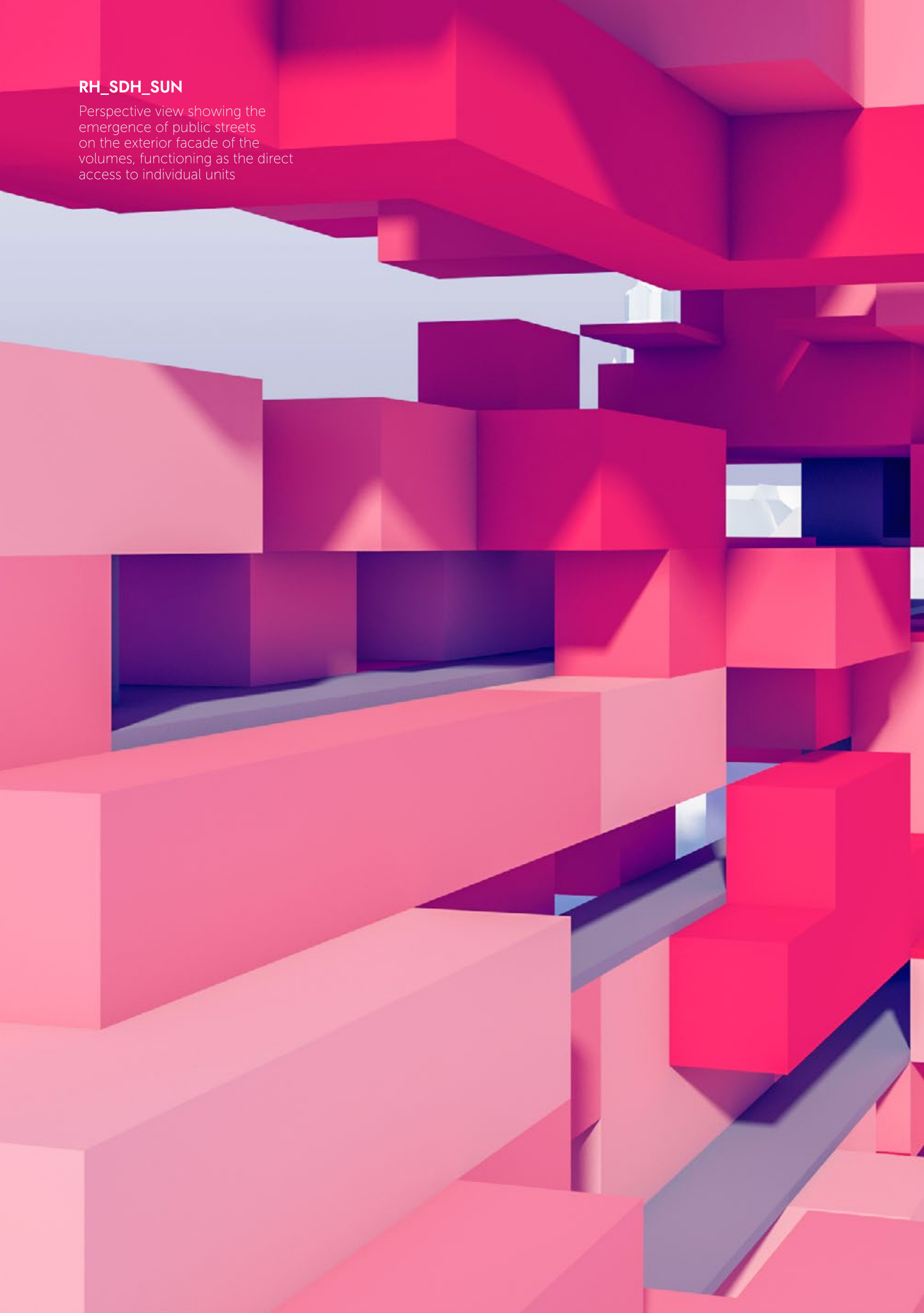
RH_SDH_SUN

The max sunlight experiment was performed with a minimum requirement of 6 sunlight hours per day, resulting in an composition starting from a thin linear base offset away from surrounding buildings and gradually expanding while growing vertically. Due to this adaptivity it outperforms the existing type in the majority of categories apart from circulation, where the values are quite similar and number of units with a terrace, which could be improved by modifying requirements. More importantly, looking at sunlight performance, not only does the generated composition perform better on average (6,25 vs 2,75 hours) but can also control the minimum, effectively eliminating units with subpar performance, while the minimum for existing row houses lies at close to 0 sunlight hours.



SCAN FOR AR MODEL



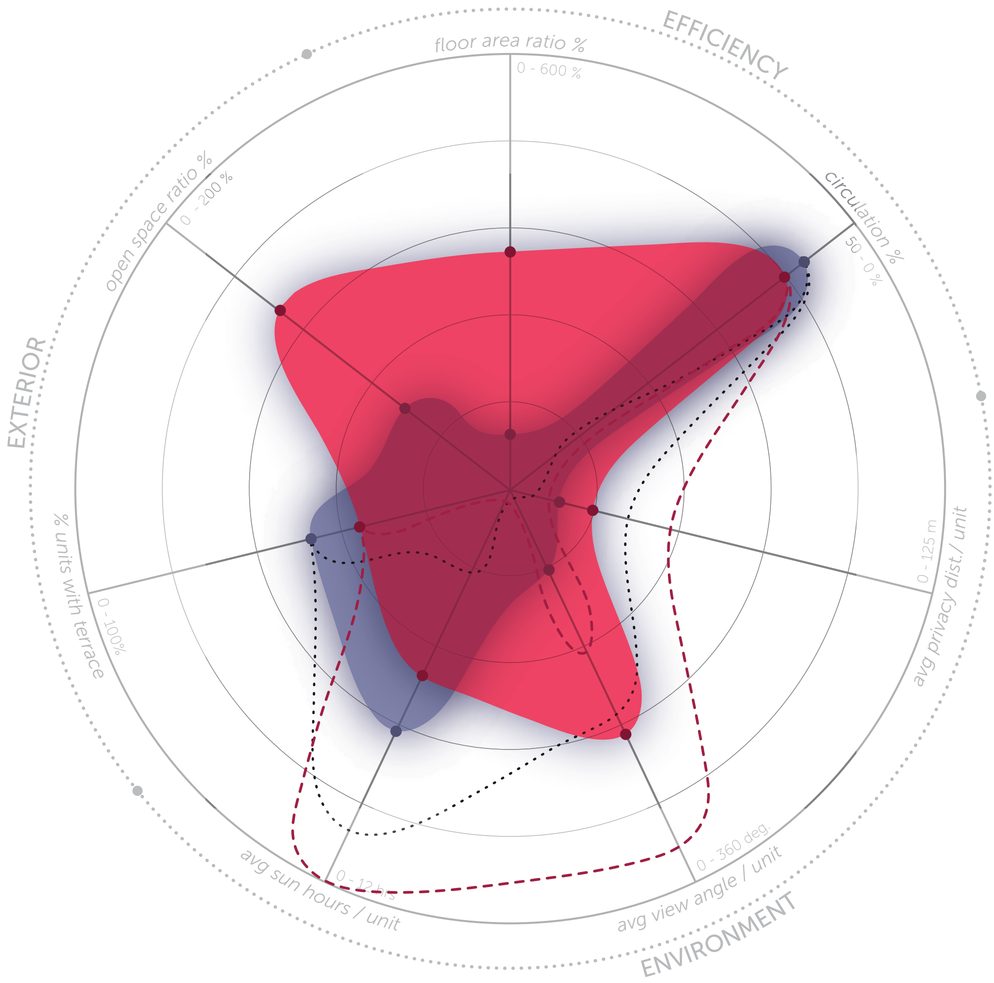


RH_SDH_SUN

Perspective view showing the emergence of public streets on the exterior facade of the volumes, functioning as the direct access to individual units

RH_M4H_VIEW

The max view experiment was performed with the requirement for panoramic views of a minumum of 135 degrees for each unit. The performance chart shows that due to this prioritisation of views and no other set requirements for sunlight or privacy the system heavily preferred views leading to very low minimum unit values for the other environmental criteria while retaining a comparatively extremely high minimum views value. This requirement along with the lack of substantial context also led to the emergence of a clearer spatial layout; linear beams of units interconnecting at vertical points of circulation forming a three dimensional spatial grid.



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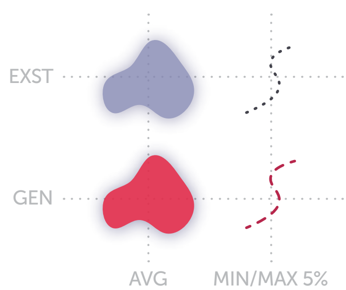
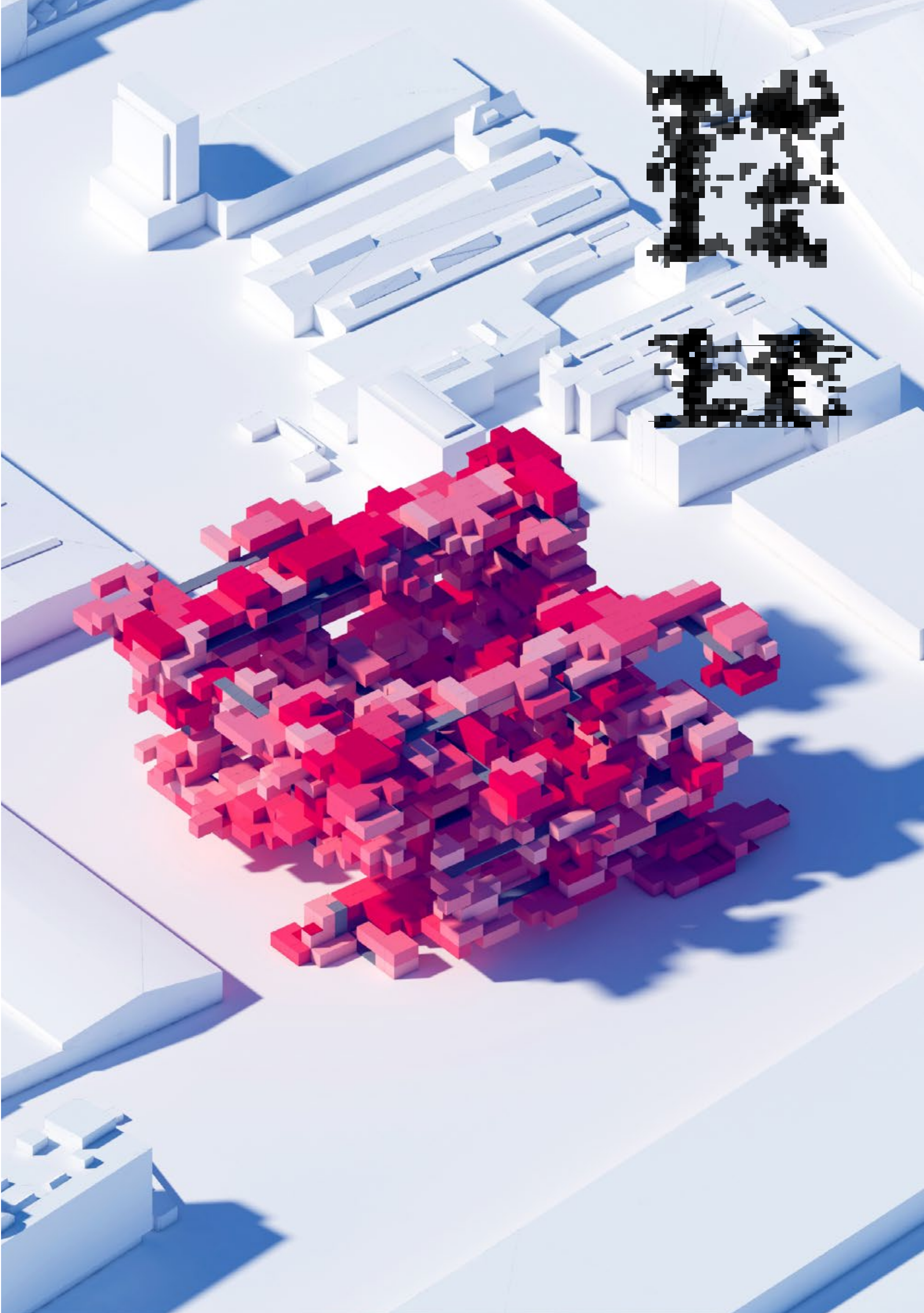
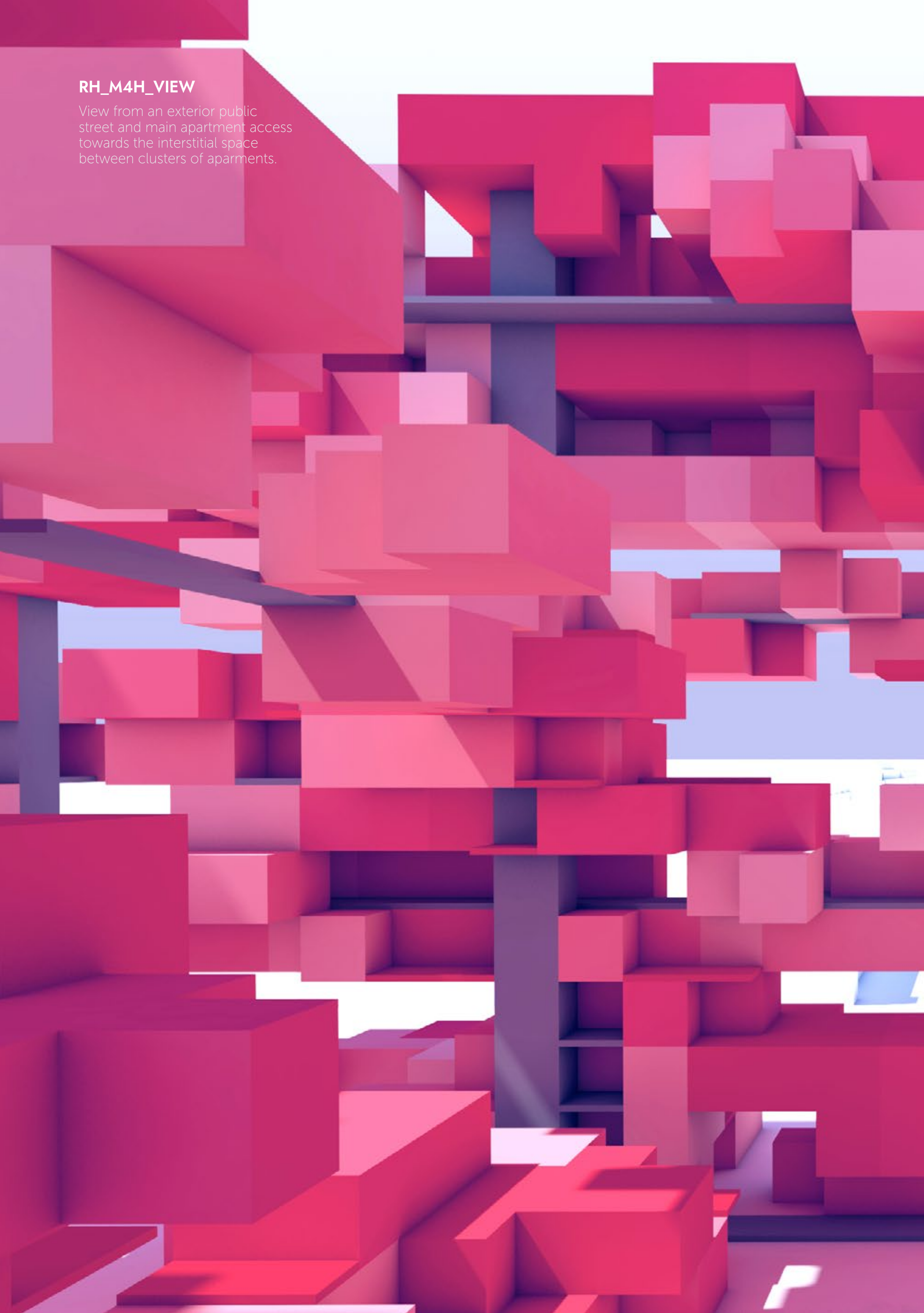
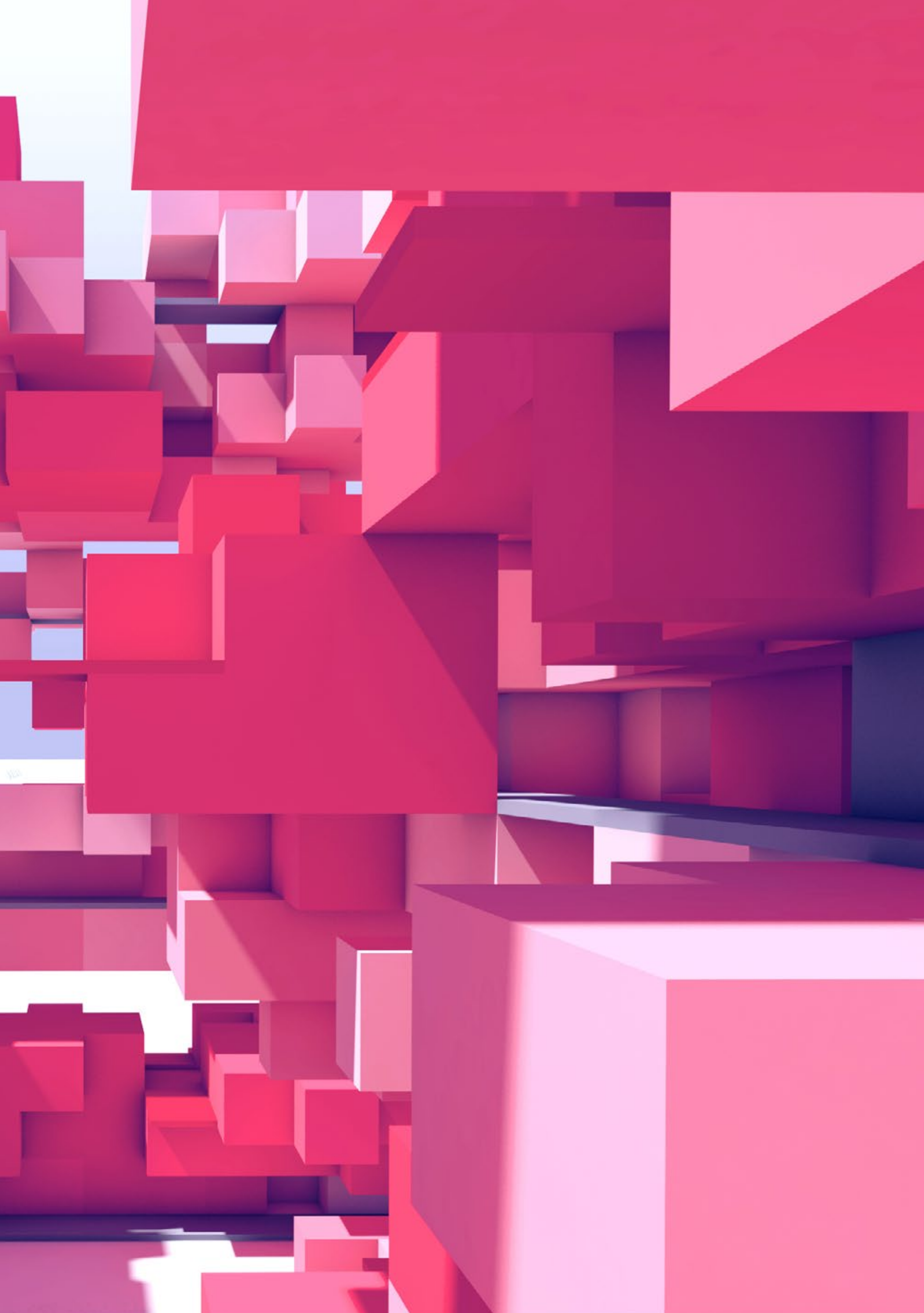






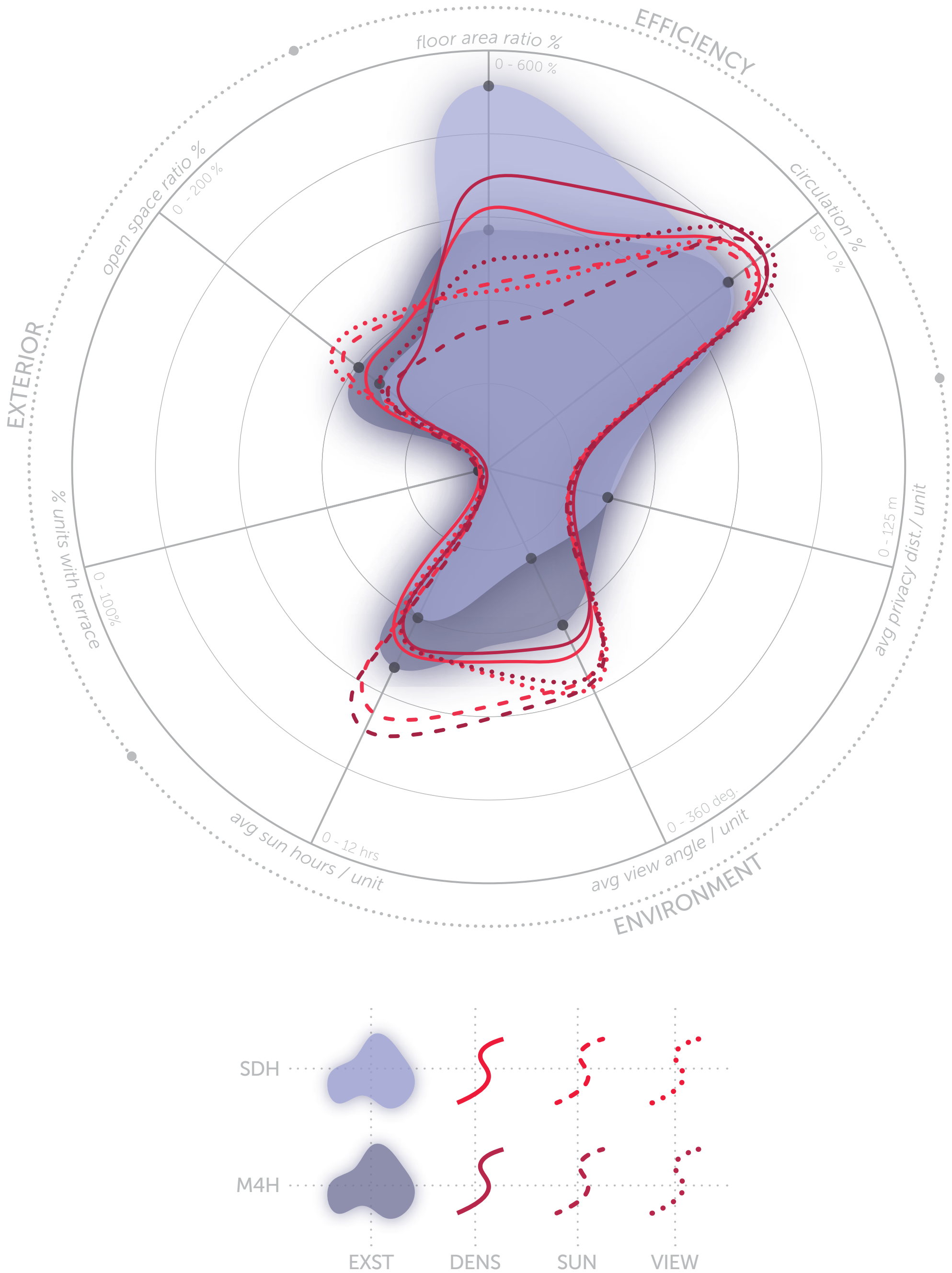
RH_M4H_VIEW

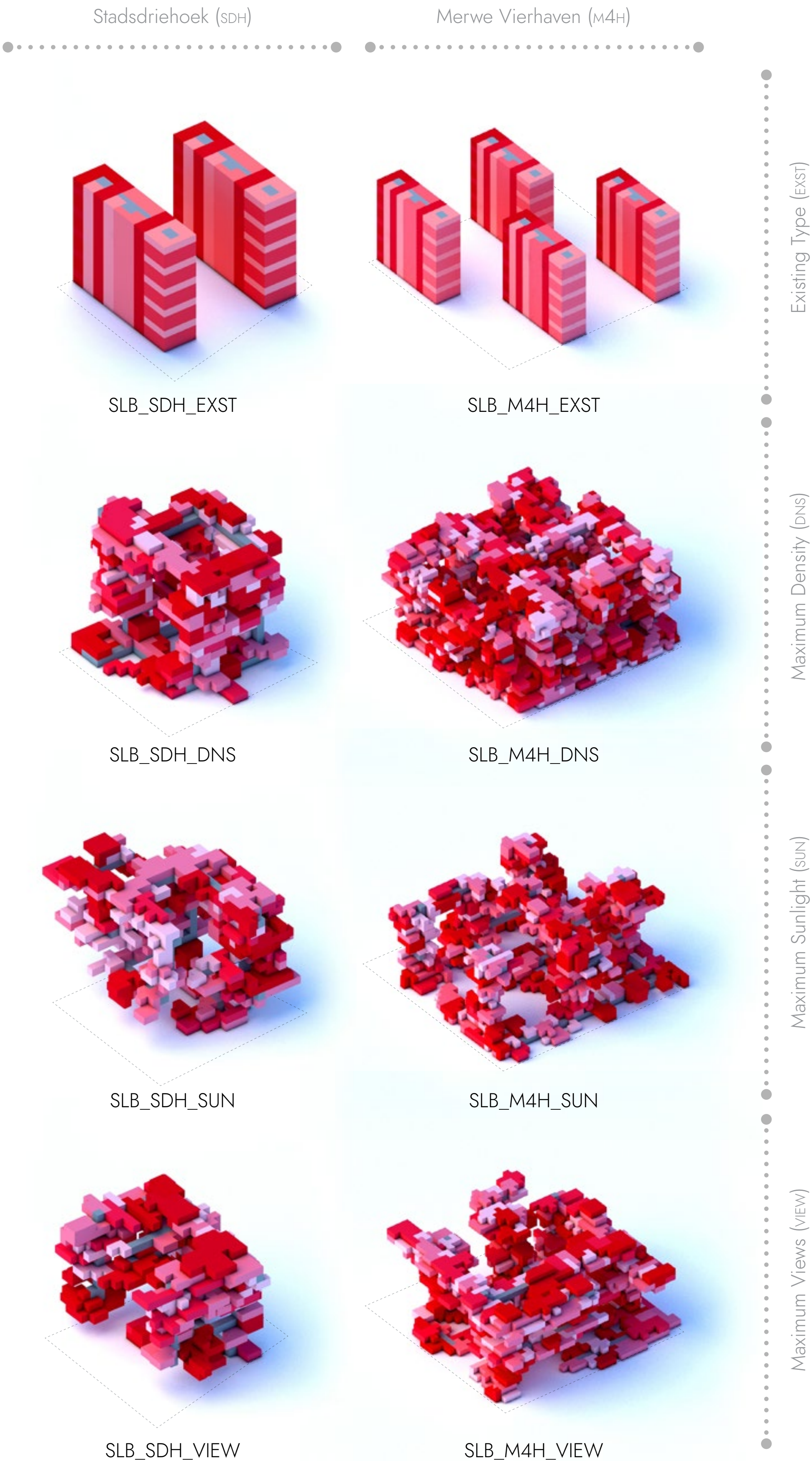
View from an exterior public street and main apartment access towards the interstitial space between clusters of apartments.



SLAB TOPOLOGY (SLB)

Comparing the results of existing and generated spatial compositions using the slab topology the performance chart shows very similar performances in the exterior parameter category, with the note that as terraces are not part of the default slab configuration they were not included as open space, which would drastically increase OSR performance of generated types. Regarding environmental parameters the generated compositions offered similar or better performance, except for privacy which was never assigned as a minimum requirement and is subject to improvement. In the efficiency category the generated types were not able to reach the high density performance of existing types, but did offer similar efficincy with regards to circulation space.




Stadsdriehoek (SDH)
Merwe Vierhaven (M4H)
Existing Type (EXST)
Maximum Density (DNS)
Maximum Sunlight (SUN)
Maximum Views (VIEW)
SLB_SDH_EXST
SLB_M4H_EXST
SLB_SDH_DNS
SLB_M4H_DNS
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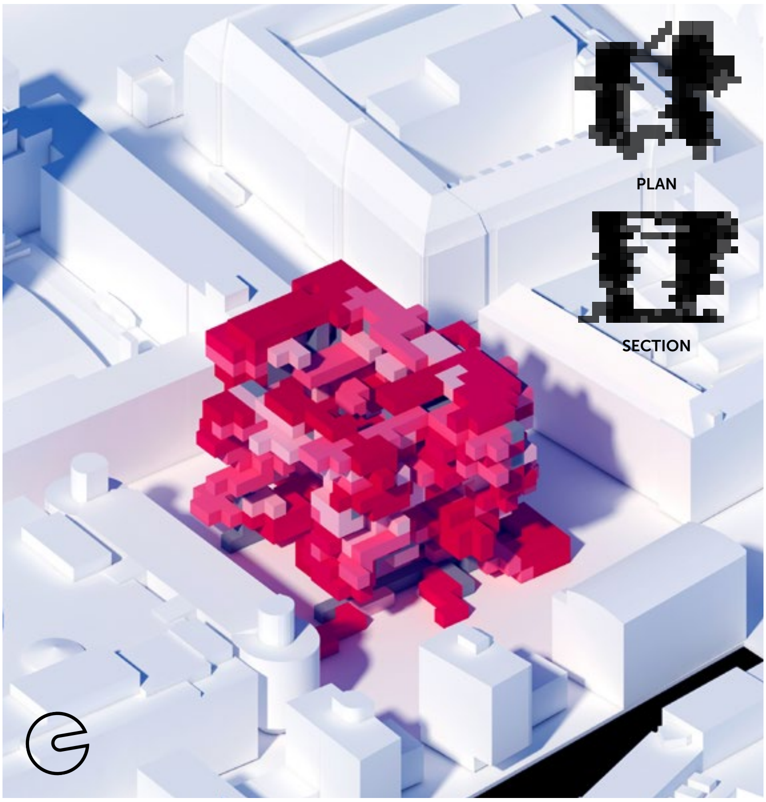
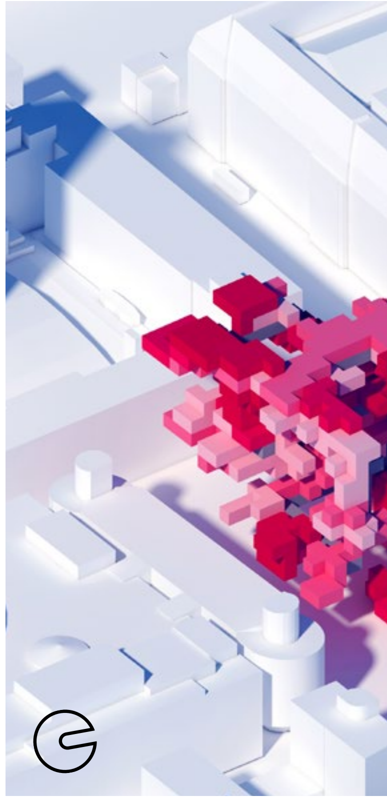
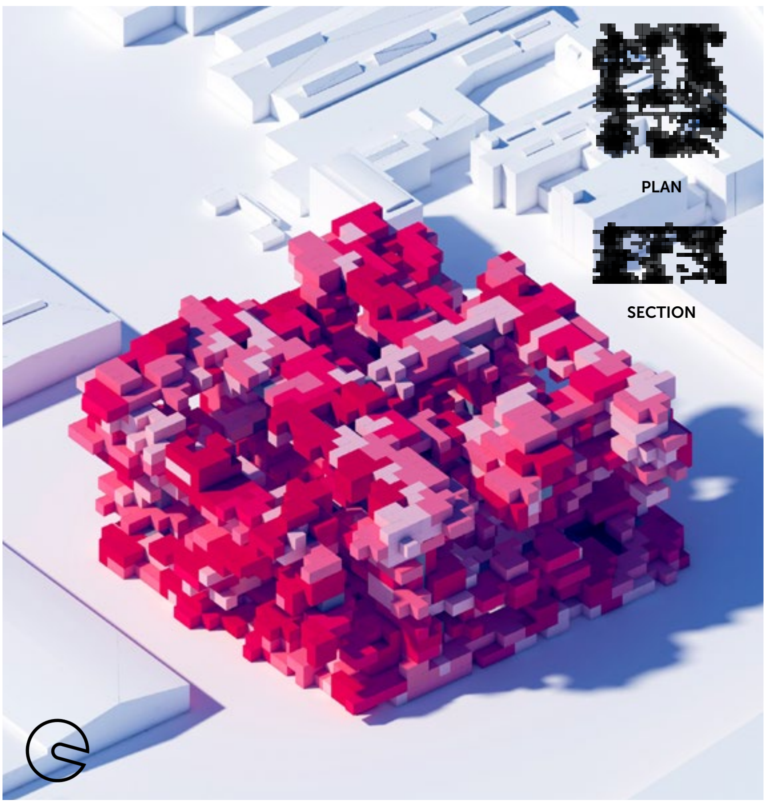
SLB_M4H_SUN
SLB_SDH_VIEW
SLB_M4H_VIEW



SLB_SDH_DNS

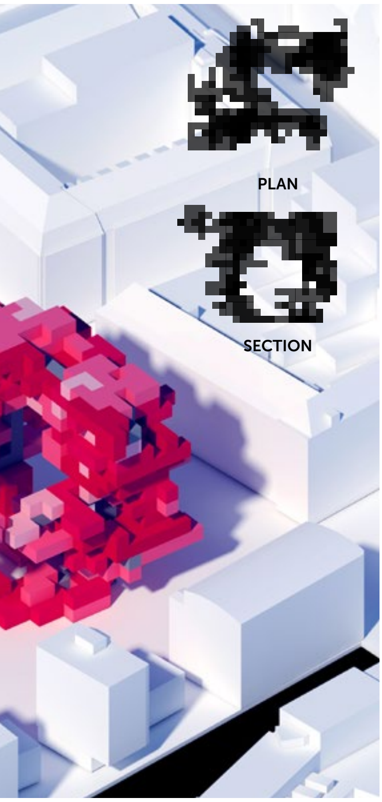


SLB_SDH_SUN

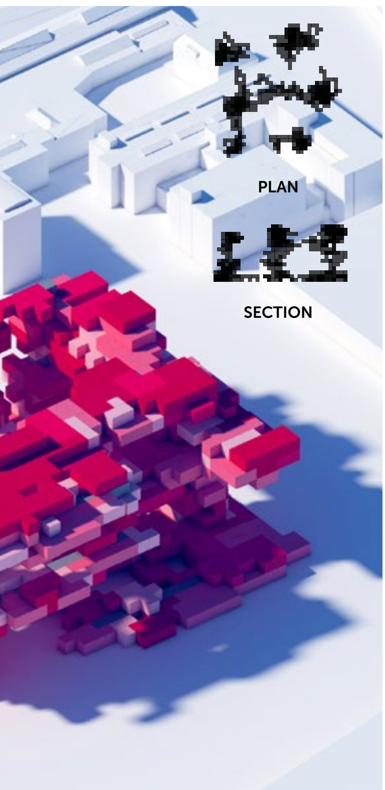


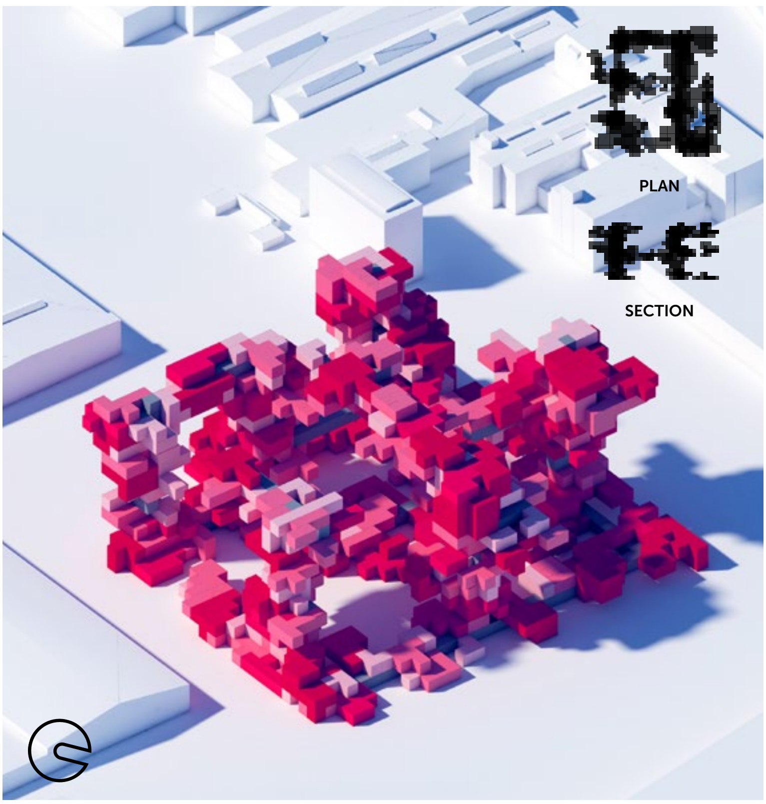
SLB_M4H_DNS

SLB_M4H_SUN



SLB_SDH_VIEW

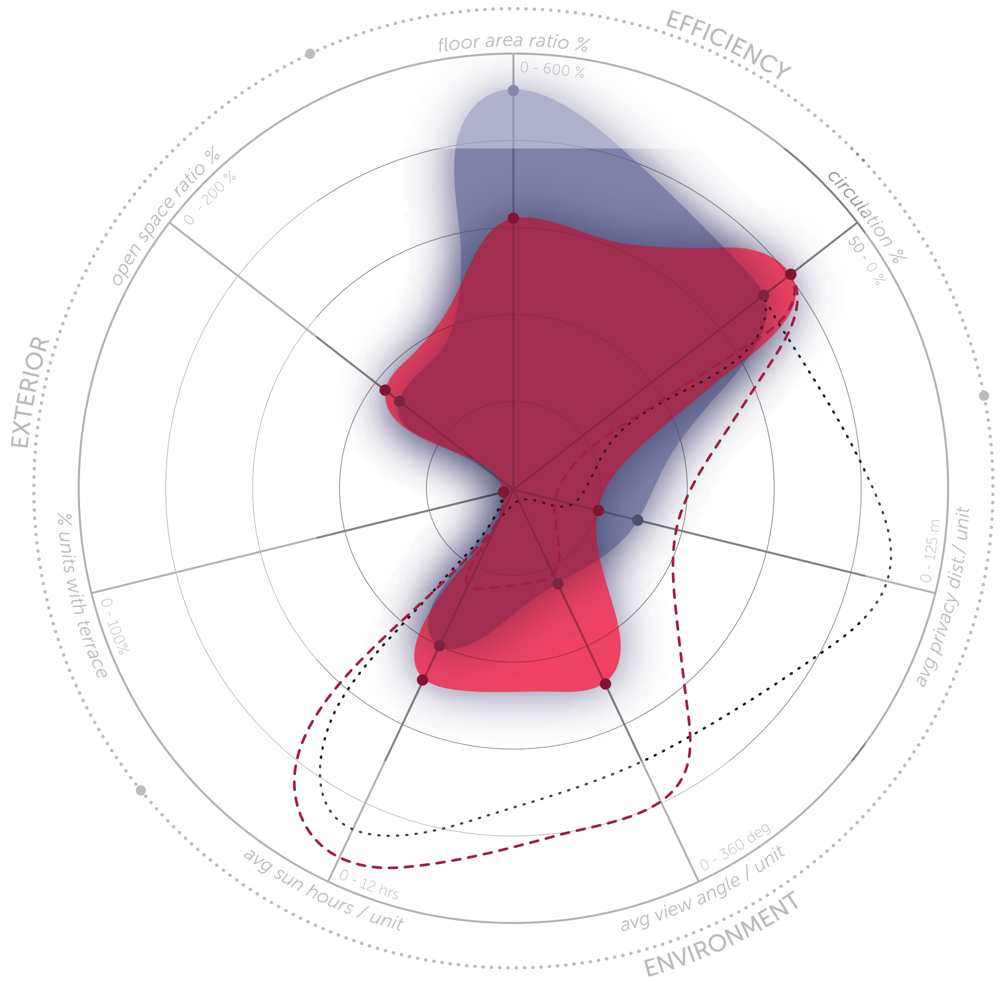




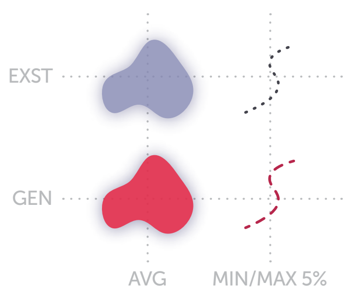
SLB_M4H_VIEW

SLB_SDH_DENS

The spatial compostion generated from the slab topology on the SDH site is one of the most compact and spatially efficient compositions that emerged from the experiments, mainly due to its arrangement in the form of two parallel slabs connected via bridge on the roof. While the composition can not compete with the existing slab typology especially in terms of density it did strongly outperform it in the environmental category which was the goal of this experiment. The large difference in minimum measured sun values per unit is again apparent, just as in the case of the RH_SDH_SUN experiment. This ensures greater control over the spatial quality of all apartments, essentially removing subpar units.

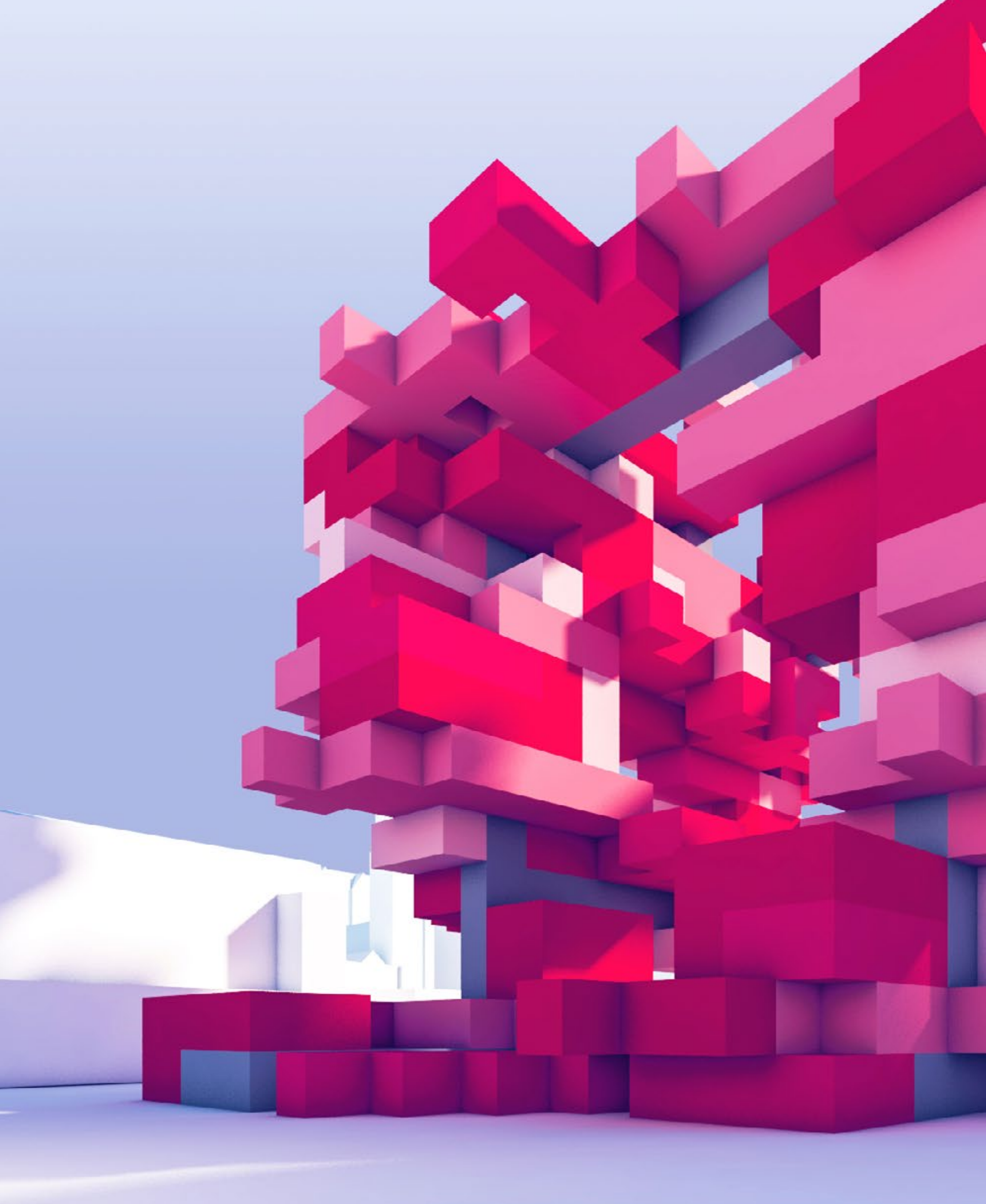


SCAN FOR AR MODEL



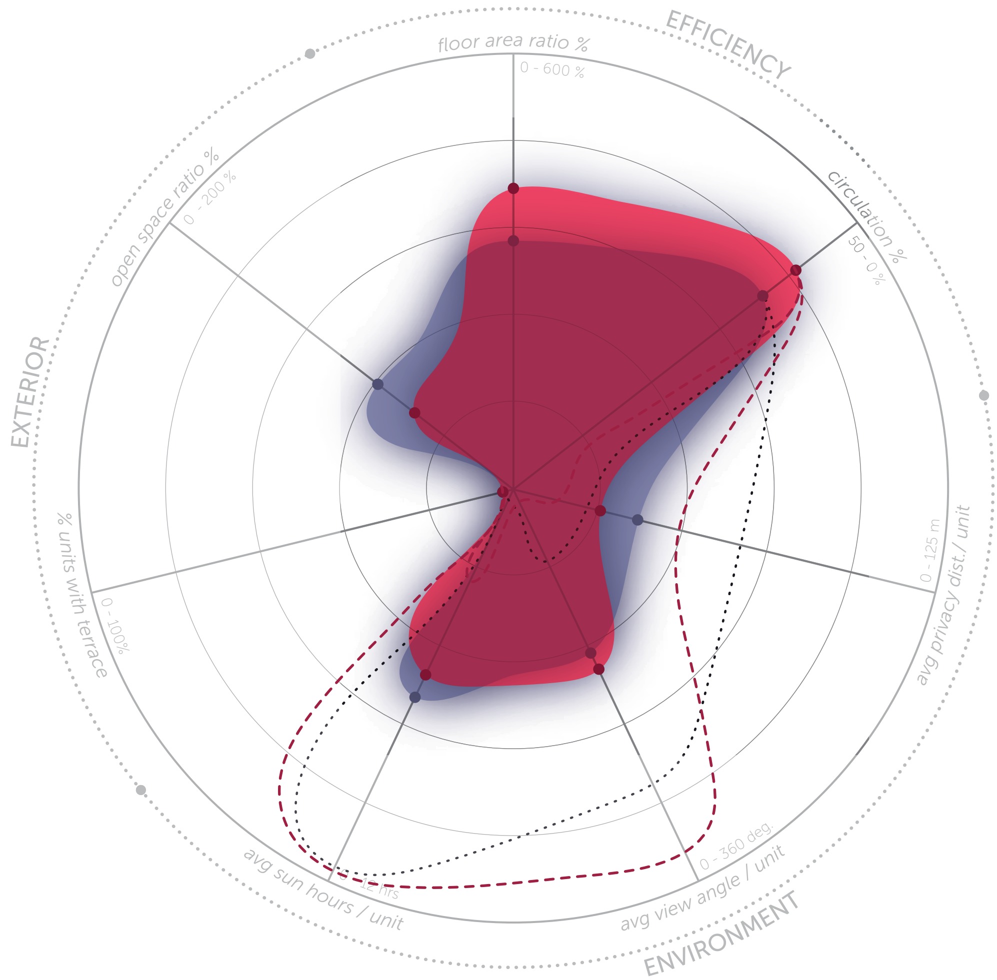
SLB_SDH_DENS

Street view of a very dense and compact aggregation formed by two parallel slab-like volumes interconnected with a bridge on the top floors.

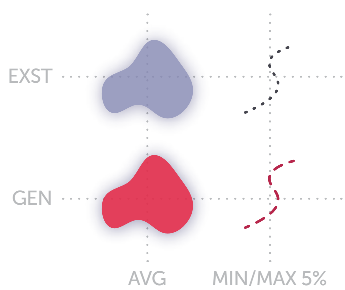


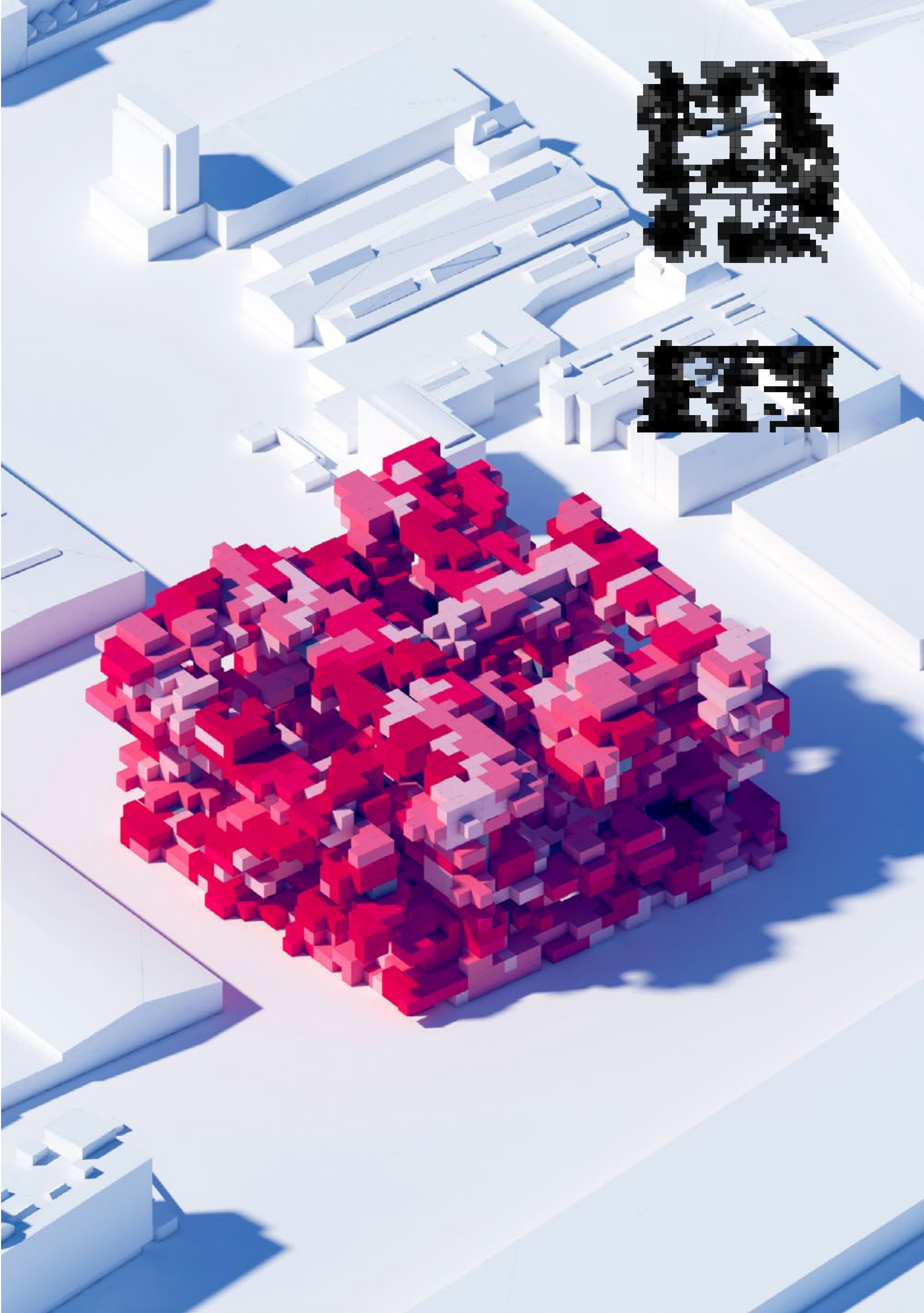
SLB_M4H_DENS

The spatial composition generated from the slab topology on the M4H location was performed with minimum requirements of 3 hours sunlight and 45 degree views of a minimum of 50 meters per each unit. This is the only experiment in which a generated slab topology outperformed the existing slab type regarding density, while offering very similar performance in other categories. Due to the lack of substantial context this has also lead to the emergence of a spatial order of vertical and horizontal "tubes" of apartments anclosing the volume, while leaving large semi-covered open spaces within. Nonetheless, this result is as much a reflection of the context and topology, as the underlying algorithm and the way in aggregates, a fact proven by the similarity of aggregations across all simulations.



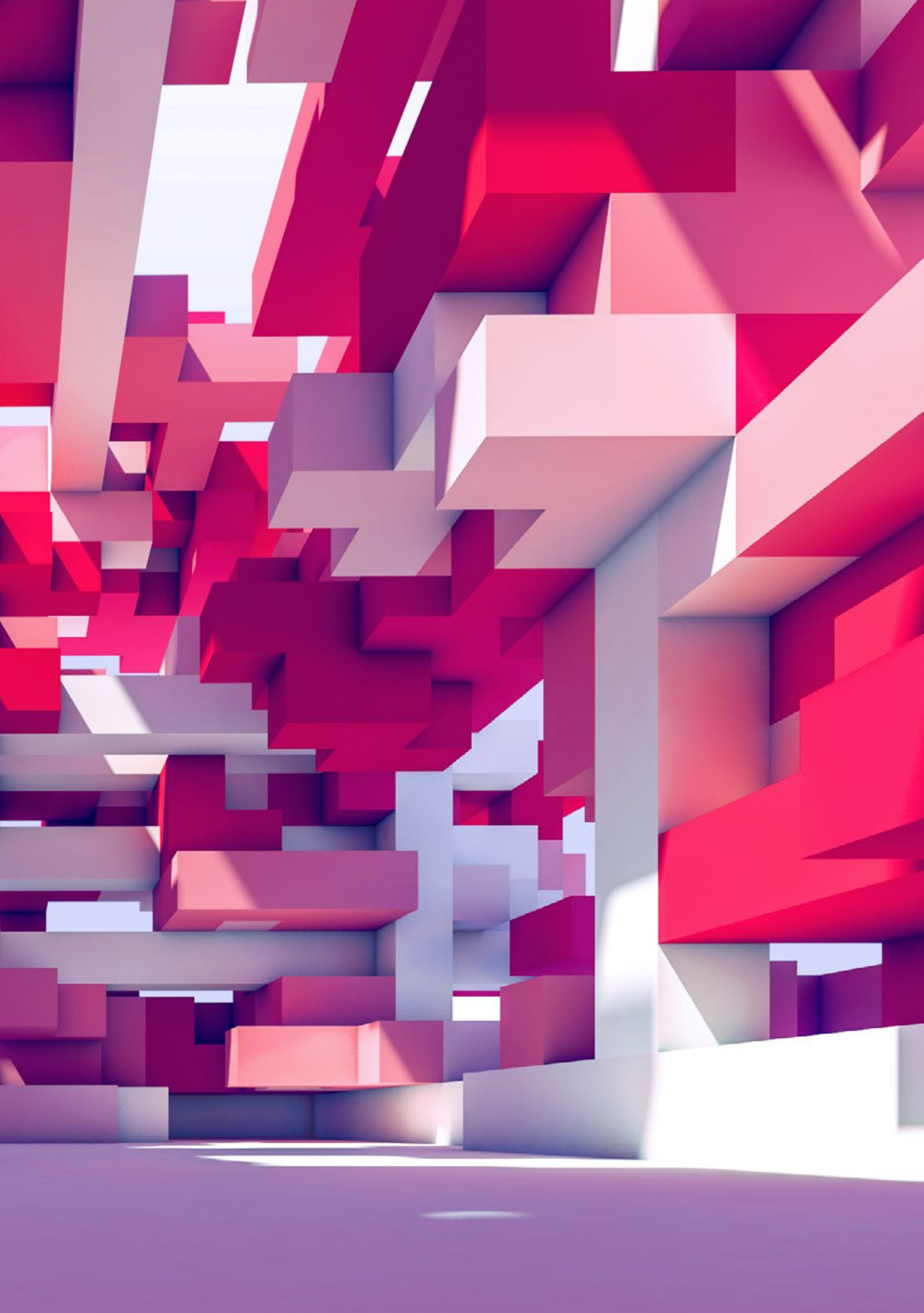
SCAN FOR
AR MODEL





SLB_SDH_DENS

View from a residual interior public space showing extreme density above ground enclosing it.



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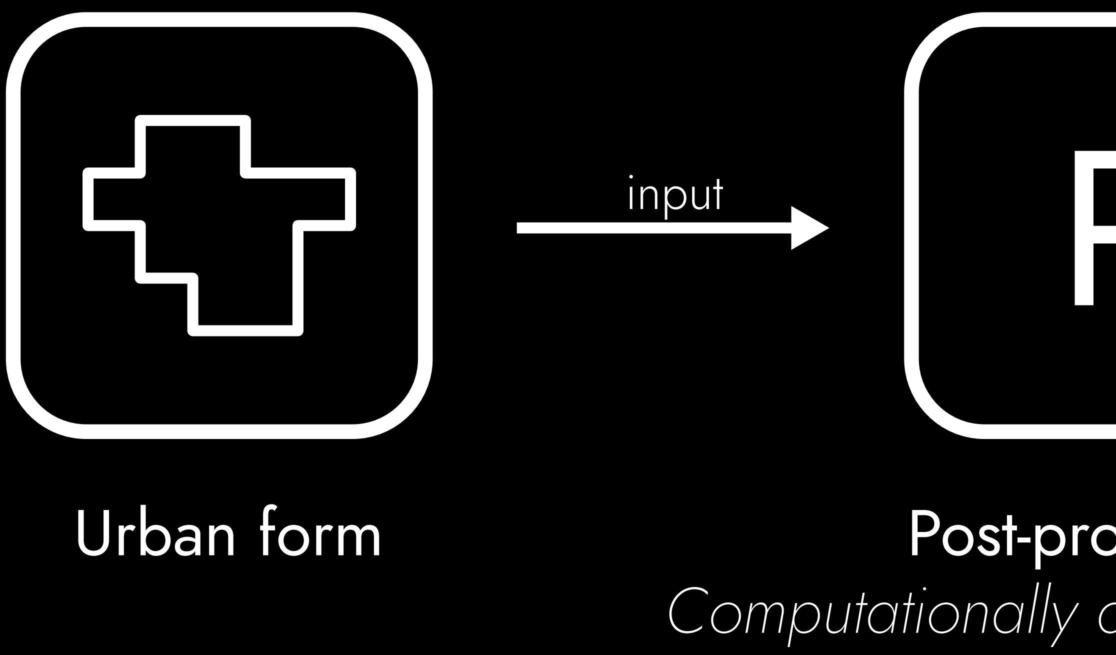

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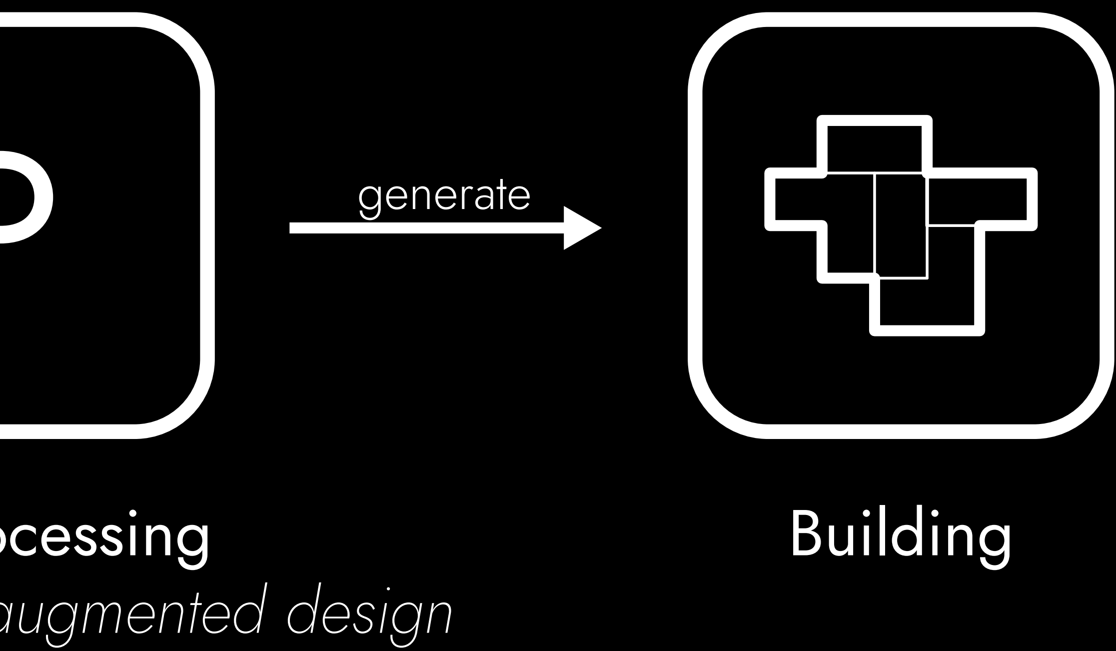
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13 ON THE... ARCHITECT

What is the role of the architect designer in the configurational design approach and what is his relationship to the underlying generative algorithms?

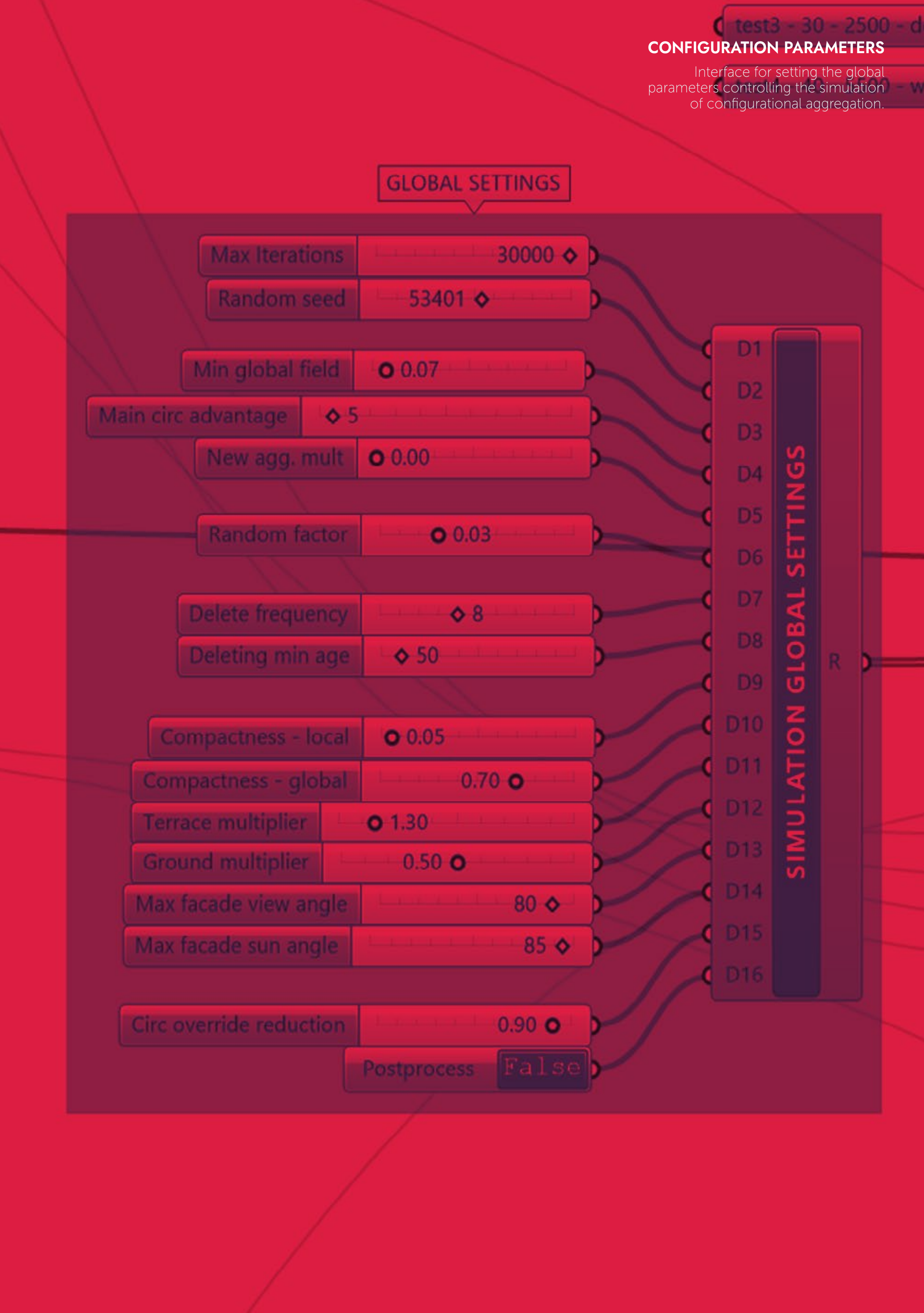
Configurational thinking in architectural design, while already latently present in the form of programme bubble-diagrams, when applied systematically as the main projective tool presents a significant departure from traditional compositional methods. Combined with digital technologies in the form of (semi-) automated **generative algorithms** capable of transforming configurations and data into architectural form, questions and doubts arise about its impact on the architect and his **role in the design process**. The majority of said apprehensions usually boil down to two specific reasons; the architect's perceived lack of control of spatial and formal aspects on one hand and control of the automated generative algorithms on the other. Both of these are false concerns stemming from the misunderstanding of the configurational approach and the way it deploys technology along with its primary purpose.

The configurational design process can be roughly divided into three phases; pre-design, the generative phase and selection phase, each of which requires conscious and purposeful intervention on the part of the architect. First, in **pre-design**, the architect is required to define the desired configuration as well as its accompanying requirements; these effectively become the main object of design within the configurational approach. Additionally, due to the incorporation of a large range of spatial, functional, technical and social aspects within configurations themselves, their design primarily falls into the domain of architects thanks to our broad skill set enabling us to successfully negotiate the multiplicity of diverse parameters and influences. Second, the **generative phase**, even though automated, is not autonomous but dependant on specified instructions. In other words, the generative algorithms employed to transform configurations into spatial compositions, although complex in their operation, are nothing more than sequences of instructions to be performed in response to the input parameters which are in turn defined by the architect-designer. Furthermore, the instructions themselves and thus the algorithms are also subject to design and created with a specific design intent. Finally, the crucial role of the designer is again apparent upon **examining the results** of the generative algorithms where in most cases there exists a large number of possible solutions, none of which can be deemed the best. It is here that whatever agency the architect loses in the pre-design phase, especially regarding formal and experiential aspects, is regained as his expertise becomes crucial to **compare** and sift through the myriad of potential solutions and pick the most appropriate one by balancing **objective performance** with otherwise unquantifiable **subjective aspects**. In effect, despite automating the arguably most important - generative - phase of design, creative control is never lost by the designer but merely temporarily exchanged for the possibility of a greater variety of potential solutions and regained with the final selection of the preferred scheme.

Returning to the issue of process, it is apparent that algorithms are no more than **tools** in service of the architect used for their ability to translate the designed configuration into a multitude of possible spatial compositions traditionally out of reach for the human designer limited by time and complexity. Furthermore, this increase in efficiency by way of partial automation could help kickstart the long-overdue technological evolution within the construction industry, currently second to last in **productivity** amongst all sectors contributing immensely to the dwindling influence of architects within the construction process.[41] In this light, the use of algorithms represents the next step in the evolution **architectural tools**; a progression that started

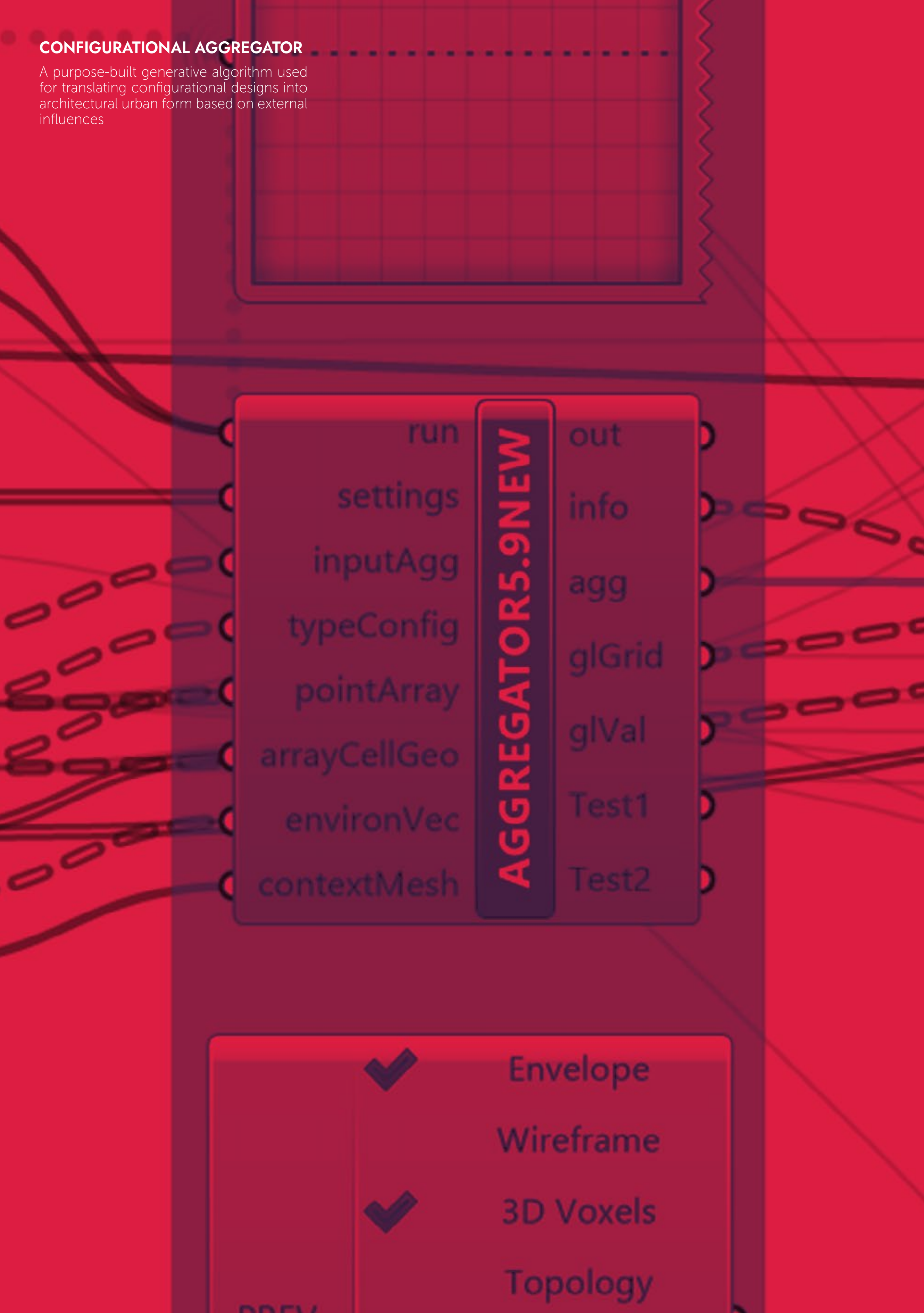
CONFIGURATION PARAMETERS

Interface for setting the global parameters controlling the simulation of configurational aggregation.



CONFIGURATIONAL AGGREGATOR

A purpose-built generative algorithm used for translating configurational designs into architectural urban form based on external influences

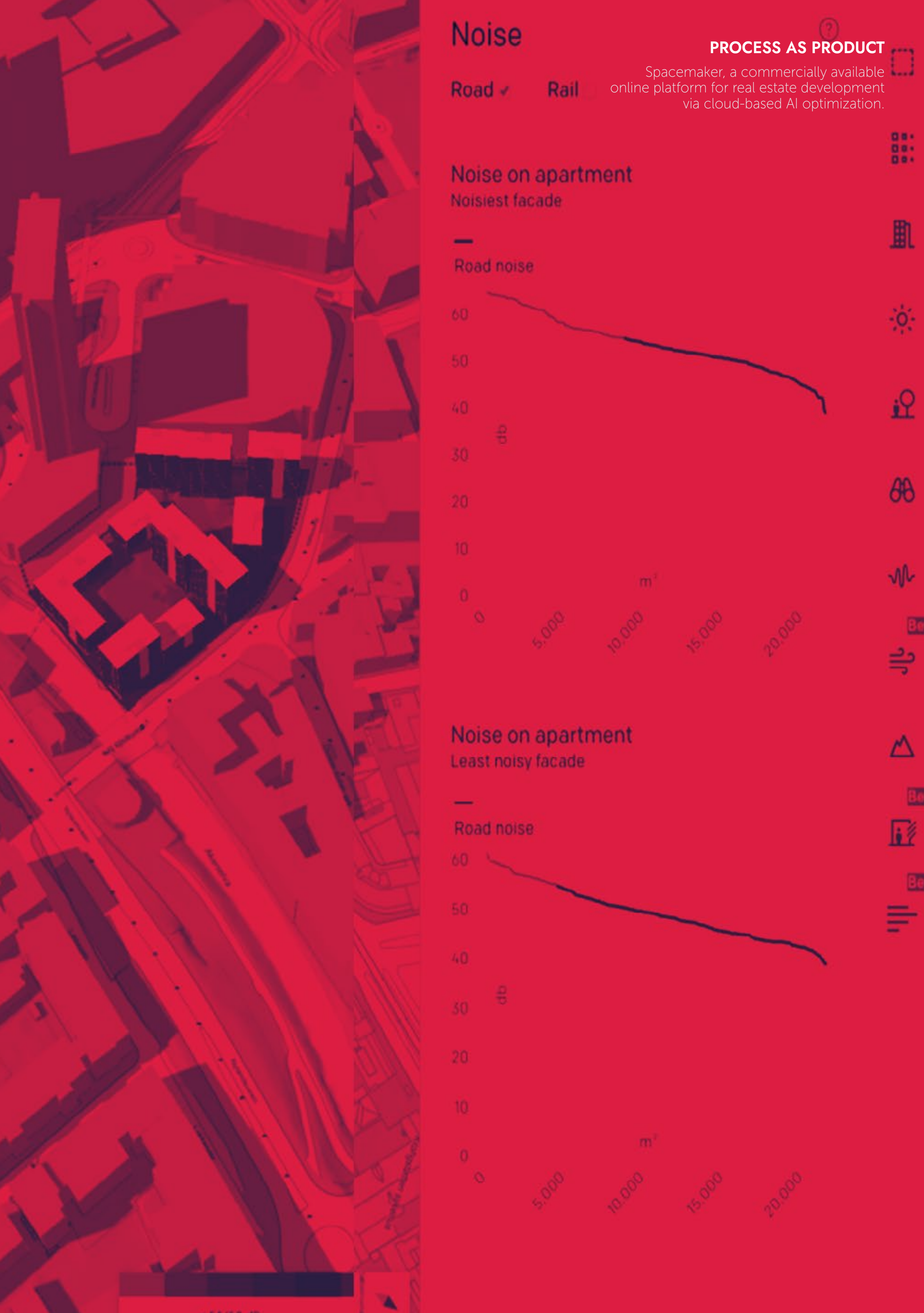


with the pencil, ruler and compass, continued with the use of drafting tables in the first half of the 20. century, the establishment of CAD software in the 1980s and increasing adoption of BIM software today. In contrast to the aforementioned tools which often prescribed the way, we design through structured interfaces, the diverse possibilities of algorithms today combined with increased digital literacy and more intuitive programming languages open up the opportunity for architects to develop our tools in ways we see fit. In other words, instead of tools defining how we work, we have the opportunity to define how our tools work.[55]

Different from existing drafting tools that often provide a generalised framework within which any architect can operate, algorithms are usually built for a specific purpose and consequently need to be **designed**. Moreover, this design needs to be architecture-specific and can only be developed by someone with the requisite knowledge in not only in the field of computer science but crucially also architecture, necessitating the inclusion of an architect. In this sense, the automation of the design process can be thought of as a **design project** in itself; a project for the development of which architects are crucial.[56] Albeit increased efficiency and productivity are the most obvious consequences, the way we automate, what algorithms we use and what type of architecture they generate can have profound economic, social and political consequences and it is the responsibility of architects to develop these technologies in a way that corresponds to our visions and desires of the future.

The benefits of appropriating and customizing technology in a way that amplifies the capabilities of the architect are increasingly visible in everyday architectural practice. Beyond pioneering examples at the end of the previous century such as Gehry Technologies, today this approach is already increasingly visible in large architecture offices with many having dedicated technological departments like **UNSense**, **MVRDV Next**, **ZHA code** and others, whereas in other cases this becomes the focus of complete studios an example of which are **Carlo Ratti Associates** operating on the crossroads of architecture, design, computation and data science.[56] Utilizing technology enables these companies to not only advance the quality of their designs but also to generate custom processes which could be protected as **intellectual property** and repeatedly used as design tools in multiple projects. This allows the companies to partially shift from service to product providers, making them less susceptible to the perpetual pressures of the market economy leading to greater **autonomy**.[57]

While configurational design may indeed bring many changes to the design process itself, the role of the architect as the head designer is by no means reduced but can in fact be expanded to new territories, which, if leveraged intelligently, could reassert and strengthen our position and influence within the construction industry, the global market economy and society at large.



PROCESS AS PRODUCT

Spacemaker, a commercially available online platform for real estate development via cloud-based AI optimization.

"..only through construction can a Utopia of the present be realized."

- Allison Smithson, Team 10 Primer, 1964

PROJECT CONFIGURATION

Practical application of configurational design

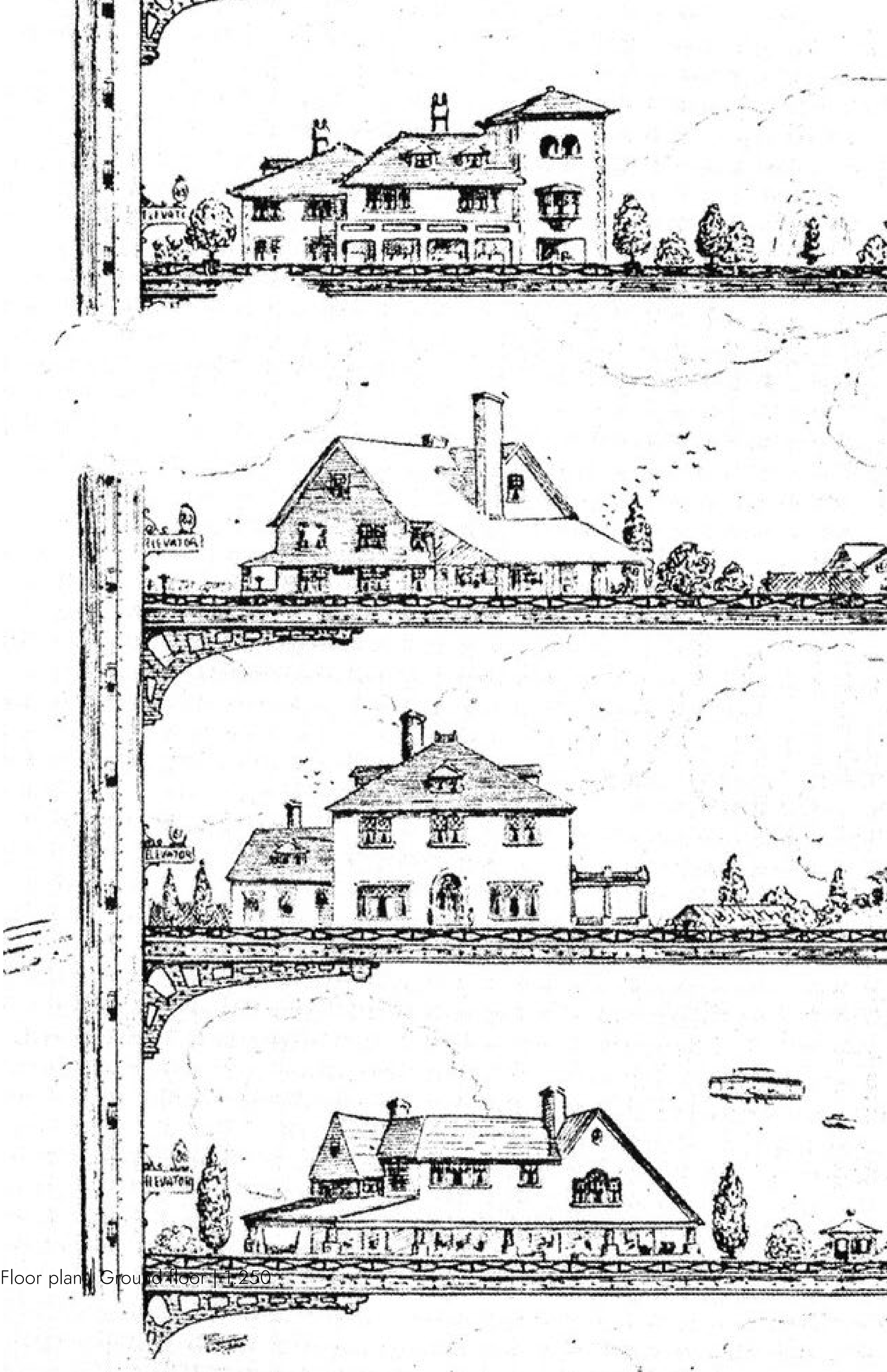
To truly test the potential of configurational design, such approaches need to be examined under the constraints of the real-world project acting as the ultimate stress test and eventually proof-of-concept.

Besides mere efficiency as a consequence of computational optimization of urban form, the largest implications of configurational design lie in its potential to fundamentally reshape the structure of the cities we live in. By operating on the level of socio-spatial patterns the approach could enable the translation of existing socio-spatial structures such as the detached house or rowhouse into new spatial compositions of higher densities and thus more in tune with the pressures of contemporary cities. Furthermore, by making the production of new spatial networks possible, it enables the synthesis of new configurations in direct response to evolving social conditions such as the increasing prevalence of co-housing, possibly leading to the emergence of a distinctive urban form, a new urban archetype.

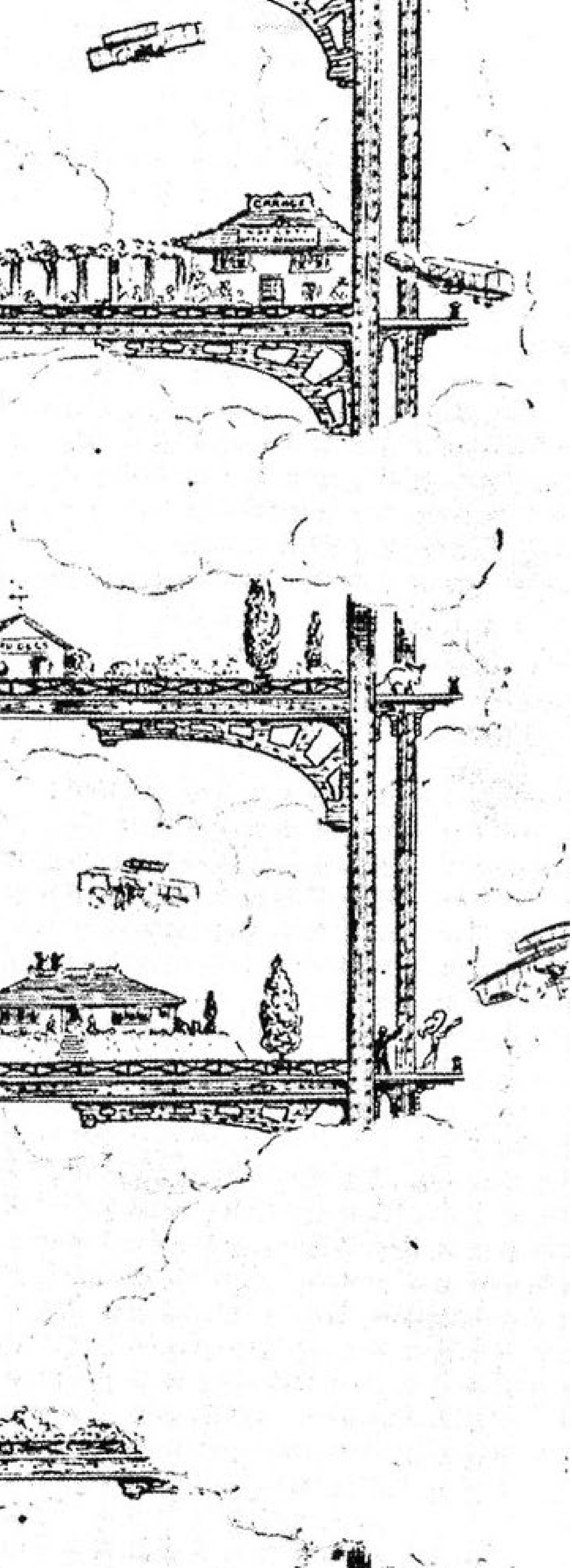
Responding to these potentials, from a configurational perspective the project tries to use configurational design to achieve the long-held ideal of vertical living. In line with its location in the Netherlands, this is conceptualised as the translation of the topology of a traditional Dutch row house into the hyper-density and efficiency of the modern high-rise tower. The result should be a vertical extrapolation of the traditional Dutch urban fabric, complete with a dense exterior street network, dwelling units with independent street access and private exterior terraces and balconies.

Taking this idea further, the approach refers to the concept of Mat-buildings established in the 1960s by members of Team 10.[58] Mat-buildings are defined as layered extensions of the urban ground plane; extended megastructures mirroring the structure of the surrounding city, not only in their patterns of streets, squares and "buildings" but also their programmatic composition and flexibility. Although initially designed with a specific programme in mind, Mat-buildings were intended to be programmatically flexible and thus capable of continual change. This idea of a flexible megastructure as a vertical extension of the urban fabric becomes increasingly relevant in the case of configurational design whose capabilities enable the production of urban form in which the qualities of every space can be precisely controlled. This can enable the production of adaptive-generic urban form; extremely adapted to the local site and environment at the global level, whilst remaining generic and open to multiple uses and the smaller local scale thus increasing its long-term durability and utility.

The project acts as a final test for the configurational approach and the configurational algorithm to prove or disprove its theoretical potentials in the real constraints of architectural practice.



Floor plan | Ground floor | 1:250



VERTICAL LIVING is a long-present ideal both in the general public but even more so in the archtiectural professtion due to its qualities of density and efficiency on one hand and the human scale and spatial diversity usually associated with suburban settings on the orher. Unfortunately this ideal has proven elusive and difficult to reach; for the most part, under the influence of market capital, it has given us high-density typologies of the slab and tower, which more closely resemble vertical storage cabinets for human activity than the qualities of openness described earlier. Part of the blame can also be attributed to the increased complexity of designing such vertical urbanisms where basic provision of sunlight for example can become a complicated endeavor. By using an automated configurational design approach, these issues could potentially be overcome. As a result the project proposes the combination of two predominant typologies in the Netherlands; first the traditional Dutch row house with its human scale, public streetscape, individual entrances and private terrace gardes and second, the modern high-rise tower for its efficiency and density, crucially important in today's inreasingly urbanised landscape. The result should be a hyper-dense vertical cityscape complete with streets and squares, building units and private terraces whose configuration should correspond to that of a row house neighbourhood. Could this ideal be realised?[59]

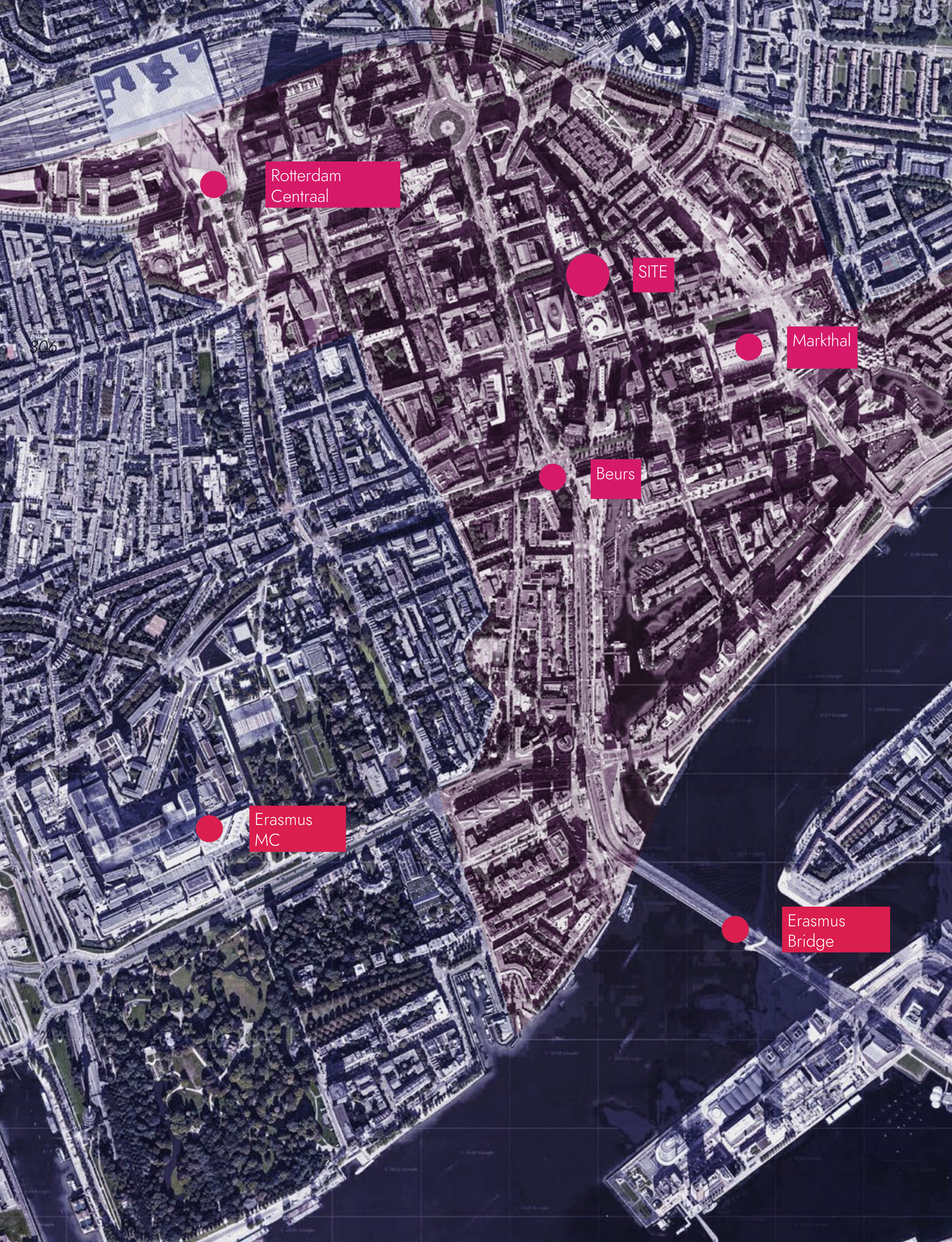
The row/terraced house type; a symbol of Dutch cities that enables individual street access and gardens for each dwelling unit. [60]

The tower urban type; a symbol of modern efficiency enabling high density cities.

Rotterdam 2050; planned housing schemes [61]

THE HOUSING CRISIS of Rotterdam further increases the importance of the topic of vertical living. Due to extreme housing shortages and sky-high prices the Rotterdam municipality is rapidly developing a plan to build 50.000 new homes by 2040[61]. One of the biggest issues in structuring the strategic plan is the lack of available land in the urban area of Rotterdam. In response to this, the project seeks to explore the possibility of further densification of the city center with dwellings which retain a profoundly suburban character. By doing this the best of both worlds becomes possible; apartments with their own direct street entrances and private terraces in a prime location in the city center. Could this be the future of Rotterdam?

LOCATION


Rotterdam Centraal
SITE
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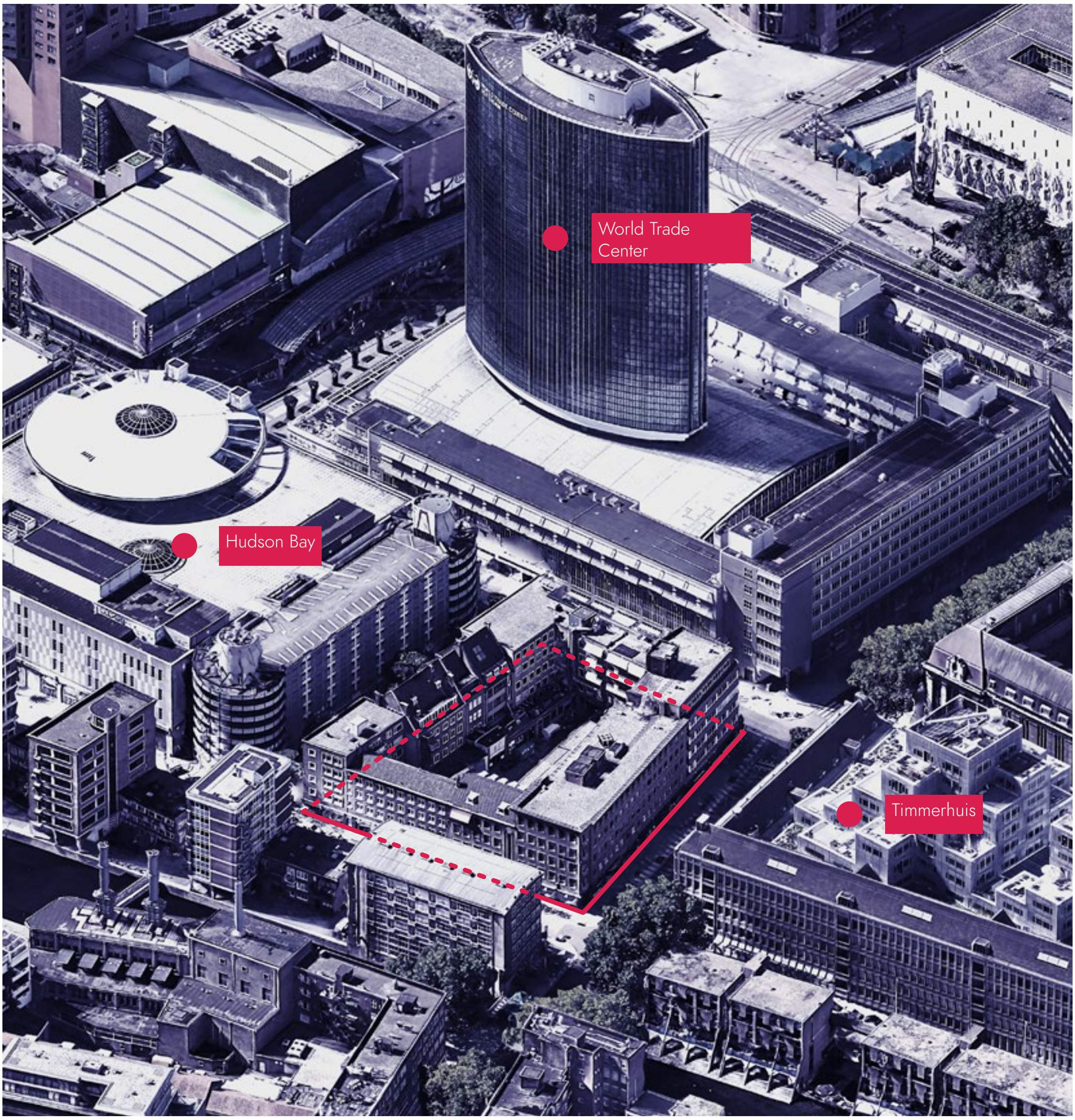
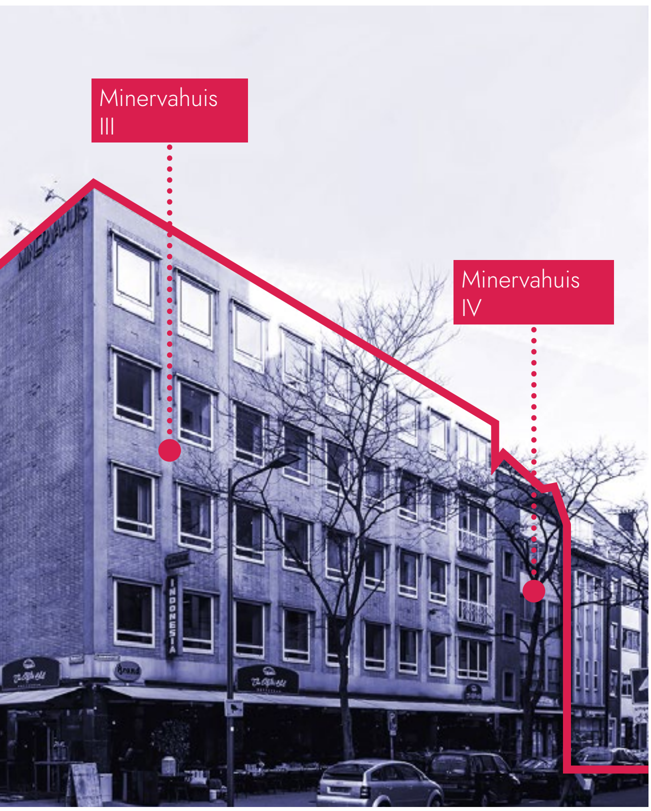
Beurs
Erasmus MC
Erasmus Bridge

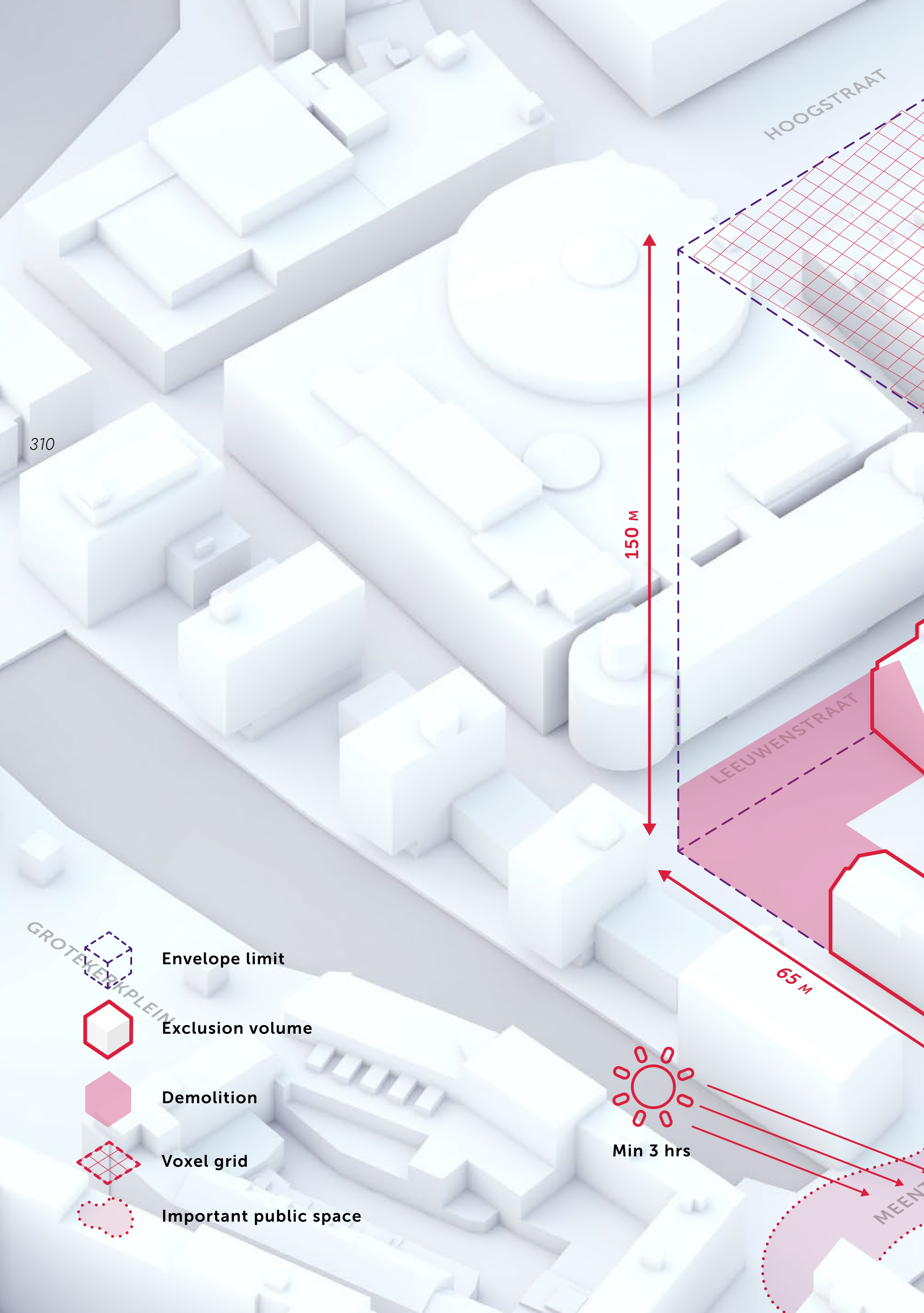


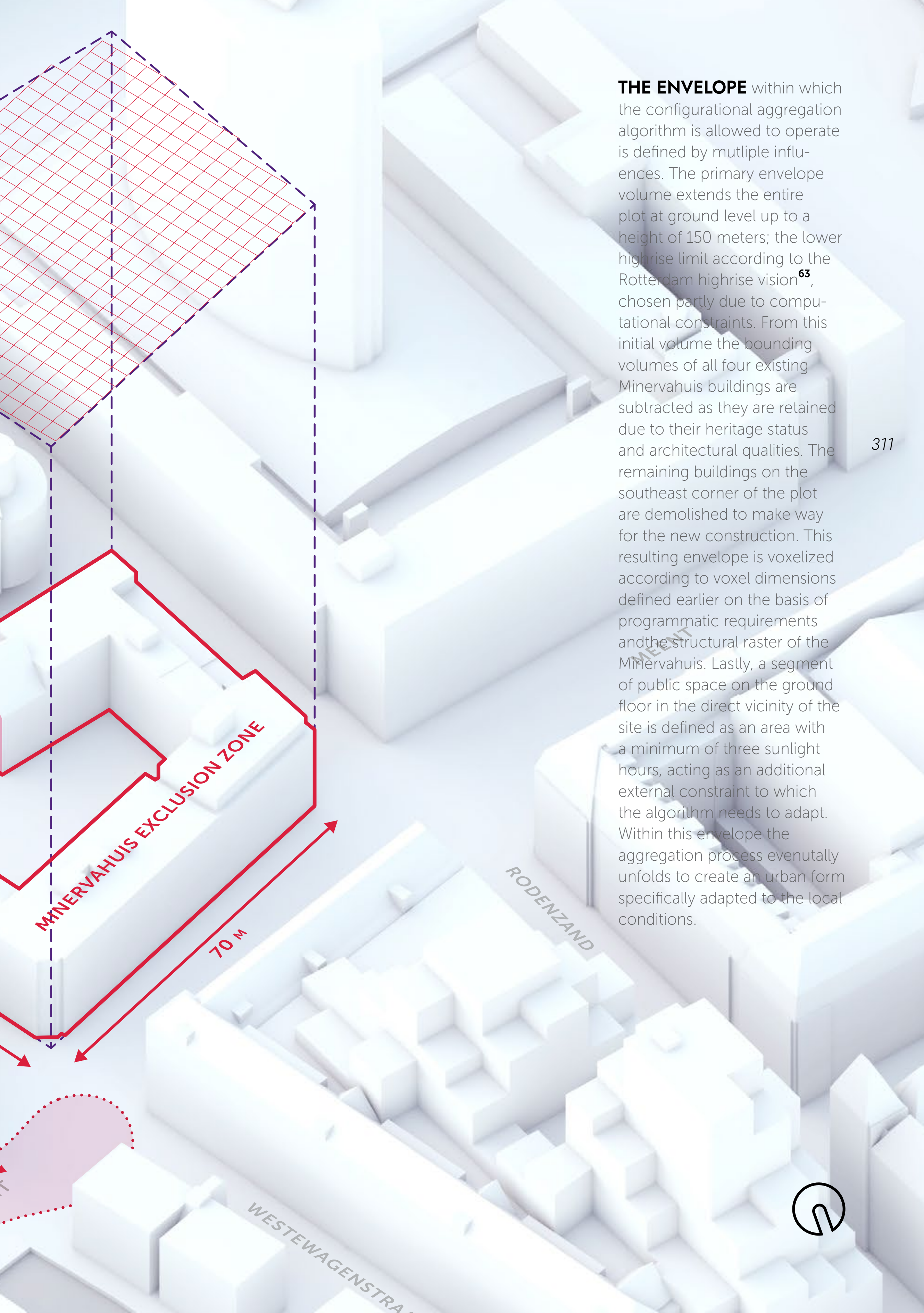
THE SITE is located in central Rotterdam on the hugely popular Meent street. Despite being in one of the denser parts of the city and surrounded by the Hudson Bay, WTC, Timmerhuis and soon the Post tower, the site itself is an old courtyard townhouse urban block of relatively low density. This, combined with its central location and its positioning within the high-rise corridor of Rotterdam makes it a prime area for speculation on potential densification strategies either through complete rebuilding or addition of new structures. The plot side dimensions range between 50 - 65m with the total area almost precisely 4000 m2. Due to its location in the high-rise zone the maximum height is limited to 150 meters, subject to certain spatial quality regulations of nearby public spaces.


Minervahuis I
Minervahuis II
MINERVAHUIS

THE CONTEXT of the project location is one of the important factors behind the choice of this specific location as a result of its diversity and the consequent opportunities for adaptation. Firstly, the external context surrounding the site consists of high density low-rise developments ans a handful of highrise towers including the neighbouring WTC. By influencng sun access, view quality and other variables these obstructions are the perfect stress-test for a design approach preaching adaptability and site specificity potentially leading to unpredictable and interesting spatial configurations directly emerging from their constraints. Secondly, on the plot itself, the four existing Minervahuis buildings are considered heritage and any densification on this location would need to take them into account, adapting and evolving around them without demolishing and rebuilding[62]. Again, this can prove to be a testing environment for an adaptive configurational algorithm and show us the extents to which such a computational approach can really respond to complex surroundings and obstacles. The context od the site chosen for the project are strategically chosen and intended to stimulate the adaptive potential inherent within a spatial configuration and in the process hopefully shed light on its potential to generate new site-specific and adaptive urban forms.



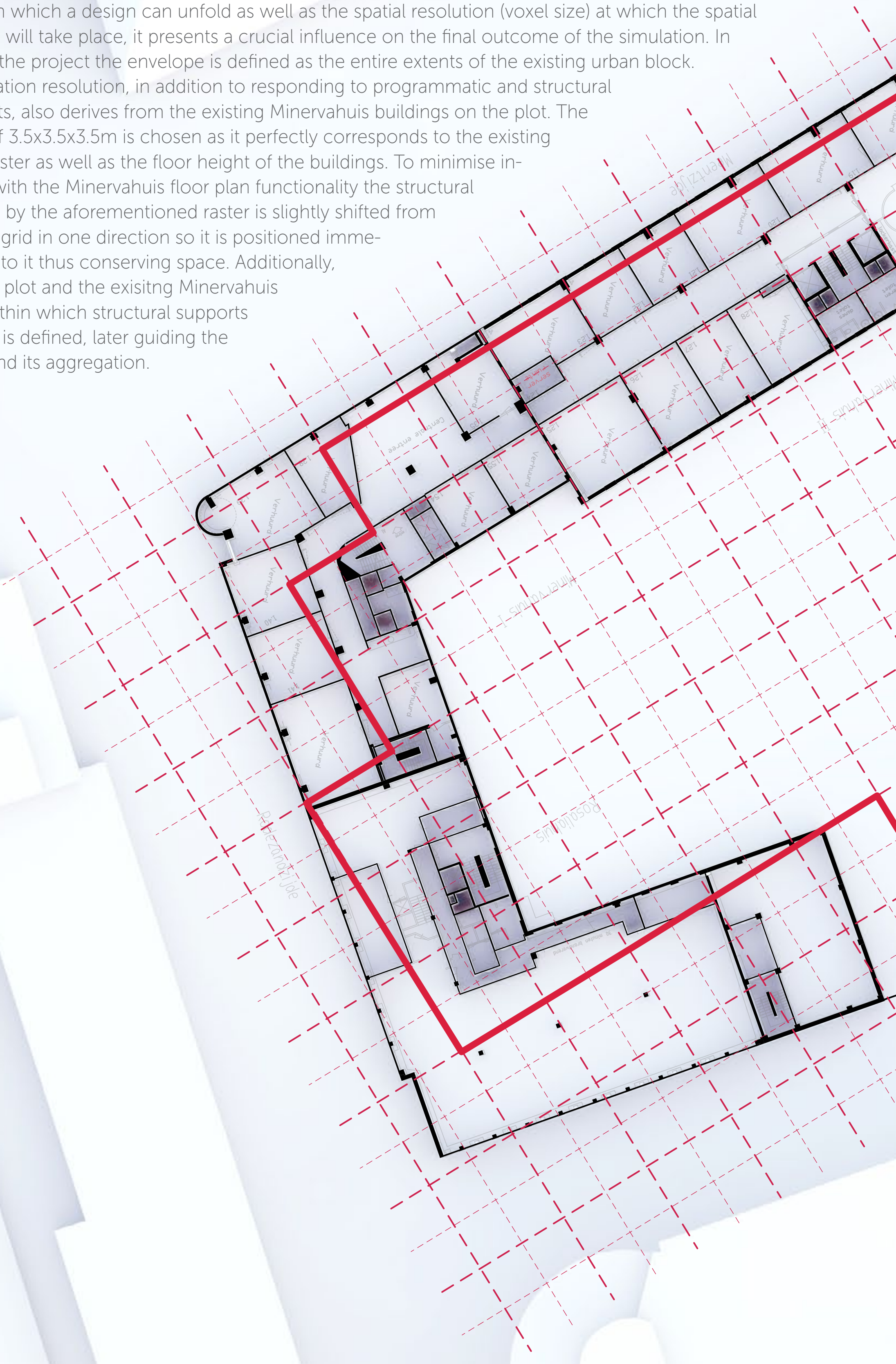

HOOGSTRAAT
150 M
LEEUWENSTRAAT
65 M
GROTEKERKPLEIN
Envelope limit
Exclusion volume
Demolition
Voxel grid
Important public space
Min 3 hrs
MEEN

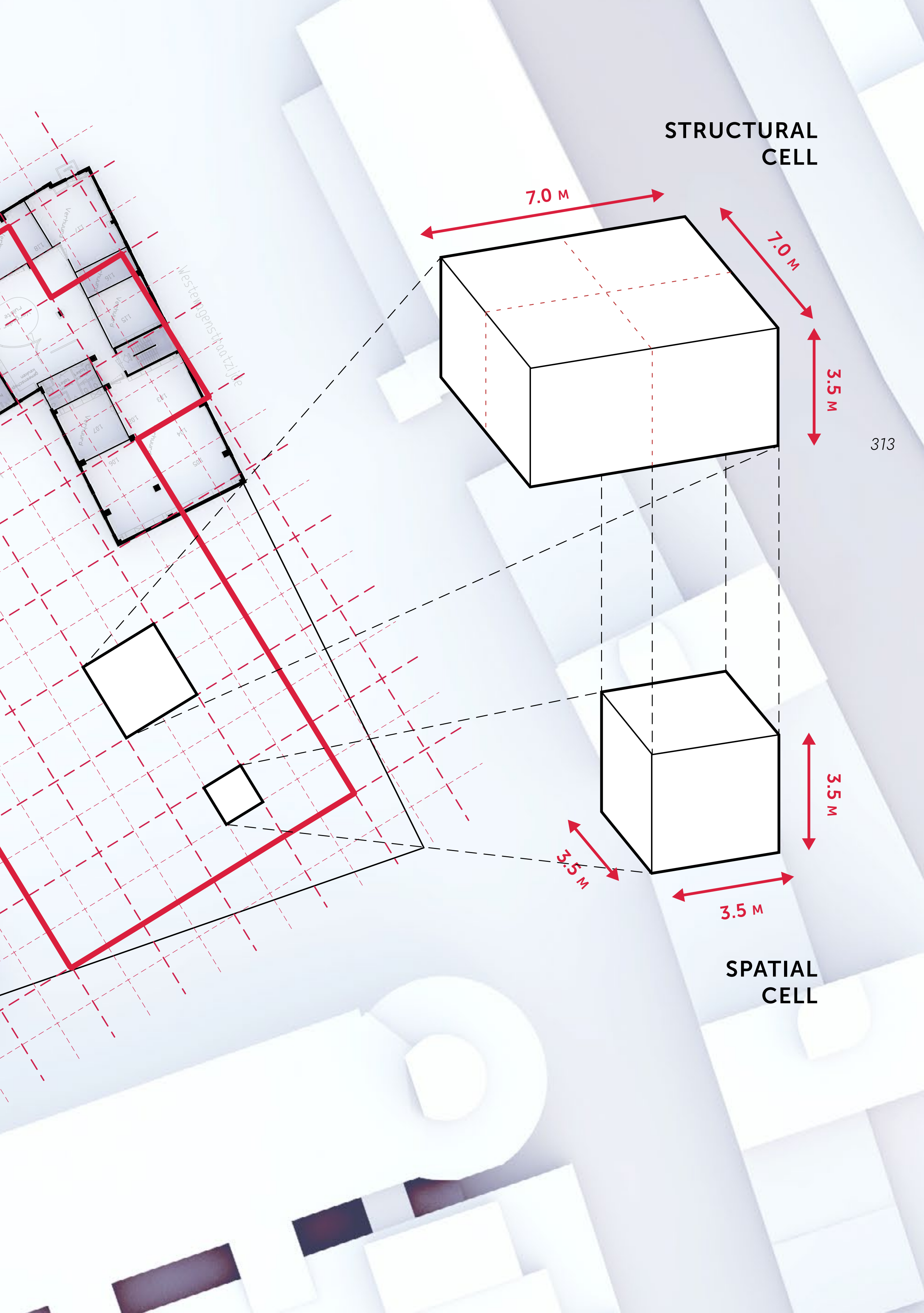


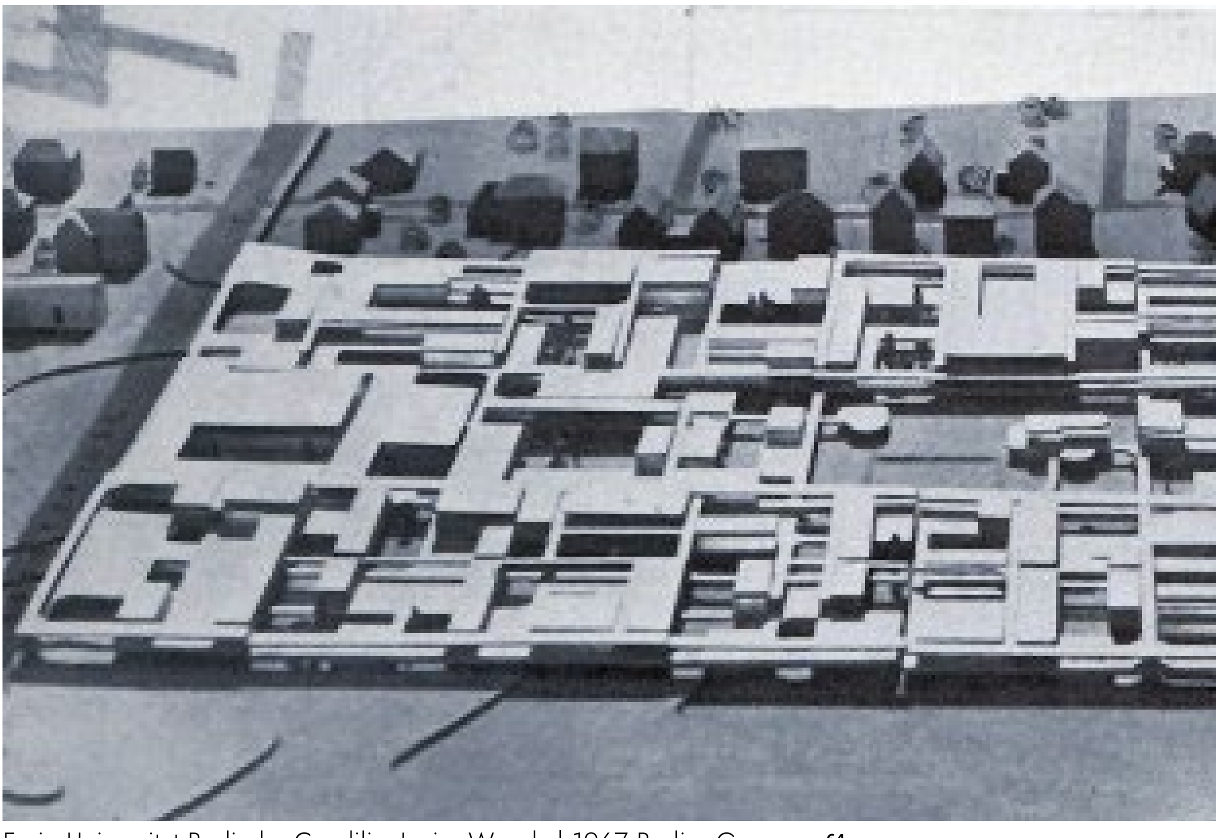
THE ENVELOPE within which the configurational aggregation algorithm is allowed to operate is defined by mutliple influences. The primary envelope volume extends the entire plot at ground level up to a height of 150 meters; the lower highrise limit according to the Rotterdam highrise vision[63], chosen partly due to computational constraints. From this initial volume the bounding volumes of all four existing Minervahuis buildings are subtracted as they are retained due to their heritage status and architectural qualities. The remaining buildings on the southeast corner of the plot are demolished to make way for the new construction. This resulting envelope is voxelized according to voxel dimensions defined earlier on the basis of programmatic requirements andthe structural raster of the Minervahuis. Lastly, a segment of public space on the ground floor in the direct vicinity of the site is defined as an area with a minimum of three sunlight hours, acting as an additional external constraint to which the algorithm needs to adapt. Within this envelope the aggregation process evenutally unfolds to create an urban form specifically adapted to the local conditions.

ENVELOPE

The envelope is the first and most important elements of configurational design. By defining the extent of space within which a design can unfold as well as the spatial resolution (voxel size) at which the spatial aggregation will take place, it presents a crucial influence on the final outcome of the simulation. In the case of the project the envelope is defined as the entire extents of the existing urban block. The voxelization resolution, in addition to responding to programmatic and structural requirements, also derives from the existing Minervahuis buildings on the plot. The voxel size of 3.5x3.5x3.5m is chosen as it perfectly corresponds to the existing structural raster as well as the floor height of the buildings. To minimise interference with the Minervahuis floor plan functionality the structural grid defined by the aforementioned raster is slightly shifted from the existing grid in one direction so it is positioned immediately next to it thus conserving space. Additionally, areas of the plot and the exisitng Minervahuis buidlings within which structural supports are allowed is defined, later guiding the algorithm and its aggregation.



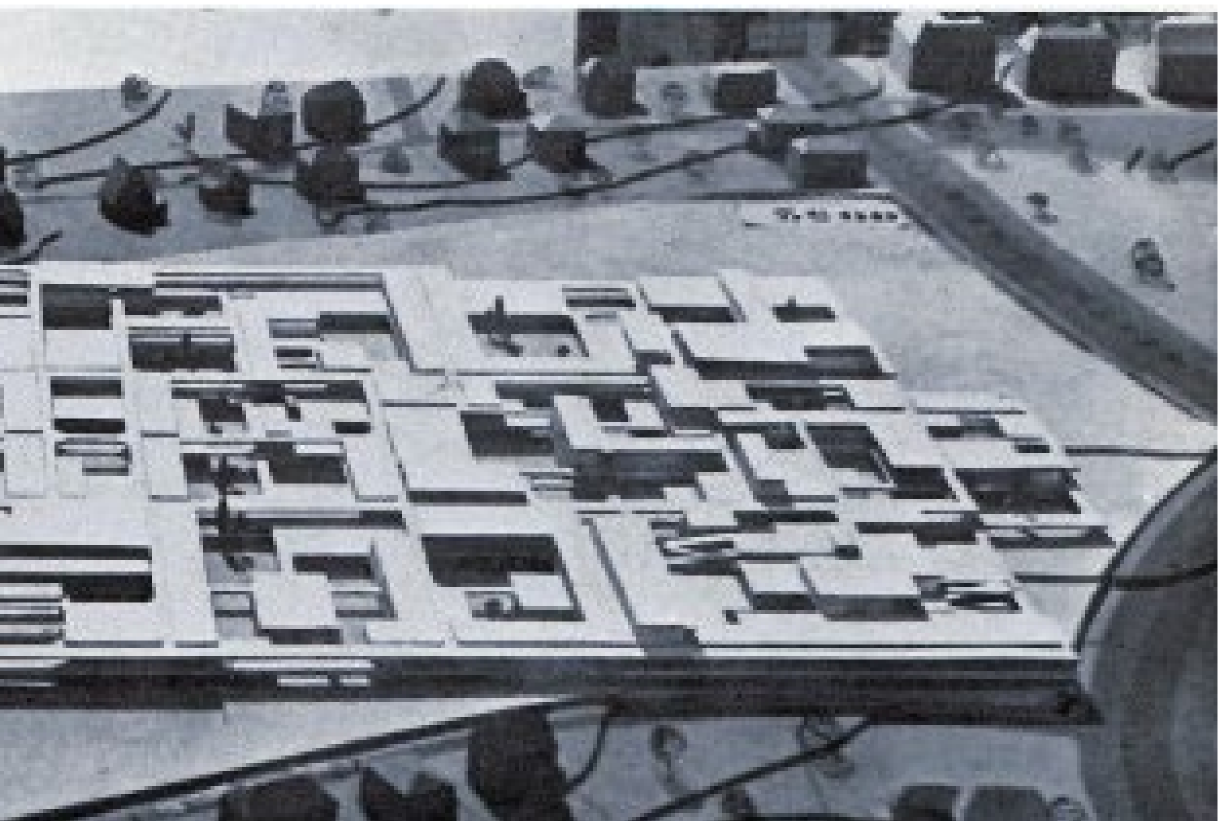

STRUCTURAL
CELL
7.0 M
7.0 M
3.5 M
3.5 M
3.5 M
3.5 M
SPATIAL
CELL



Freie Universitat Berlin by Candilis, Josic, Woods | 1967 Berlin, Germany [64]

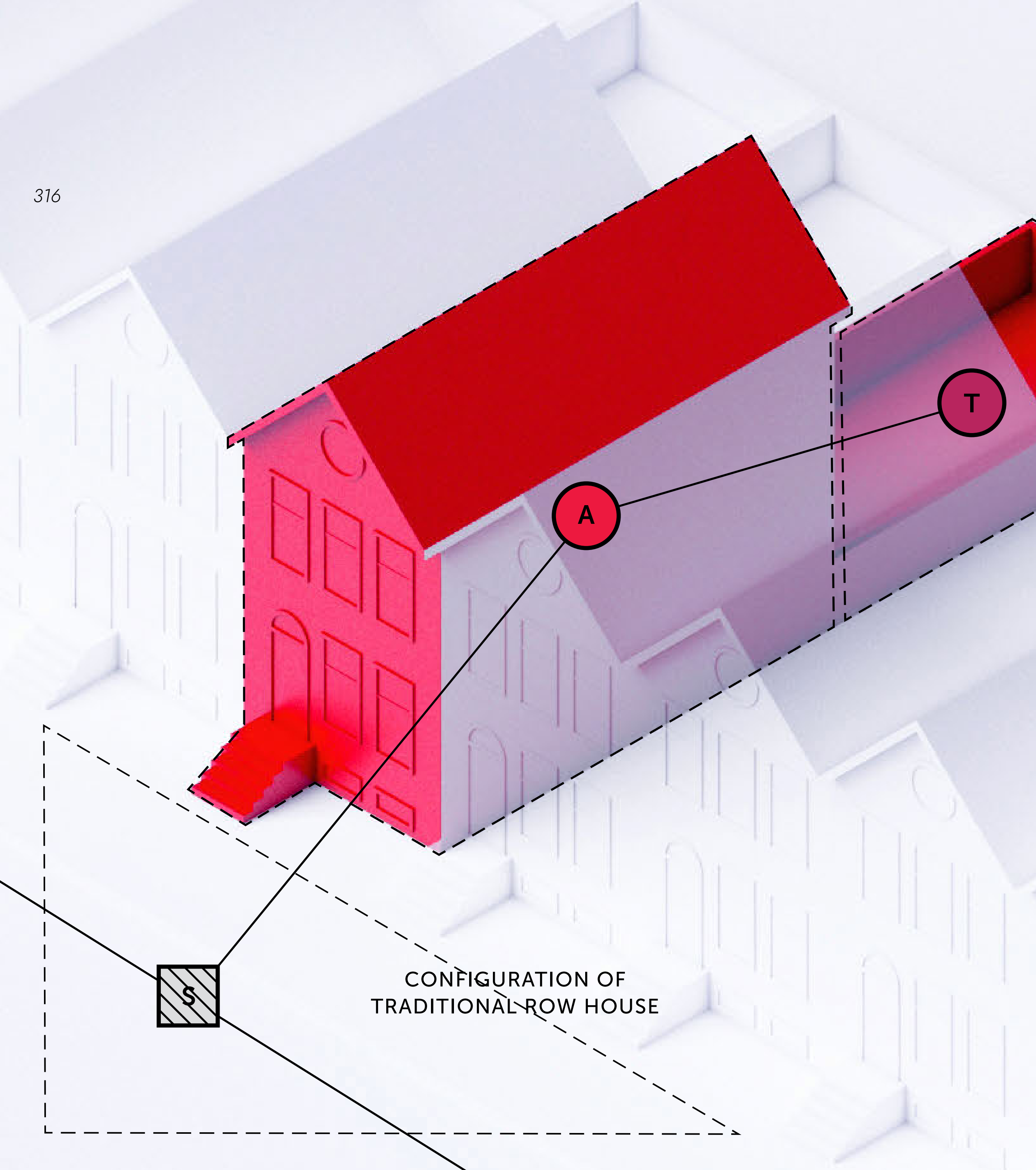
MAT-BUILDING

The mat-building as a programmatic concept; a versatile spatial framework, a multi-layer extension of the urban fabric appropriate for diverse programmatic use.[64]

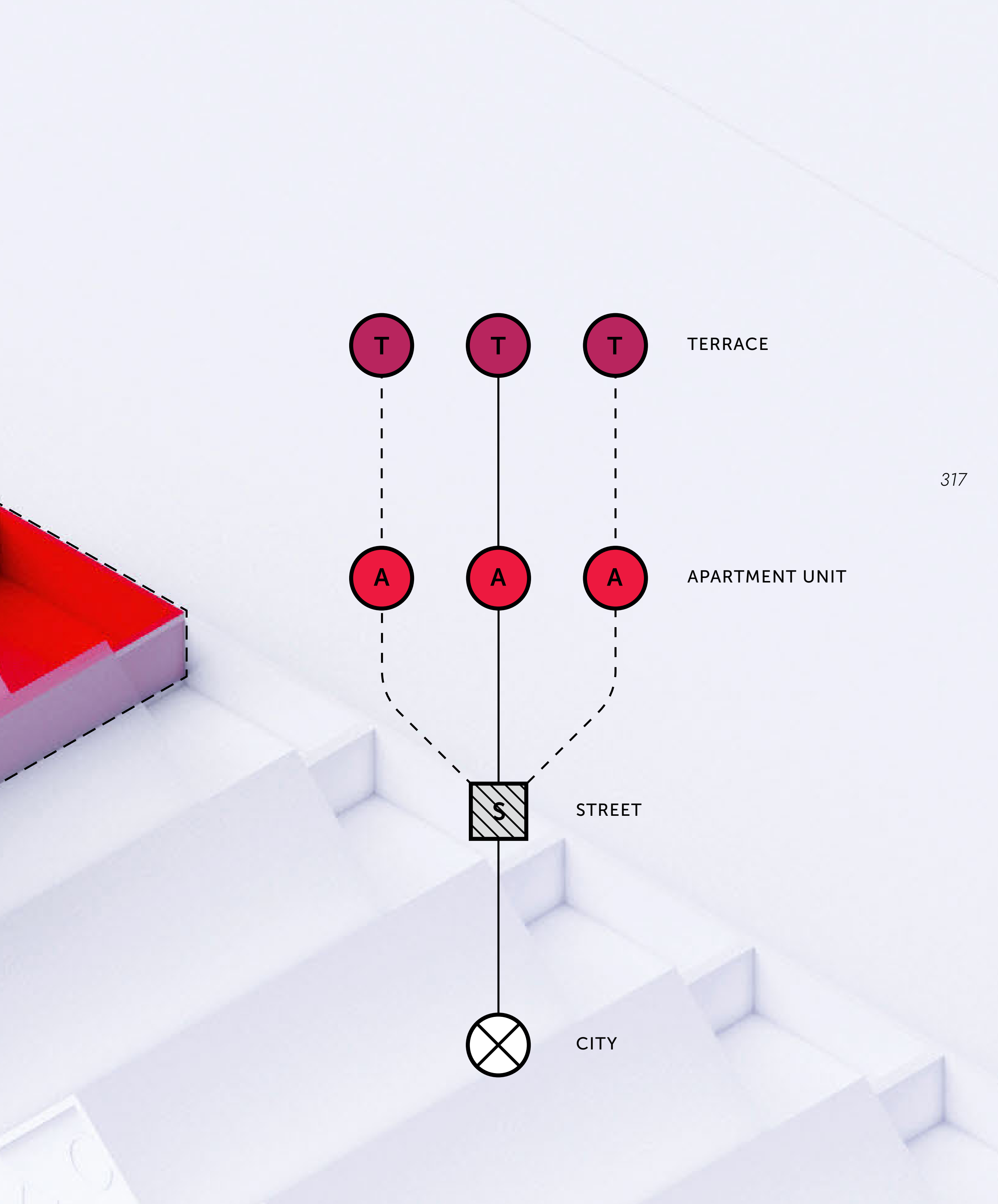


TOPOLOGY

In the spirit of cross-breeding the configuration of the traditional Dutch row house type with the efficiency of modern skyscrapers and slabs, the main configuration for the project was derived from the topology of a row house. At the scale of a unit its most important traits include a direct access from the exterior public street to the unit itself, as well as the provision of a private exterior space in the form of a terrace or balcony to the majority if not all units. This creates a tree-like configuration which, despite its simplicity, can generate the emergence of complex spatial compositions in response to the surrounding environment.



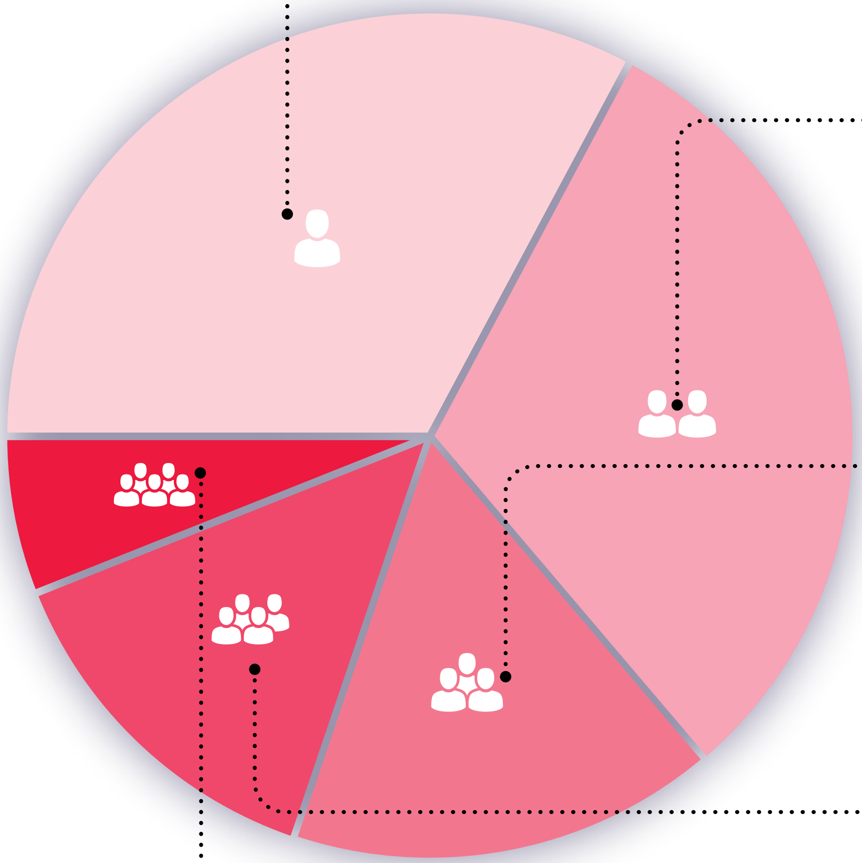
CONFIGURATION OF
TRADITIONAL ROW HOUSE



CORRESPONDING
SPATIAL NETWORK

PROGRAMME

In the context of a mat-building-like generic programme, the idea of vertical living through cross-breeding a row house type with high-rise density and the topic of the Rotterdam housing crisis, the base programme for the project was defined to be dwelling. To retain systematism and the broadest possible appeal the specifics of unit sizes and their total proportion in the building was defined through a statistical analysis of household sizes in the Netherlands. This ensures a good fit between the demographic situation and the spaces the buildings initially offers with the flexibilty of further adaptation and change ingrained within its design.



32,9% ⟶ 1 person ⟶ 30 m^2
31,1% ⟶ 2 person ⟶ 50 m2
16,2% ⟶ 3 person ⟶ 70 m2
13,6% ⟶ 4 person ⟶ 90 m2
6,2% ⟶ 5+ person ⟶ 110 m2

Netherlands average household size distribution [65]

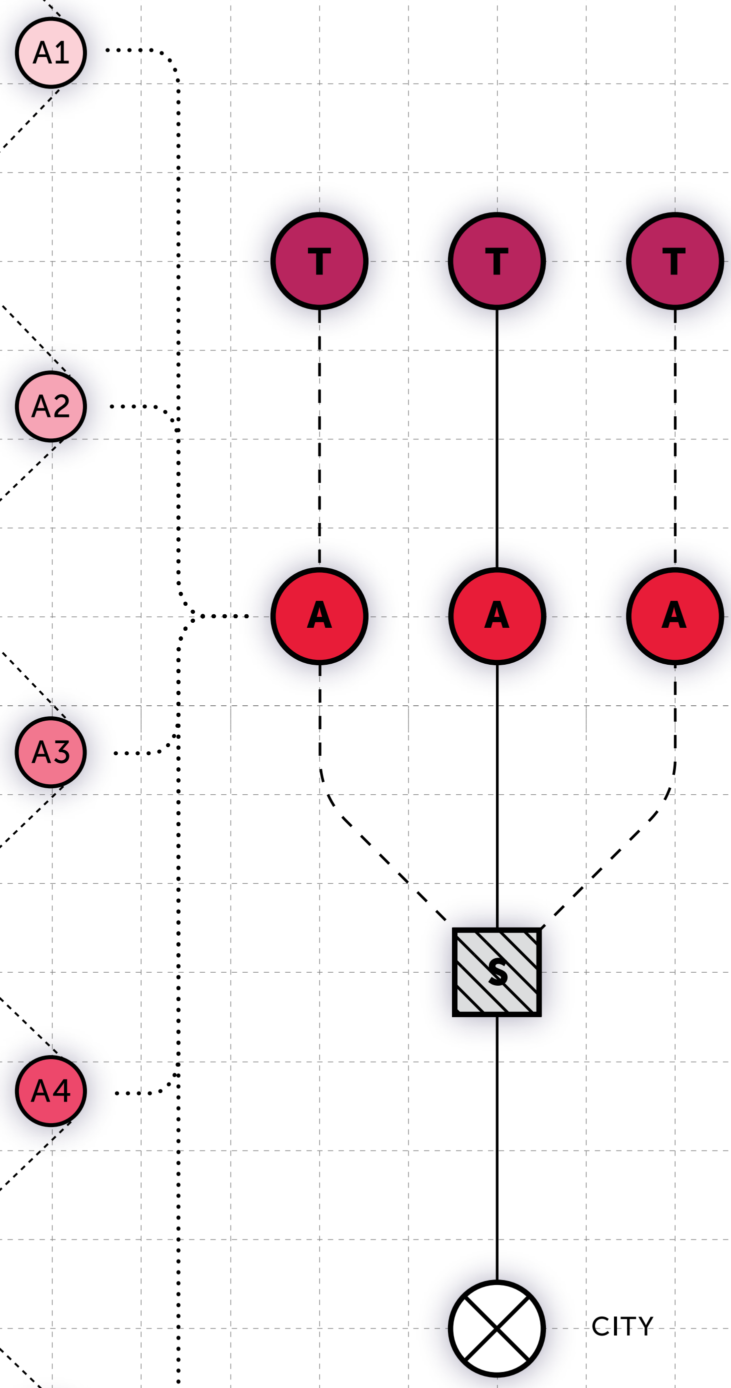
Size	30 m2
Levels	1 floors
Geometry	interior
Facade %	50%
Shape	compact
Sunlight	4 hrs
Views	60 deg, 50 m
Privacy	10 meters

Size	50 m2
Levels	1 floors
Geometry	interior
Facade %	50%
Shape	compact
Sunlight	4 hrs
Views	60 deg, 50 m
Privacy	10 meters

Size	70 m2
Levels	1 floors
Geometry	interior
Facade %	50%
Shape	compact
Sunlight	4 hrs
Views	60 deg, 50 m
Privacy	10 meters

Size	90 m2
Levels	1 - 2 floors
Geometry	interior
Facade %	50%
Shape	compact
Sunlight	4 hrs
Views	60 deg, 50 m
Privacy	10 meters

Size	110 m2
Levels	1 - 2 floors
Geometry	interior
Facade %	50%
Shape	compact
Sunlight	4 hrs
Views	60 deg, 50 m
Privacy	10 meters



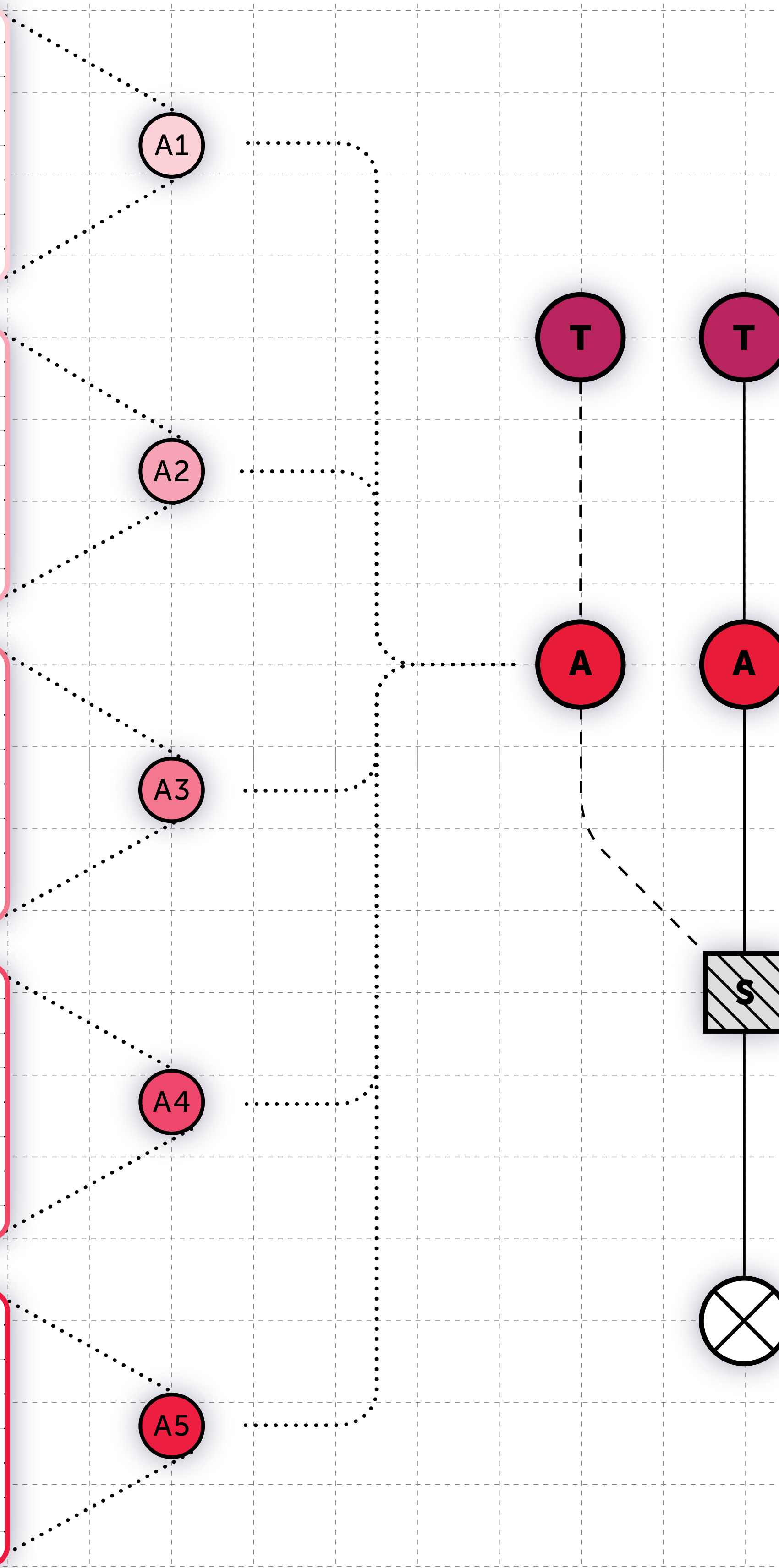
Size	30 m2
Levels	1 floors
Geometry	interior
Facade %	50%
Shape	compact
Sunlight	4 hrs
Views	60 deg, 50 m
Privacy	10 meters

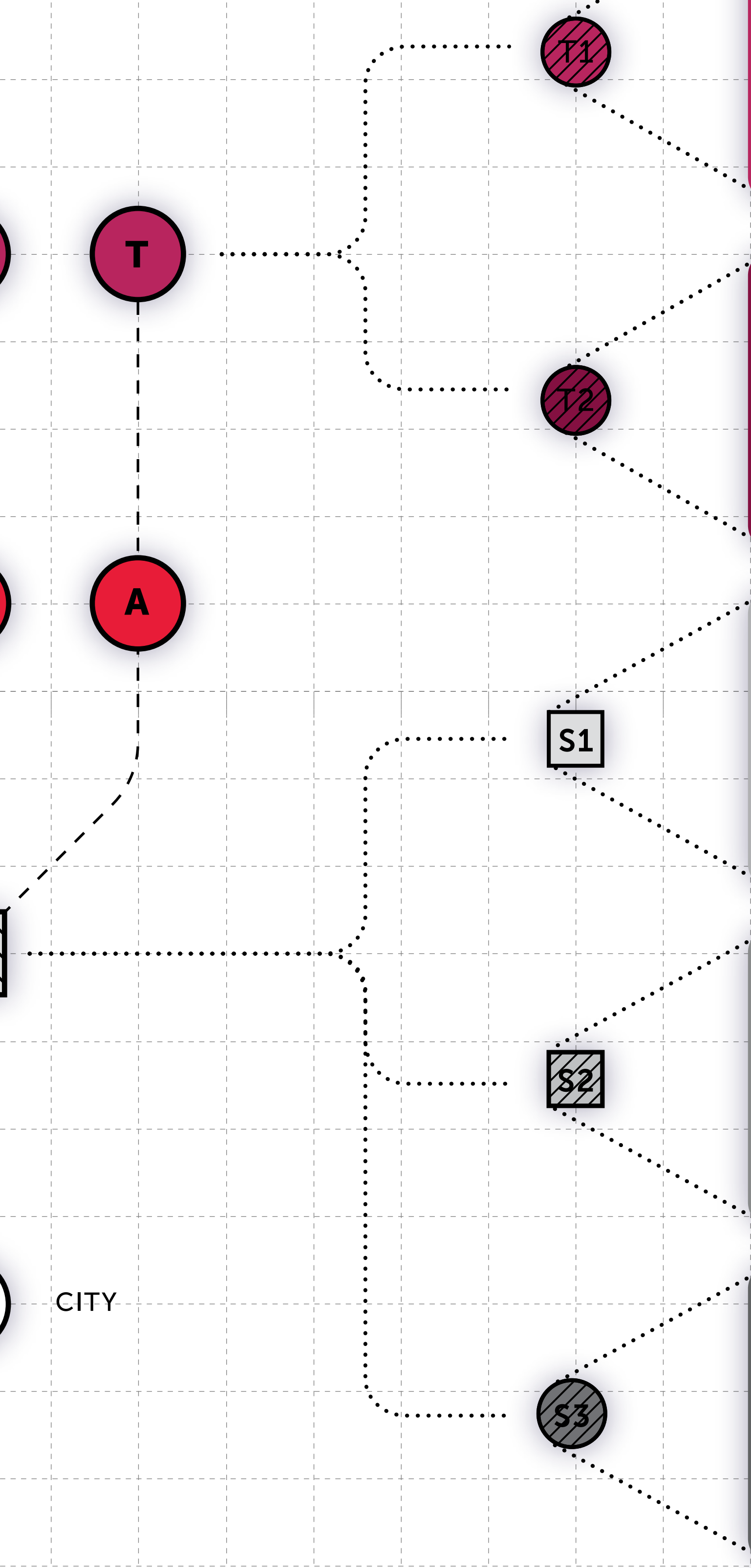
Size	50 m2
Levels	1 floors
Geometry	interior
Facade %	50%
Shape	compact
Sunlight	4 hrs
Views	60 deg, 50 m
Privacy	10 meters

Size	70 m2
Levels	1 floors
Geometry	interior
Facade %	50%
Shape	compact
Sunlight	4 hrs
Views	60 deg, 50 m
Privacy	10 meters

Size	90 m2
Levels	1 - 2 floors
Geometry	interior
Facade %	50%
Shape	compact
Sunlight	4 hrs
Views	60 deg, 50 m
Privacy	10 meters

Size	110 m2
Levels	1 - 2 floors
Geometry	interior
Facade %	50%
Shape	compact
Sunlight	4 hrs
Views	60 deg, 50 m
Privacy	10 meters





Size	10 m2
Levels	1 floors
Geometry	exterior
Facade %	/
Shape	compact
Sunlight	1 hours
Views	60 degrees
Privacy	0 meters

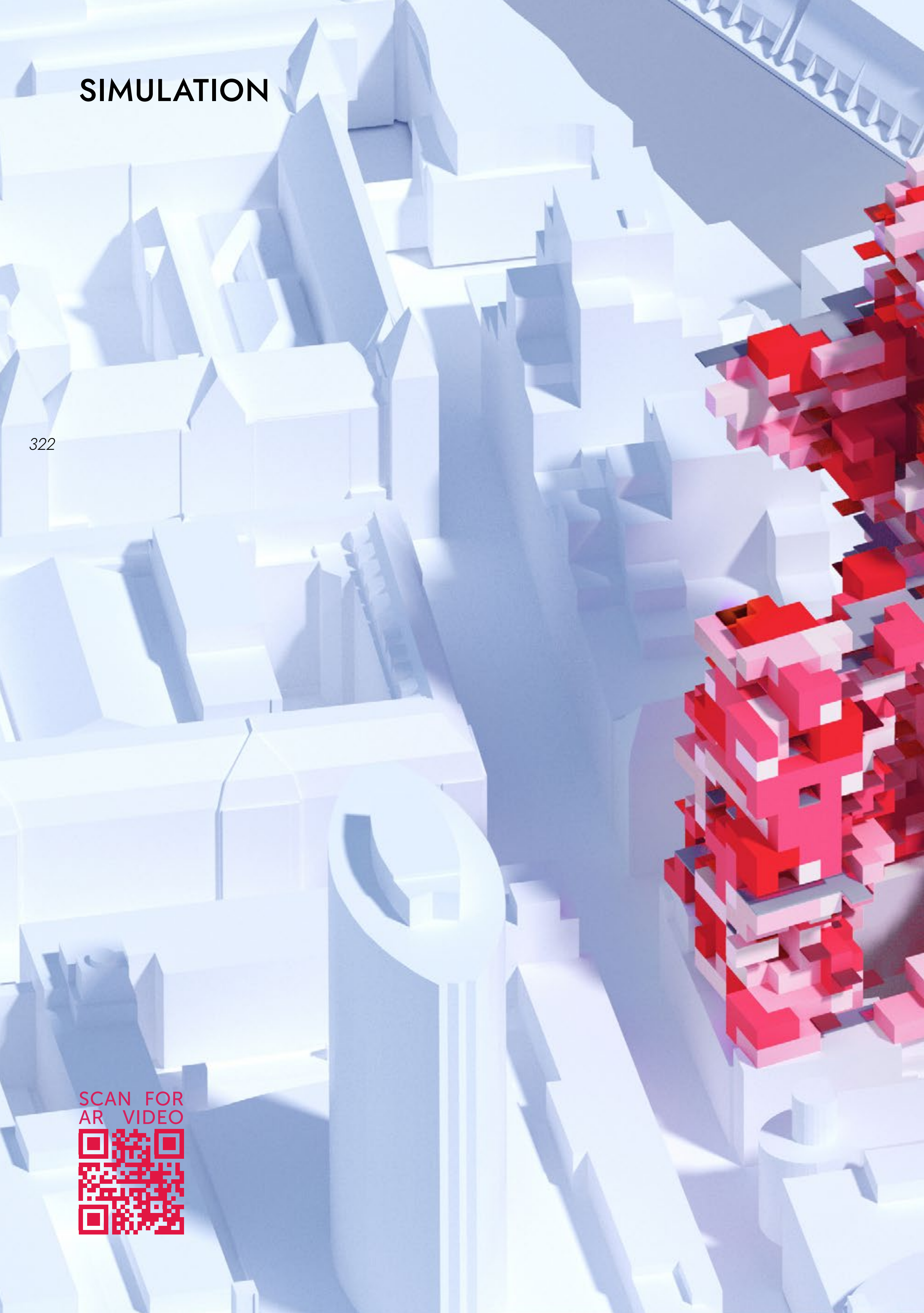
Size	20 m2
Levels	1 floors
Geometry	exterior
Facade %	/
Shape	compact
Sunlight	1 hours
Views	60 degrees
Privacy	0 meters

Size	unlimited
Levels	unlimited
Geometry	interior
Facade %	0%
Shape	linear
Sunlight	0 hours
Views	0 degrees
Privacy	0 meters

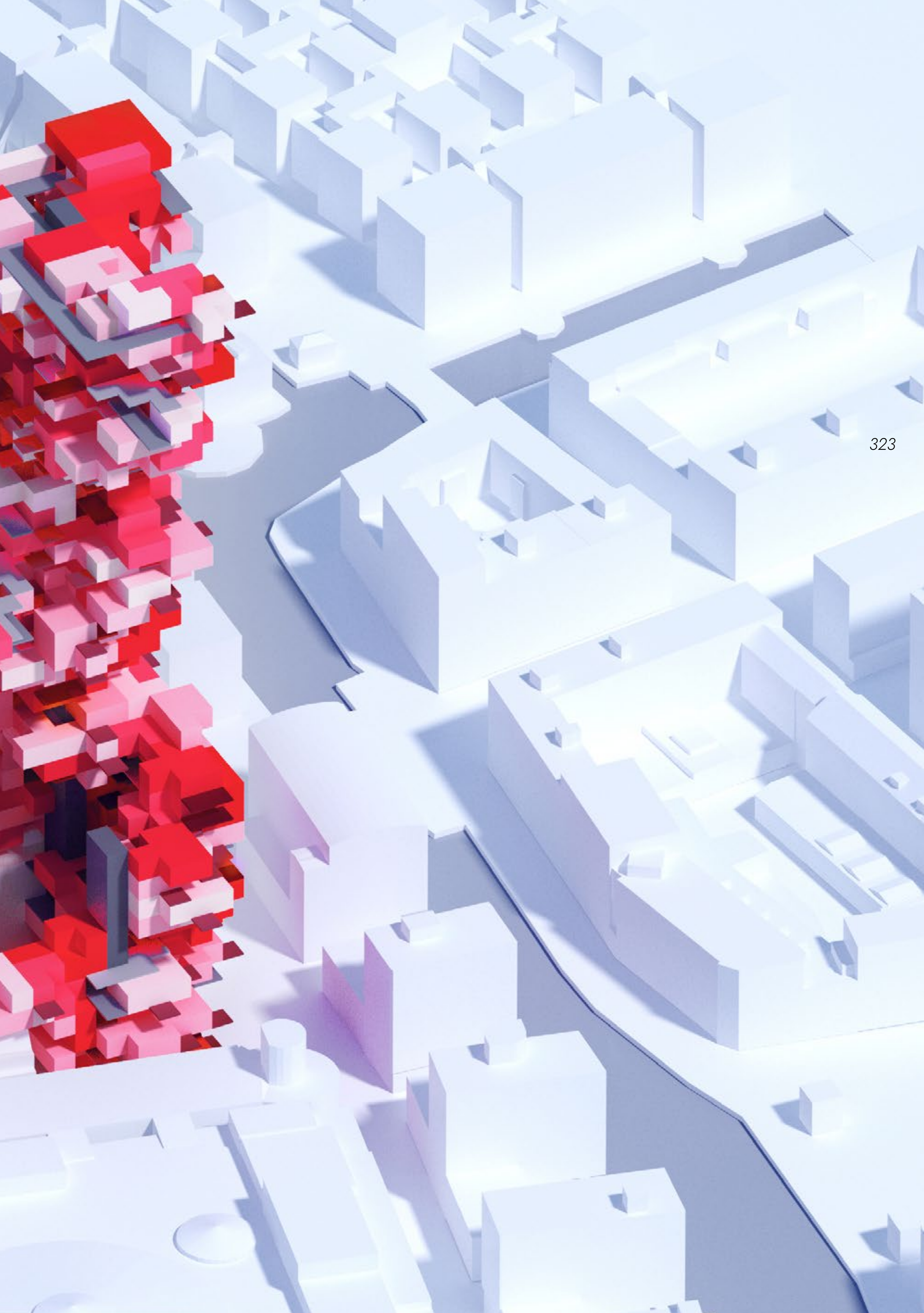
Size	unlimited
Levels	1 floors
Geometry	exterior
Facade %	/
Shape	linear
Sunlight	0 hours
Views	0 degrees
Privacy	0 meters

Size	100 m2
Levels	1 floors
Geometry	exterior
Facade %	/
Shape	compact
Sunlight	6 hours
Views	180 degrees
Privacy	0 meters

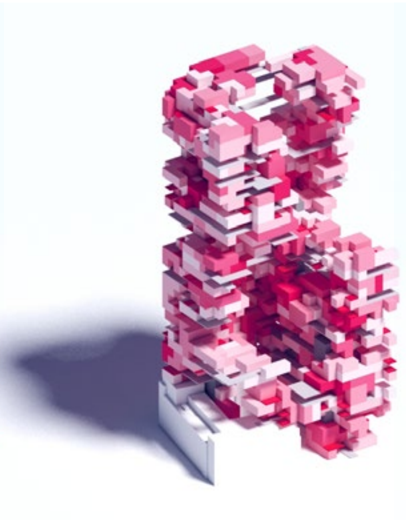
SIMULATION



SCAN FOR AR VIDEO



01

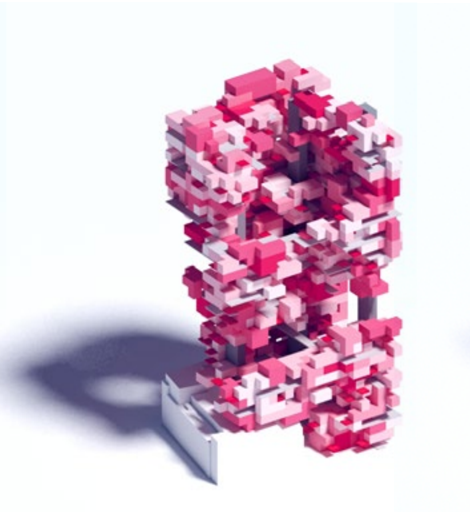


02

03

06

07



08

11

12

13

04

05

09

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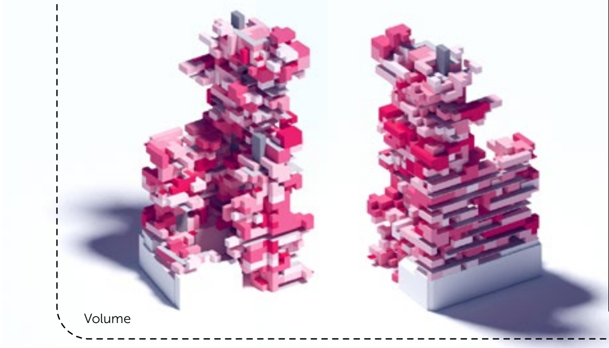
14

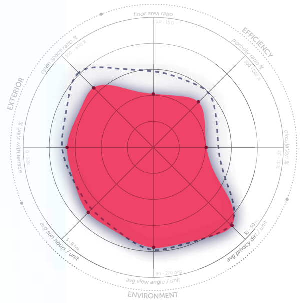
15

THE POPULATION of possible spatial compositions generated from a specific spatial network with certain spatial requirements on a selected site is near-infinite and very diverse. Due to a multiplicity of competing parameters often none of these solutions can objectively called the best. They coexist as the diverse possible spatial materializations of a configuration and one must be chosen by an architect or an algorith. To ease the selection process the iterations can be evaluated using desired criteria to enable comparability and eventually informed decision-making. The fifteen aggregations on the left present the best performing outcomes of the simulations performed. Due to the nature of the algorithm of strict control of environmental (sun, view,...) and outdoor parameters (OSR, terraces), the most meaningful differences occured in the categories of circulation efficiency and overall porosity. These were the deciding factors in choosing iteration #12 as the final design scheme on the basis of which the project will be elaborated.

SCAN FOR AR MODEL



Volume



Performance

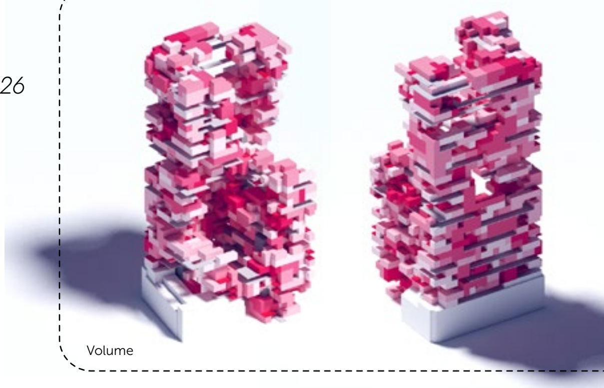
AGGREG. #01
Information

Units: 392

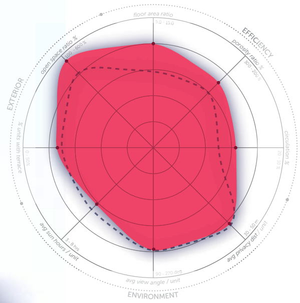
FAR: 9.11
Porosity: 251 %
Circulation: 15.9 %

OSR: 425 %
Terraces: 33.2 %

Sunlight: 6.54 HRS
View: 213.3 DEG
Privacy: 47.1 M



Volume



Performance

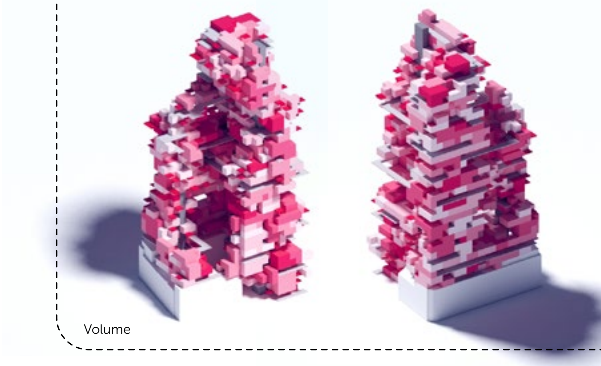
AGGREG. #02
Information

Units: 575

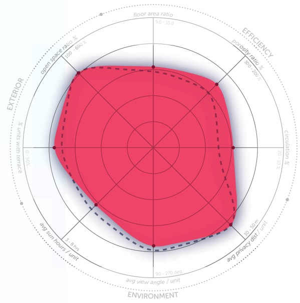
FAR: 12.98
Porosity: 229 %
Circulation: 13.7 %

OSR: 573 %
Terraces: 37.0 %

Sunlight: 6.09 HRS
View: 216.0 DEG
Privacy: 46.5 M



Volume



Performance

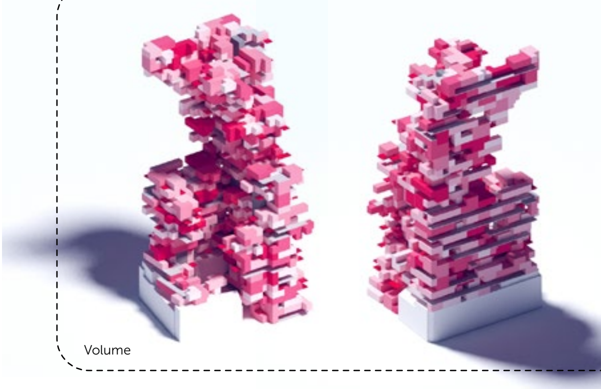
AGGREG. #03
Information

Units: 496

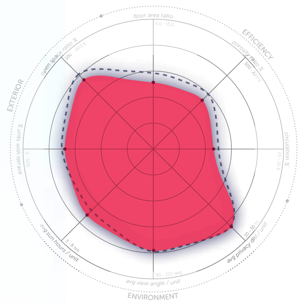
FAR: 11.23
Porosity: 231 %
Circulation: 13.9 %

OSR: 507 %
Terraces: 37.9 %

Sunlight: 6.11 HRS
View: 211.1 DEG
Privacy: 46.8 M



Volume



Performance

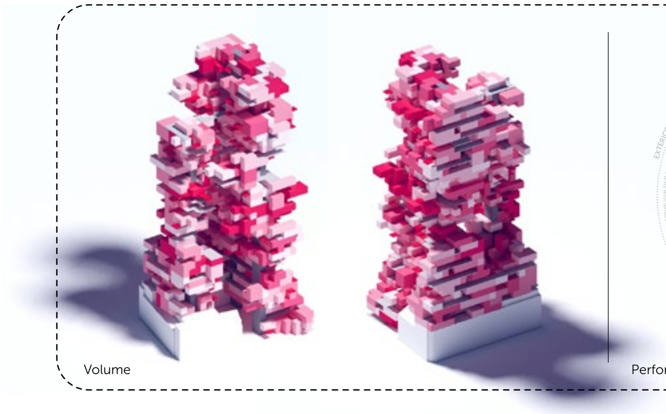
AGGREG. #04
Information

Units: 436

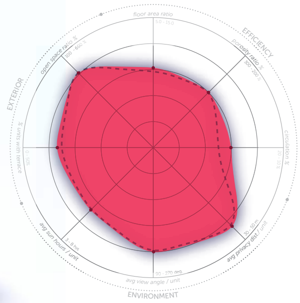
FAR: 10.12
Porosity: 247 %
Circulation: 15.4 %

OSR: 477 %
Terraces: 34.0 %

Sunlight: 6.61 HRS
View: 215.2 DEG
Privacy: 46.9 M



Volume



Performance

AGGREG. #05

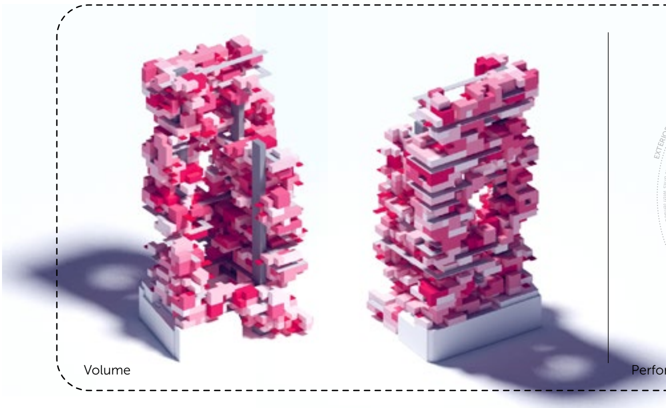
Information

Units: 493

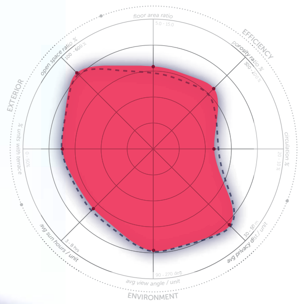
FAR: 11.14
Porosity: 240 %
Circulation: 14.0 %

OSR: 505 %
Terraces: 36.9 %

Sunlight: 6.39 HRS
View: 218.4 DEG
Privacy: 47.1 M



Volume



Performance

AGGREG. #06

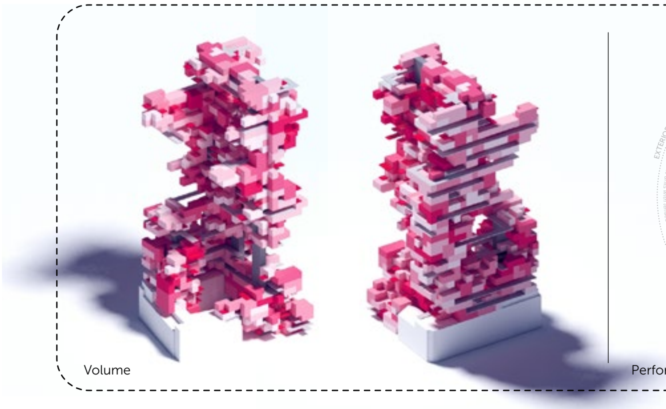
Information

Units: 495

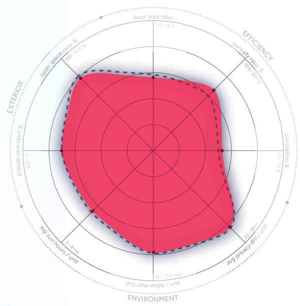
FAR: 11.37
Porosity: 234 %
Circulation: 15.3 %

OSR: 514 %
Terraces: 34.9 %

Sunlight: 6.25 HRS
View: 215.6 DEG
Privacy: 46.6 M



Volume



Performance

AGGREG. #07

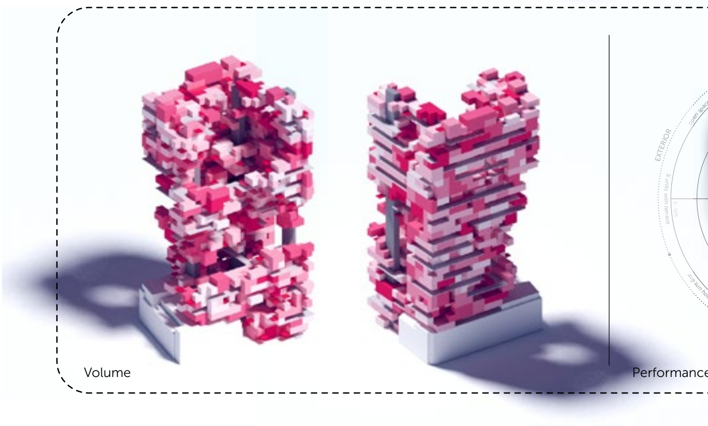
Information

Units: 470

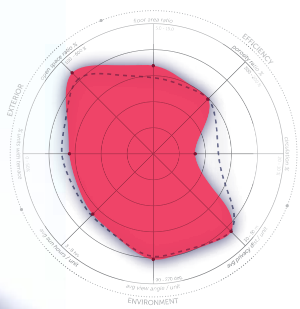
FAR: 10.63
Porosity: 234 %
Circulation: 14.7 %

OSR: 494 %
Terraces: 35.1 %

Sunlight: 6.29 HRS
View: 215.3 DEG
Privacy: 46.6 M



Volume



Performance

AGGREG. #08

Information

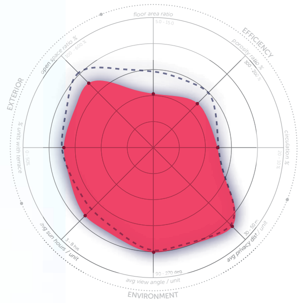
Units: 509

FAR: 11.78
Porosity: 240 %
Circulation: 16.8 %

OSR: 540 %
Terraces: 32.2 %

Sunlight: 6.29 HRS
View: 220.0 DEG
Privacy: 46.9 M

Volume



Performance

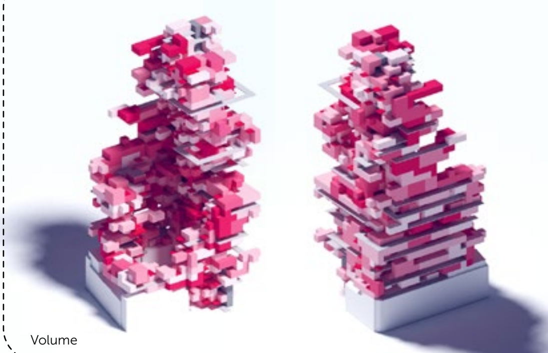
AGGREG. #09
Information

Units: 399

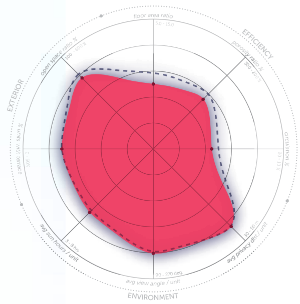
FAR: 9.14
Porosity: 252 %
Circulation: 15.1 %

OSR: 451 %
Terraces: 34.4 %

Sunlight: 6.70 HRS
View: 218.8 DEG
Privacy: 47.2 M



Volume



Performance

AGGREG. #10
Information

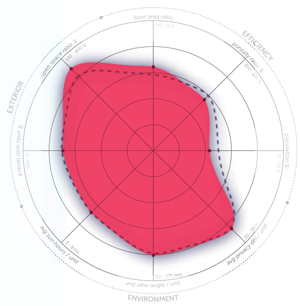
Units: 436

FAR: 10.01
Porosity: 245 %
Circulation: 15.6 %

OSR: 487 %
Terraces: 35.1 %

Sunlight: 6.45 HRS
View: 218.8 DEG
Privacy: 46.9 M

Volume



Performance

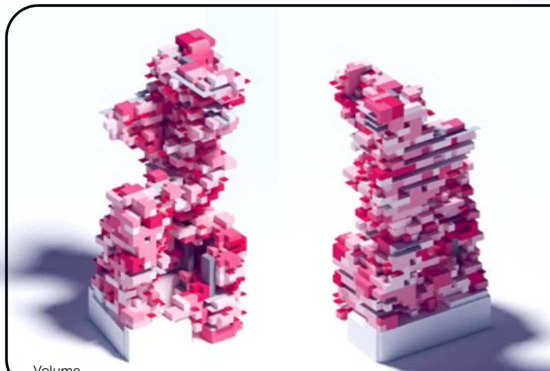
AGGREG. #11
Information

Units: 488

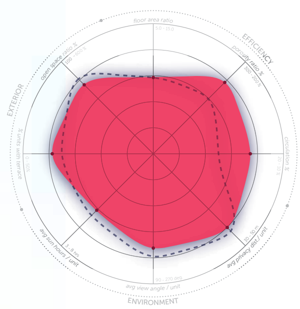
FAR: 11.45
Porosity: 244 %
Circulation: 15.7 %

OSR: 546 %
Terraces: 34.6 %

Sunlight: 6.36 HRS
View: 218.6 DEG
Privacy: 47.0 M



Volume



Performance

AGGREG. #12
Information

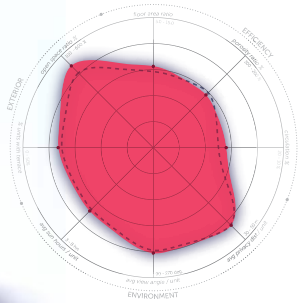
Units: 485

FAR: 10.87
Porosity: 222 %
Circulation: 12.5 %

OSR: 476 %
Terraces: 38.8 %

Sunlight: 6.09 HRS
View: 206.0 DEG
Privacy: 46.1 M

Volume



Performance

AGGREG. #13
Information

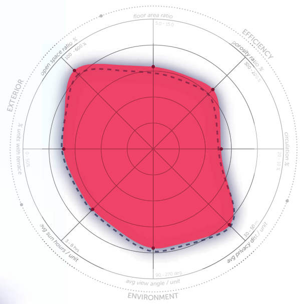
Units: 495

FAR: 11.27
Porosity: 242 %
Circulation: 14.4 %

OSR: 544 %
Terraces: 36.4 %

Sunlight: 6.45 HRS
View: 219.9 DEG
Privacy: 46.9 M

Volume



Performance

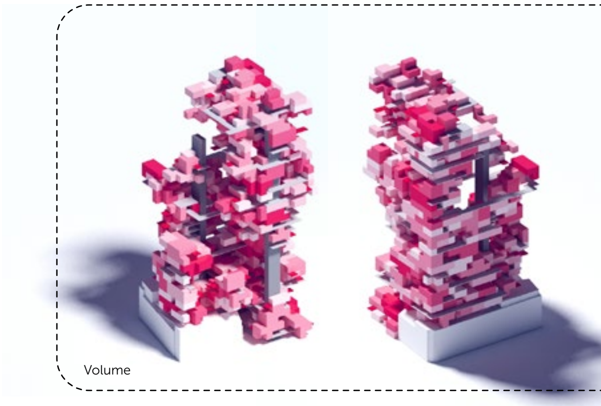
AGGREG. #14
Information

Units: 495

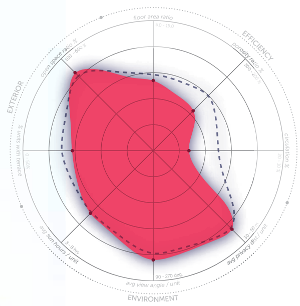
FAR: 11.33
Porosity: 235 %
Circulation: 14.8 %

OSR: 528 %
Terraces: 34.5 %

Sunlight: 6.29 HRS
View: 212.3 DEG
Privacy: 46.6 M



Volume



Performance

AGGREG. #15
Information

Units: 500

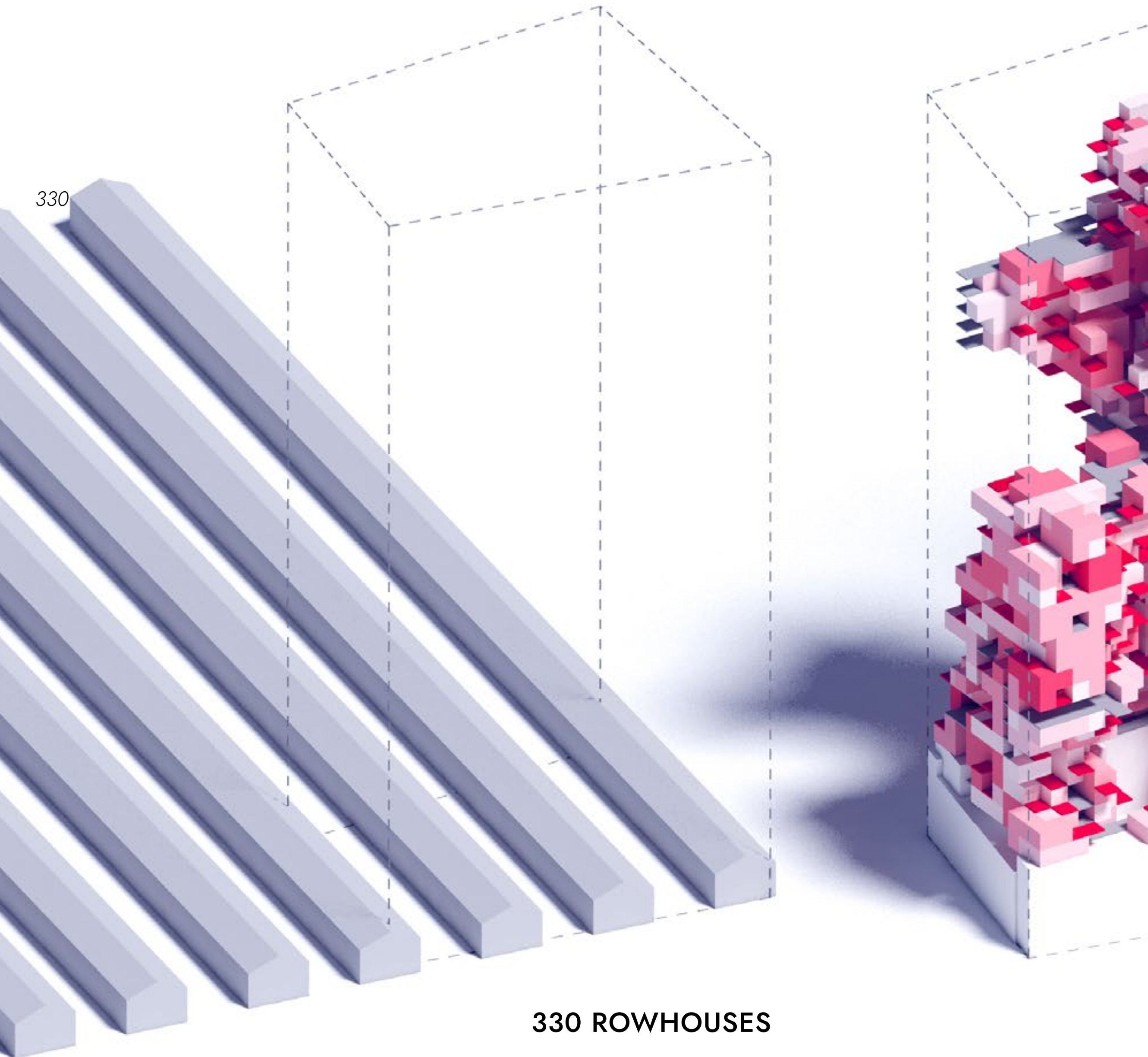
FAR: 10.38
Porosity: 256 %
Circulation: 17.3 %

OSR: 522 %
Terraces: 31.2 %

Sunlight: 6.41 HRS
View: 224.3 DEG
Privacy: 47.1 M

THE ROWHOUSE-TOWER HYBRID

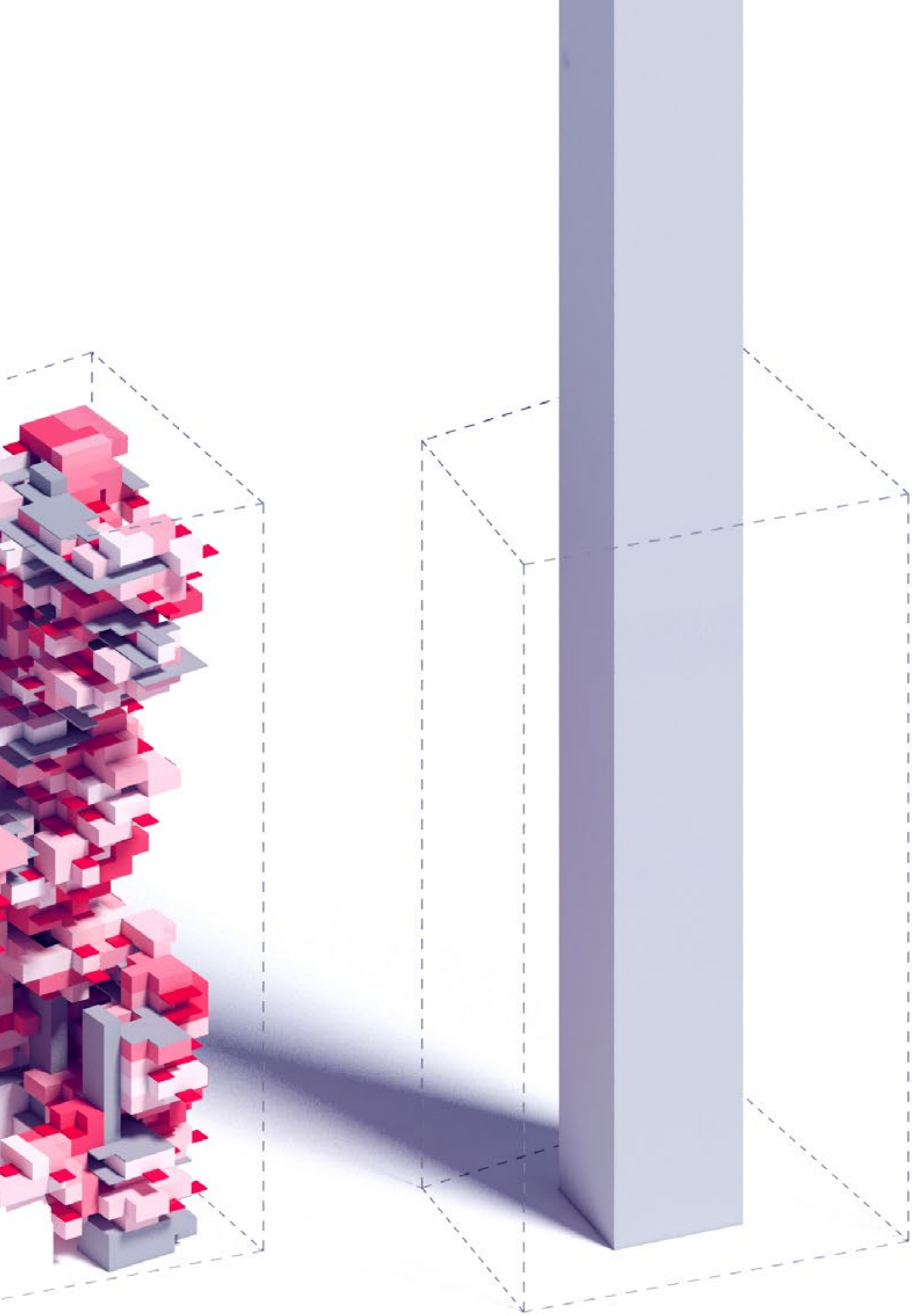
The resulting building represents a succesful cross-breeding of the traditional Dutch rowhouse and the modern tower. SImplified, the hybrid equals 330 traditional two-story rowhouses with private gardens stacked vertically into an efficient tower-like envelope, all while adding benefits of increased diversity and spatial quality.



330 ROWHOUSES

Gross area *47.500 m2*
Persons *1075*

Coverage *42.300 m2* ***(1075 %)***
Height *8 m* ***(5 %)***
Porosity *160 %* ***(72 %)***



ROWHOUSE-TOWER

Gross area *47.500 m2*
Persons *1075*

Coverage *4000 m2* ***(100 %)***
Height *150 m* ***(100 %)***
Porosity *223 %* ***(100 %)***

TOWER

Gross area *47.500 m2*
Persons *1075*

Coverage *600 m2* ***(15 %)***
Height *266 m* ***(177 %)***
Porosity *70 %* ***(32 %)***

How does urban form generated by configuration translate to a real-world project?

PROJECT DESIGN

Designing with configurations and complexity

The adaptive and customized site-specific nature of configurationally generated urban form often results in a high degree of spatial complexity needing to be confronted in the design process. Every cantilever, hole, tower or indent in the building mass is a consequence of a direct response to a set of external constraints, usually giving it unique spatial qualities, advantages and drawbacks. This is true at all spatial levels, from the modest hallway, a terrace, an apartment unit al the way up to the entire spatial configuration.

This uniqueness of spaces and their properties presents both a problem as well as an opportunity in the context of design. On one hand, this enormous complexity and the need for customised design solutions at seemingly every corner can lead to inefficiency at best or unfeasibility at worst, due to the limited time and resources at the disposal of the architect. On the other hand, it is precisely this complexity that is the generator of diversity both in spatial as well as performative terms. Provided we are able to channel this complexity productively in the design process it can lead to a myriad of rich spatial experiences while also ensuring optimal performance and use of the generated space. Working with complexity brings the opportunity to create urban form in which the function and design of each space, terrace, rooftop and facade are defined according to its spatial and performative characteristics.

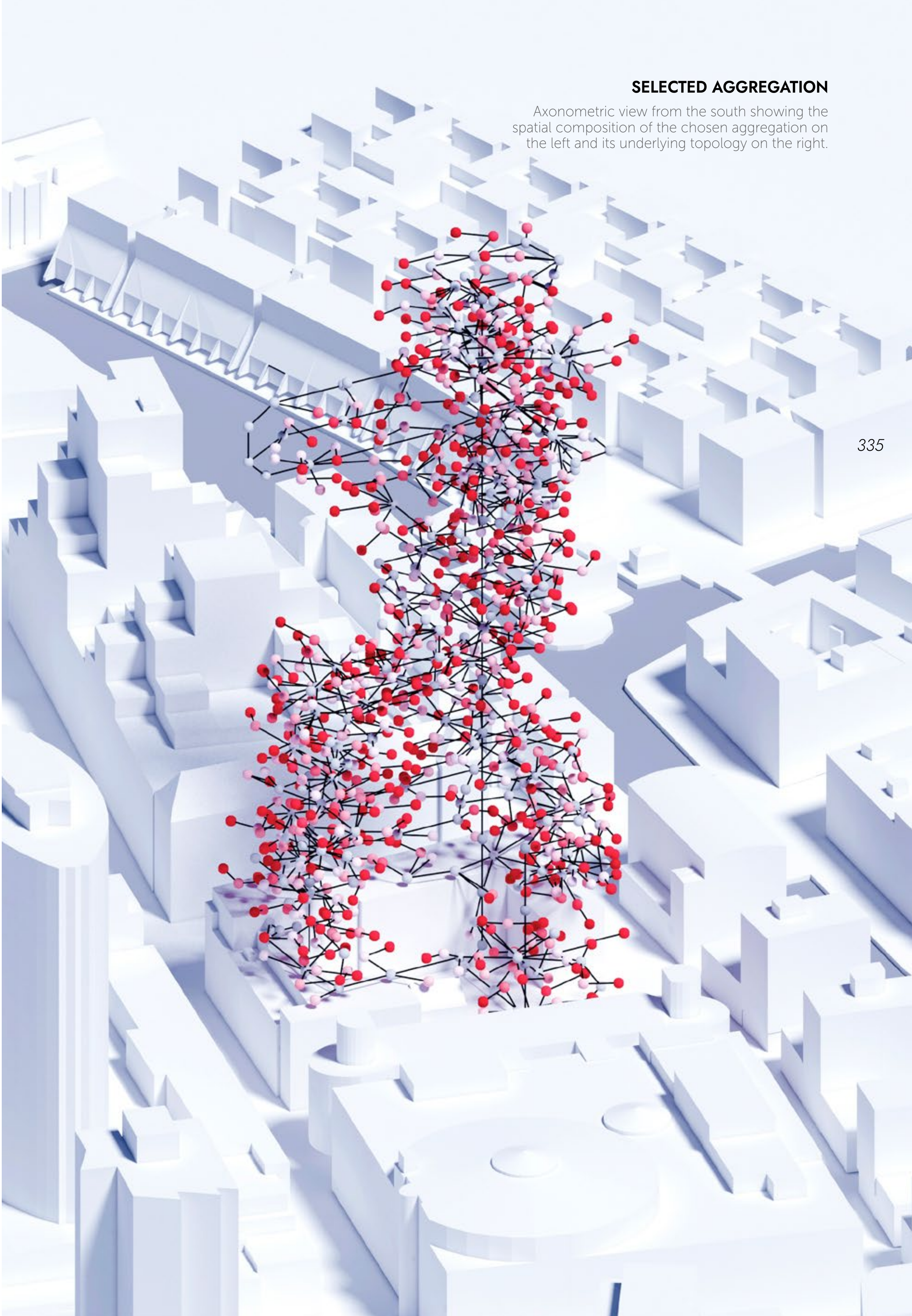
To enable such design with complexity, computational tools need to be employed due to their capacity to operate efficiently with large amounts of data enabling both the systematic analysis of the complexity contained within configurational form as well as its eventual design development. This can be achieved via the use of procedural design algorithms which, much like BIM, can automatically apply pre-designed modular elements in response to local conditions and performance qualities. Such a process can be performed in varying amounts of detail, starting from the definition of precise functions of spaces, their interior layout, the application of construction elements and finally the design of construction details as well as finishing layers such as the exterior facade.

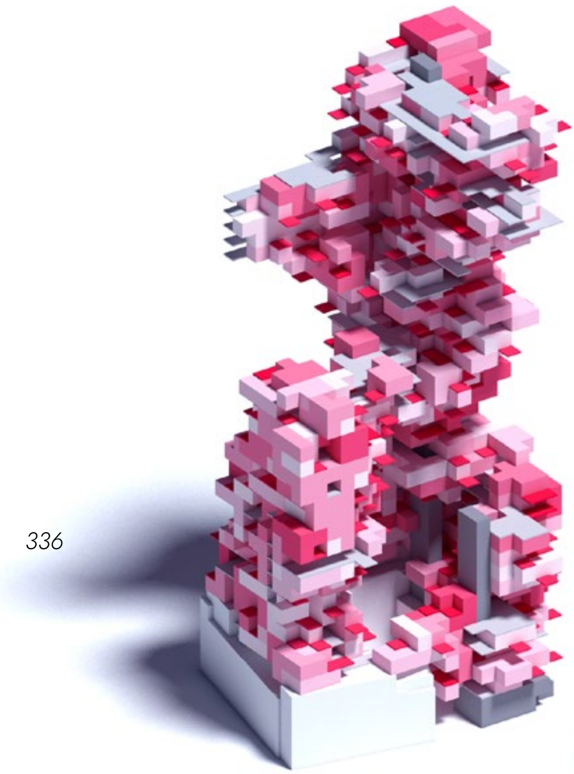
Designing with complexity in this way could lead to a truly adaptive urban form responding to its site and environment at all spatial levels while enabling the spatial efficiency required to radically improve the density and sustainability of our cities whilst maintaining or possibly even improving their spatial qualities.


SCAN FOR
AR MODEL

SELECTED AGGREGATION

Axonometric view from the south showing the spatial composition of the chosen aggregation on the left and its underlying topology on the right.

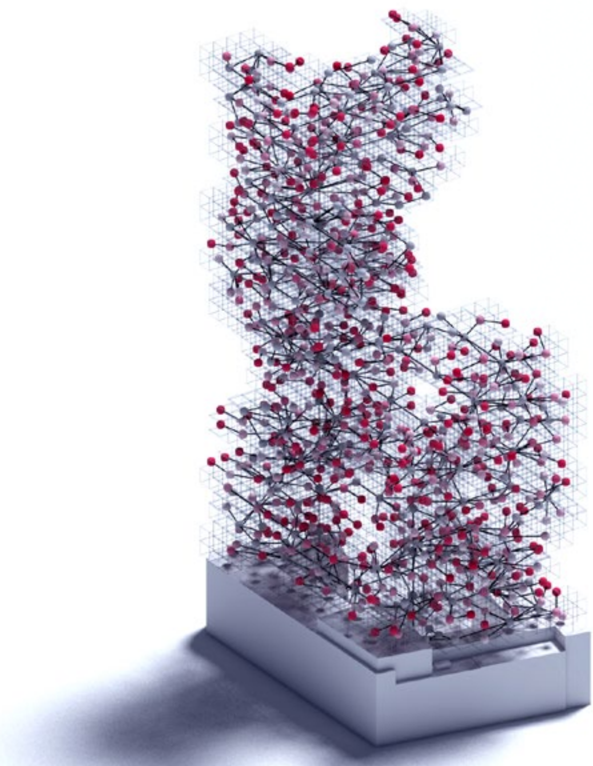




Geometry | South

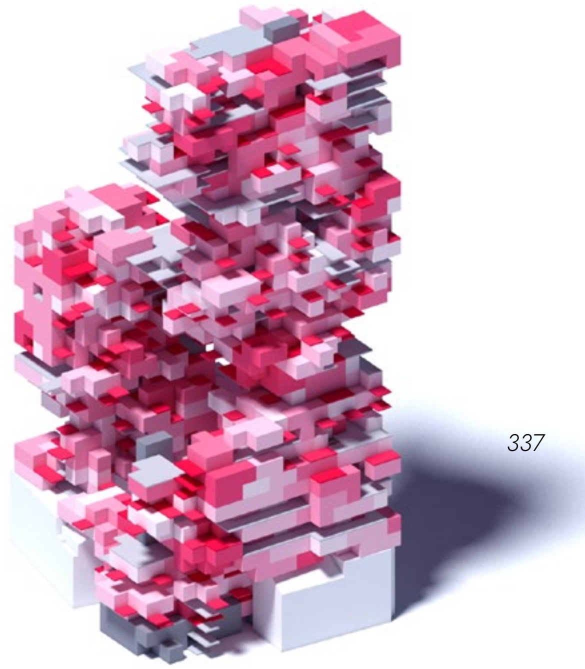
Geometry | West

Topology | South

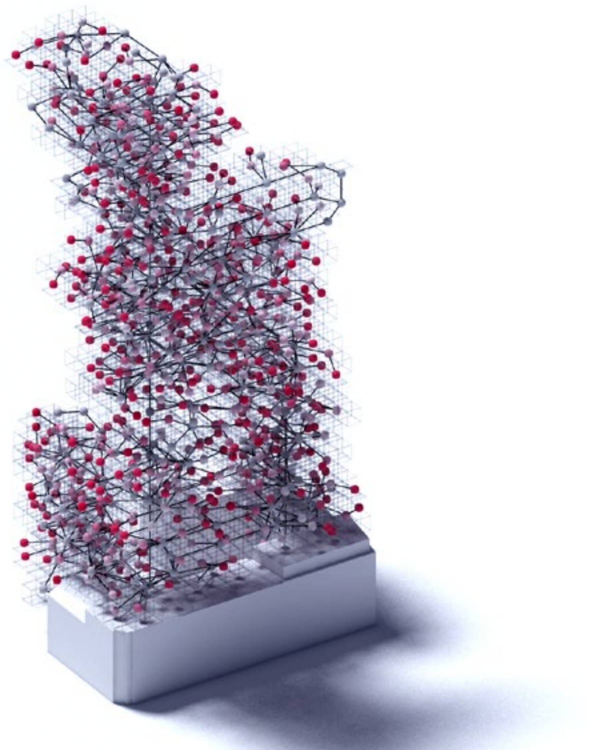


Topology | West

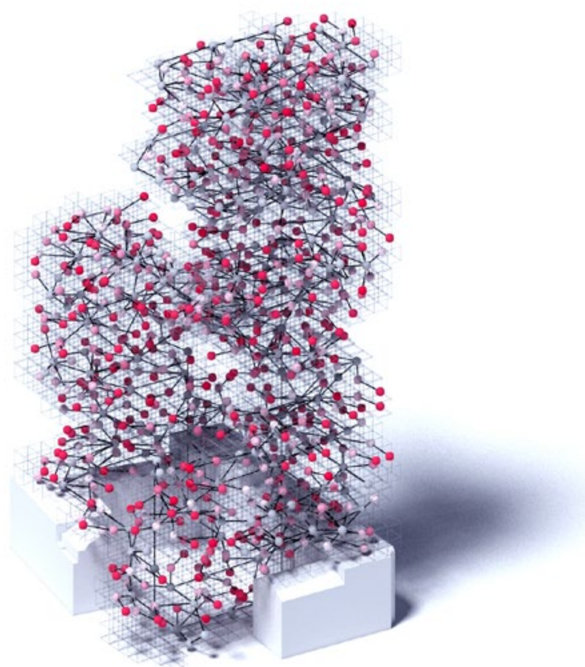
Geometry | North



Geometry | East



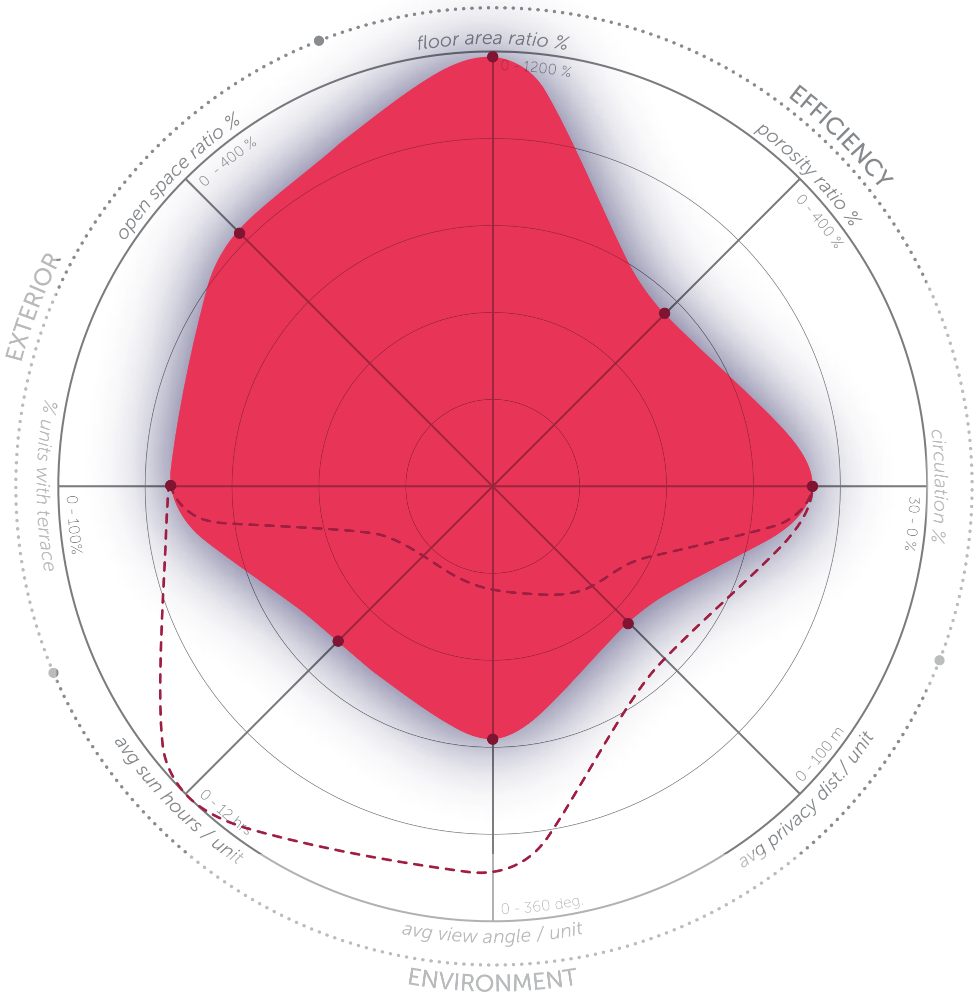
Topology | North

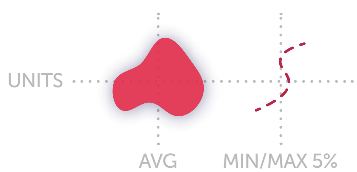


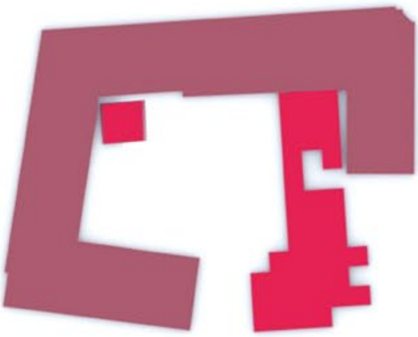
Topology | East

BUILDING ANALYSIS

Analysis of the aggregation at the building scale enables a fast and efficient look into the overall characteristics of the final urban form. Such analysis can be performed either based on performative criteria indicating the overall efficiency of the aggregation or spatially by decomposing the three-dimensional form into layers to get a better sense of its spatial disposition, how it responds to the site and environment and its spatial qualities and ambience within. Such global analysis can prove useful within the early design phases as a guide within the design process both for the architect as well as potential other stakeholders.







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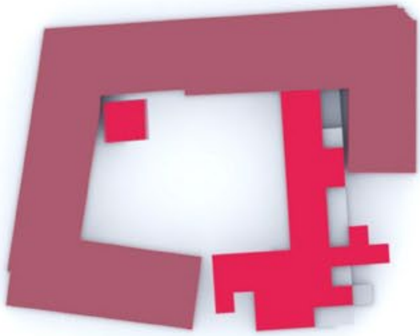

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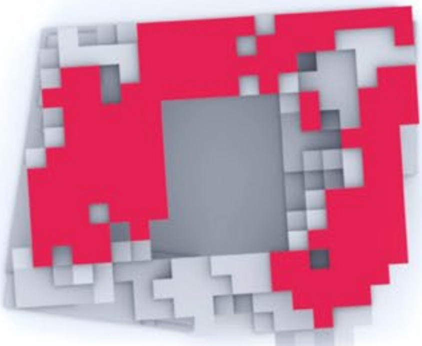

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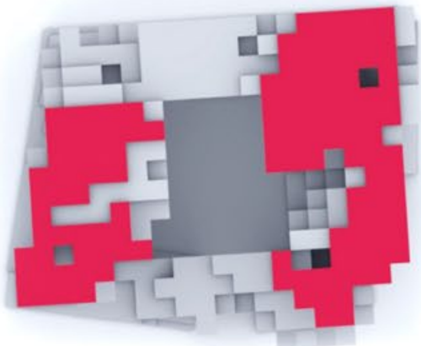

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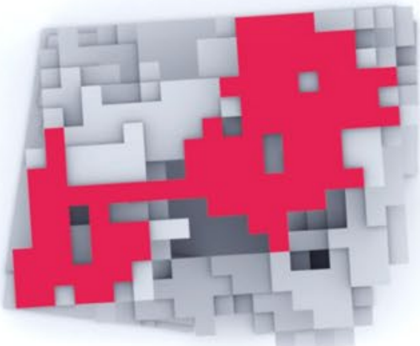

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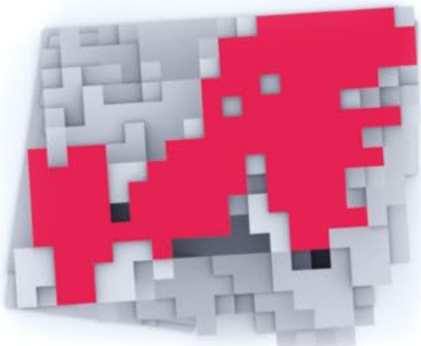

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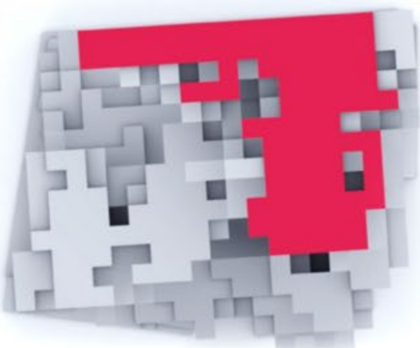

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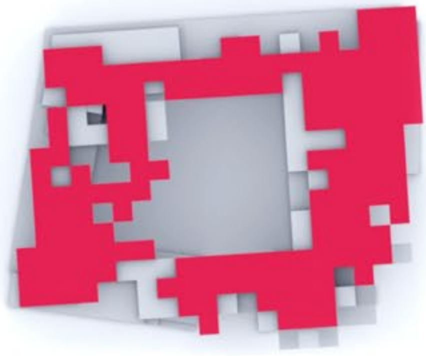

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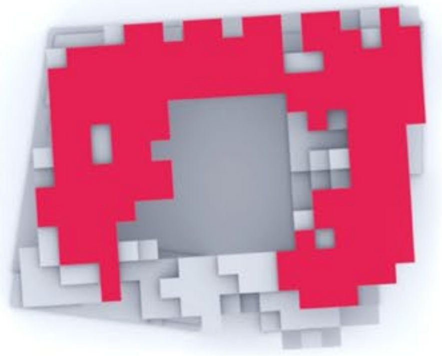

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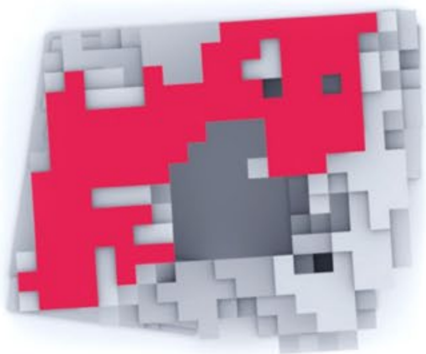

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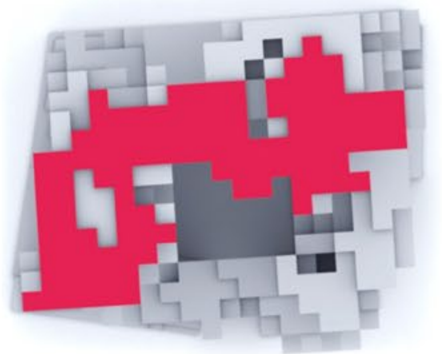

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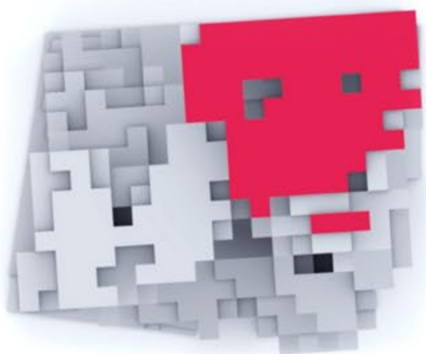

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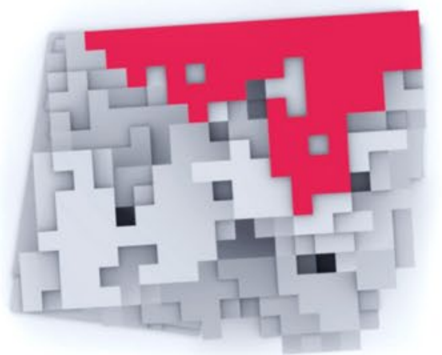

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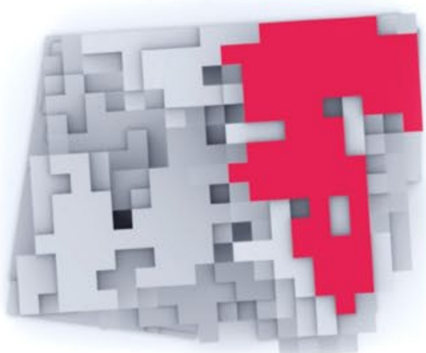

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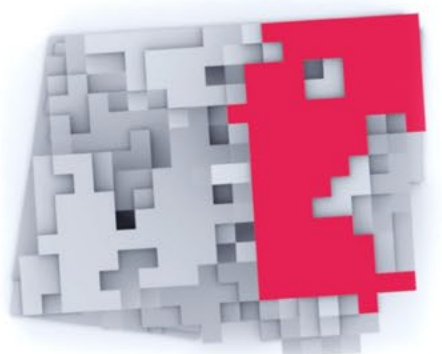

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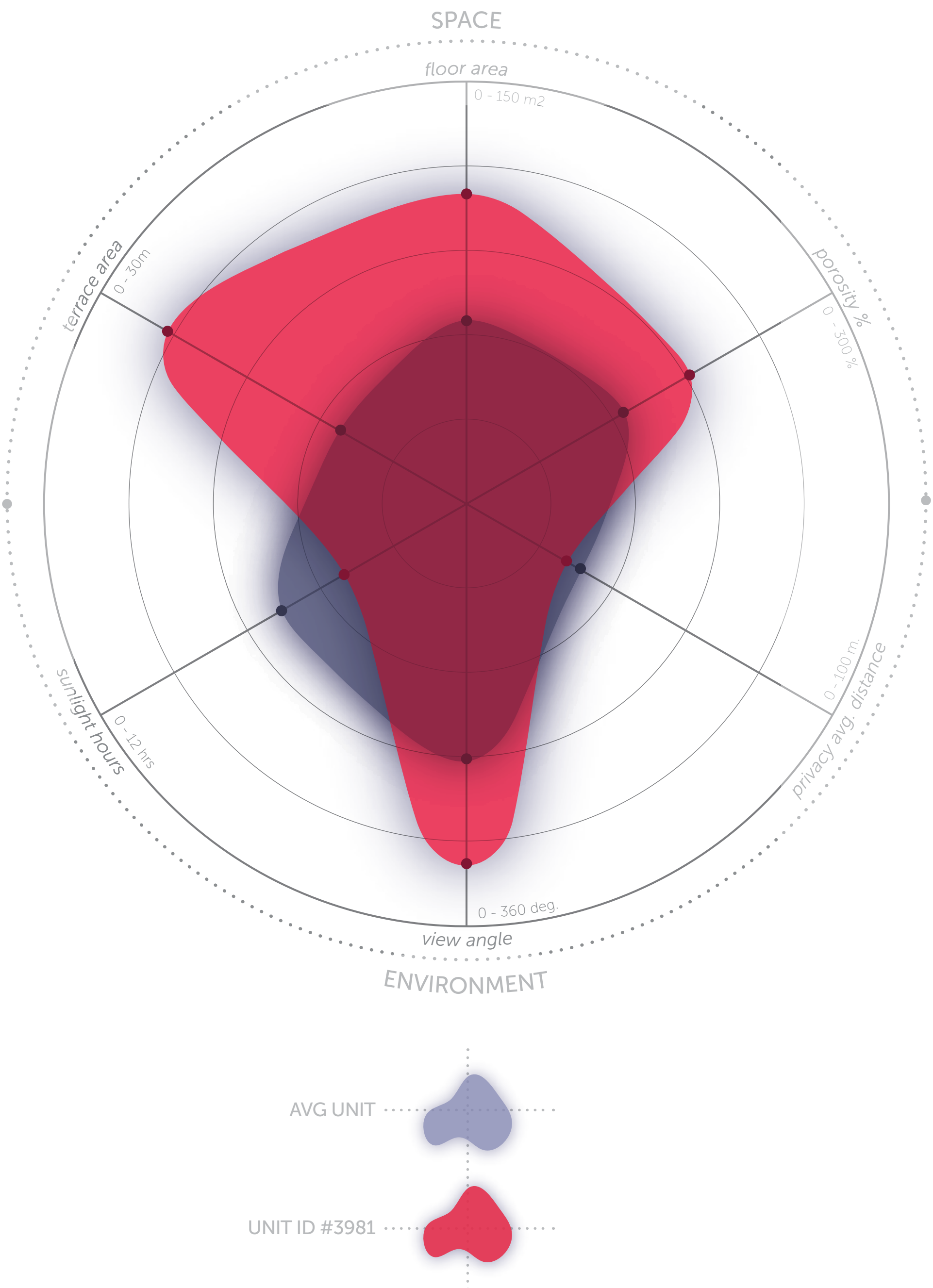
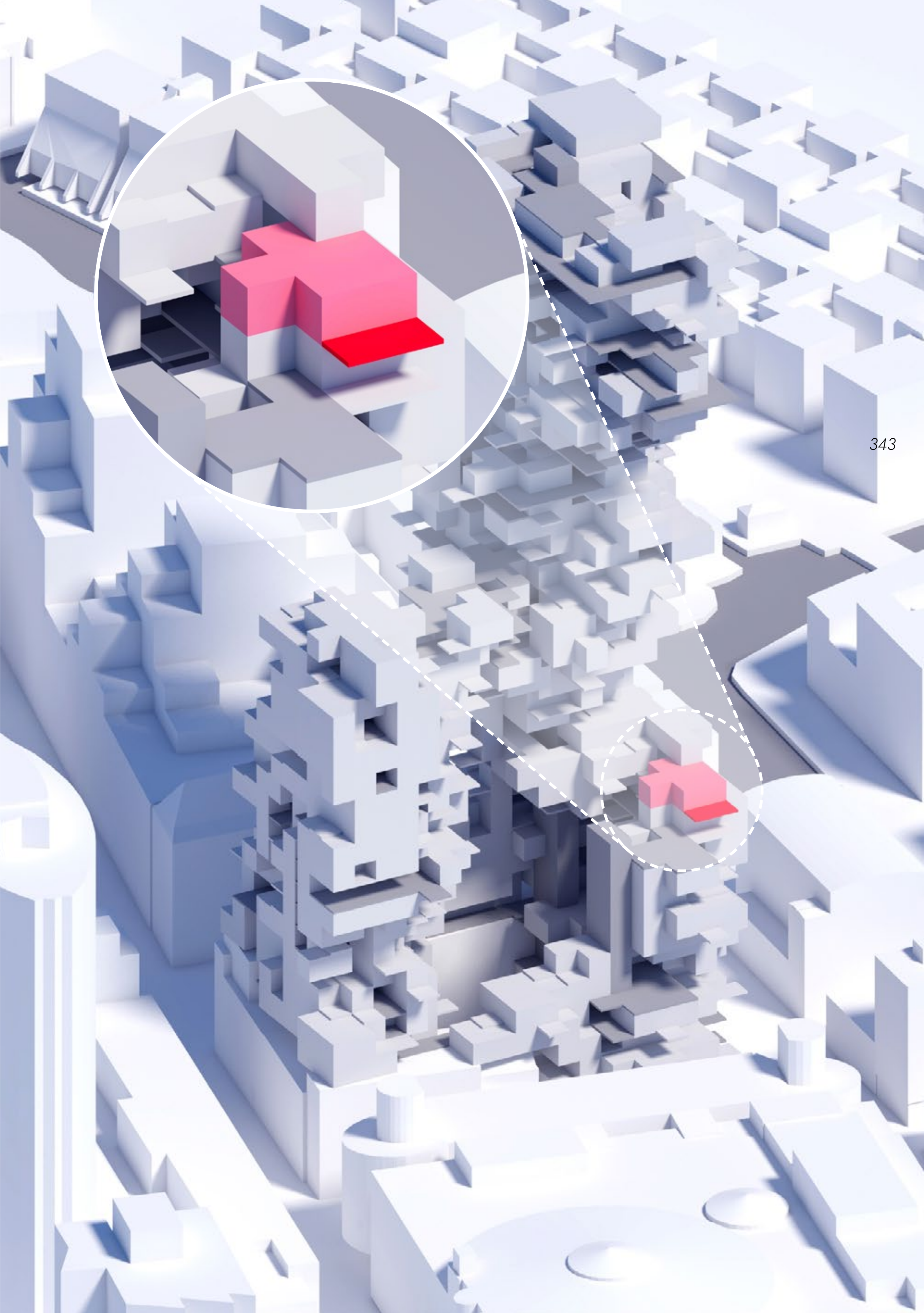
UNIT ANALYSIS

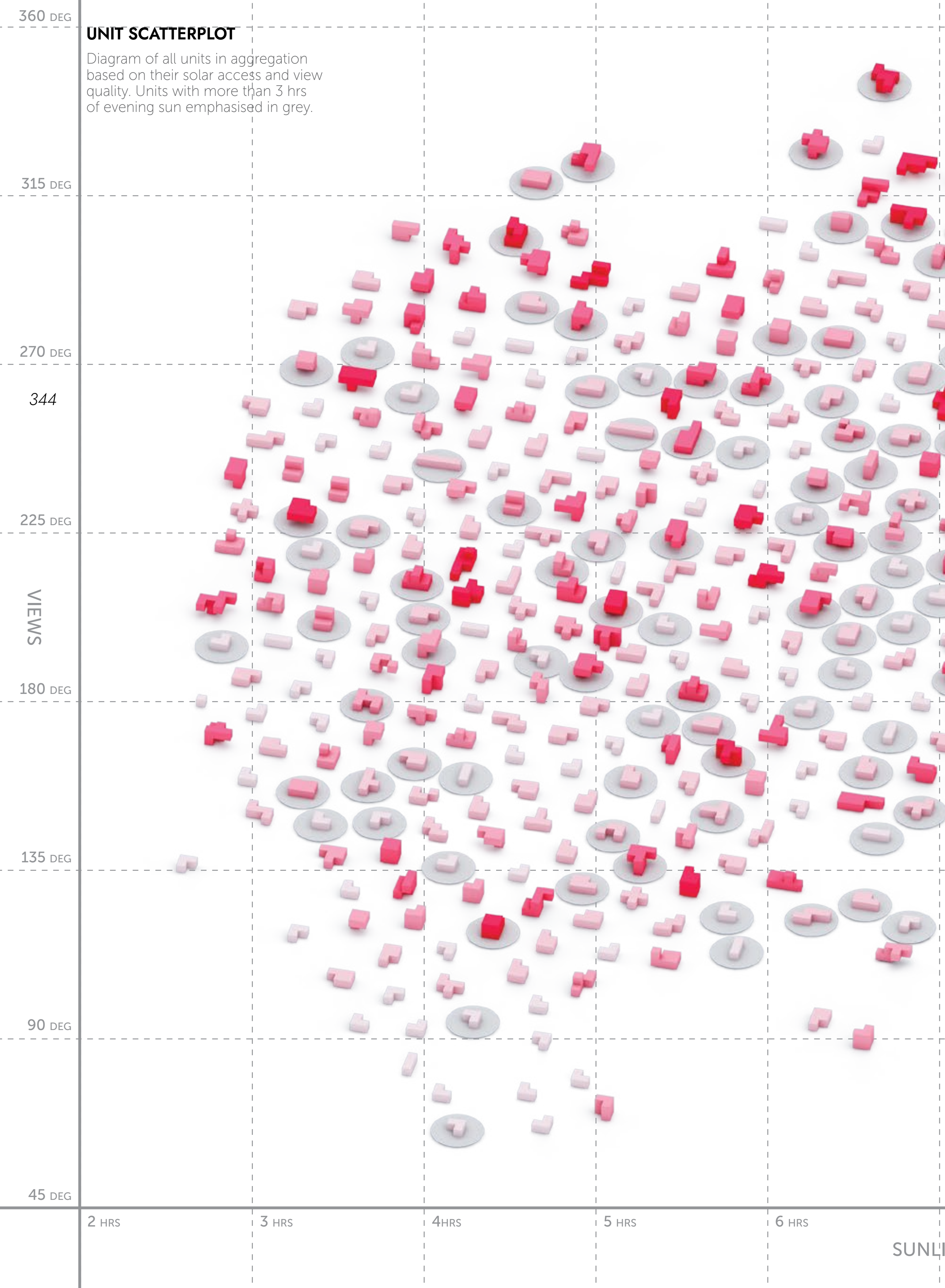
Analysis at the scale of a unit / apartment allows for a more in-depth and detailed look into both the overall aggregation characteristics as well as individual qualities of units within the aggregation. To start, it is easily possible to inspect any desired unit within the aggregation both spatially as well as performatively, either in isolation or in comparison to the global average. This information is crucial not only for the architect and investors, but also for potential users of the building such as potential buyers and tenants who could inspect such a database to help them find their ideal apartment. Furthermore the unit information can be used for customized sorting based on performance giving an additional layer of comparison and ease of choice.

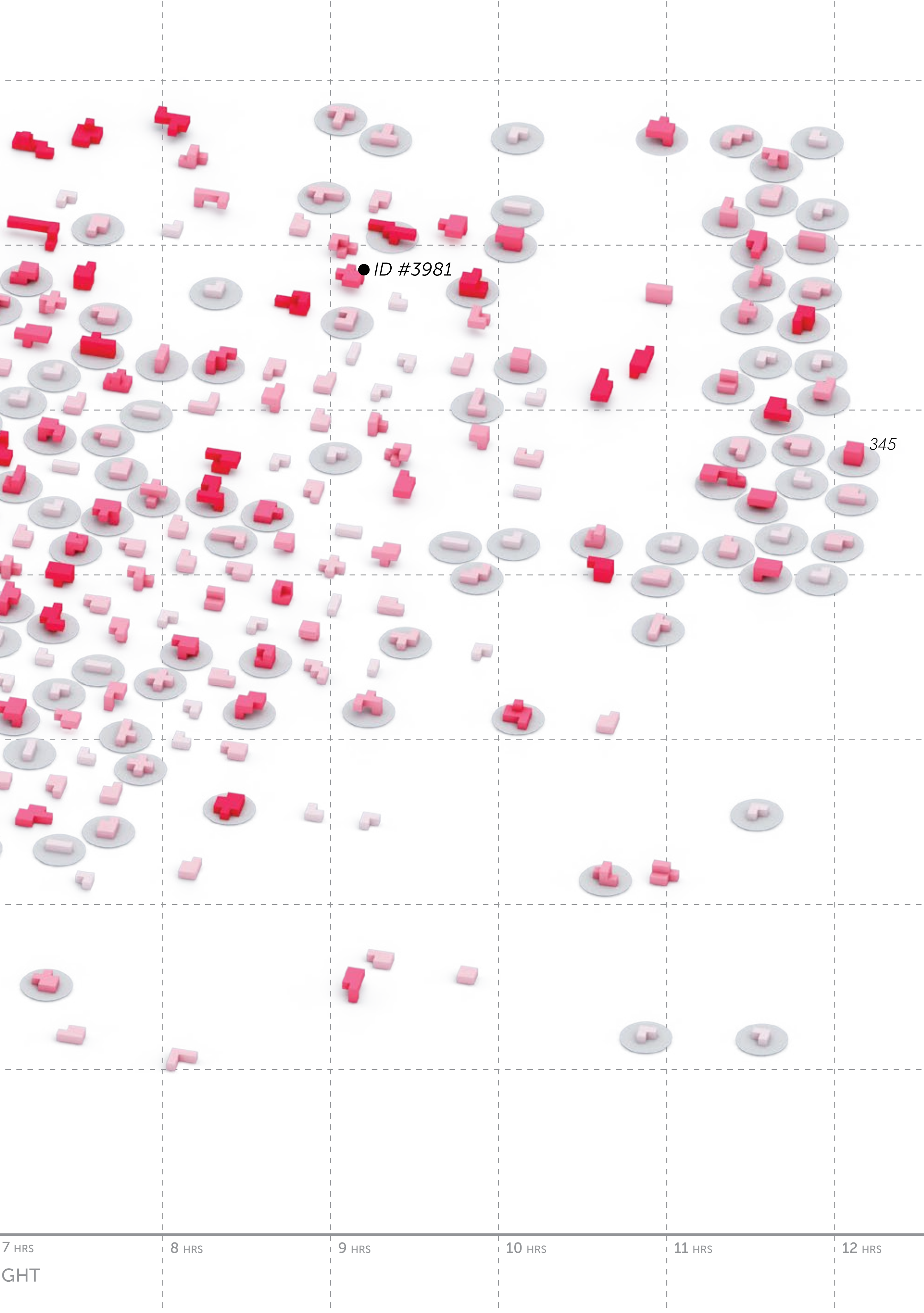




UNIT SCATTERPLOT

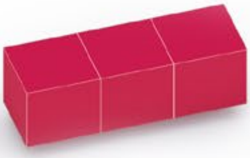
Diagram of all units in aggregation based on their solar access and view quality. Units with more than 3 hrs of evening sun emphasised in grey.




ID #3981
7 HRS
8 HRS
9 HRS
10 HRS
11 HRS
12 HRS
GHT

UNIT SHAPE CLUSTERING

Automated evaluation of unit geometric properties utilising K-Means clustering to reveal distinct spatial typologies.

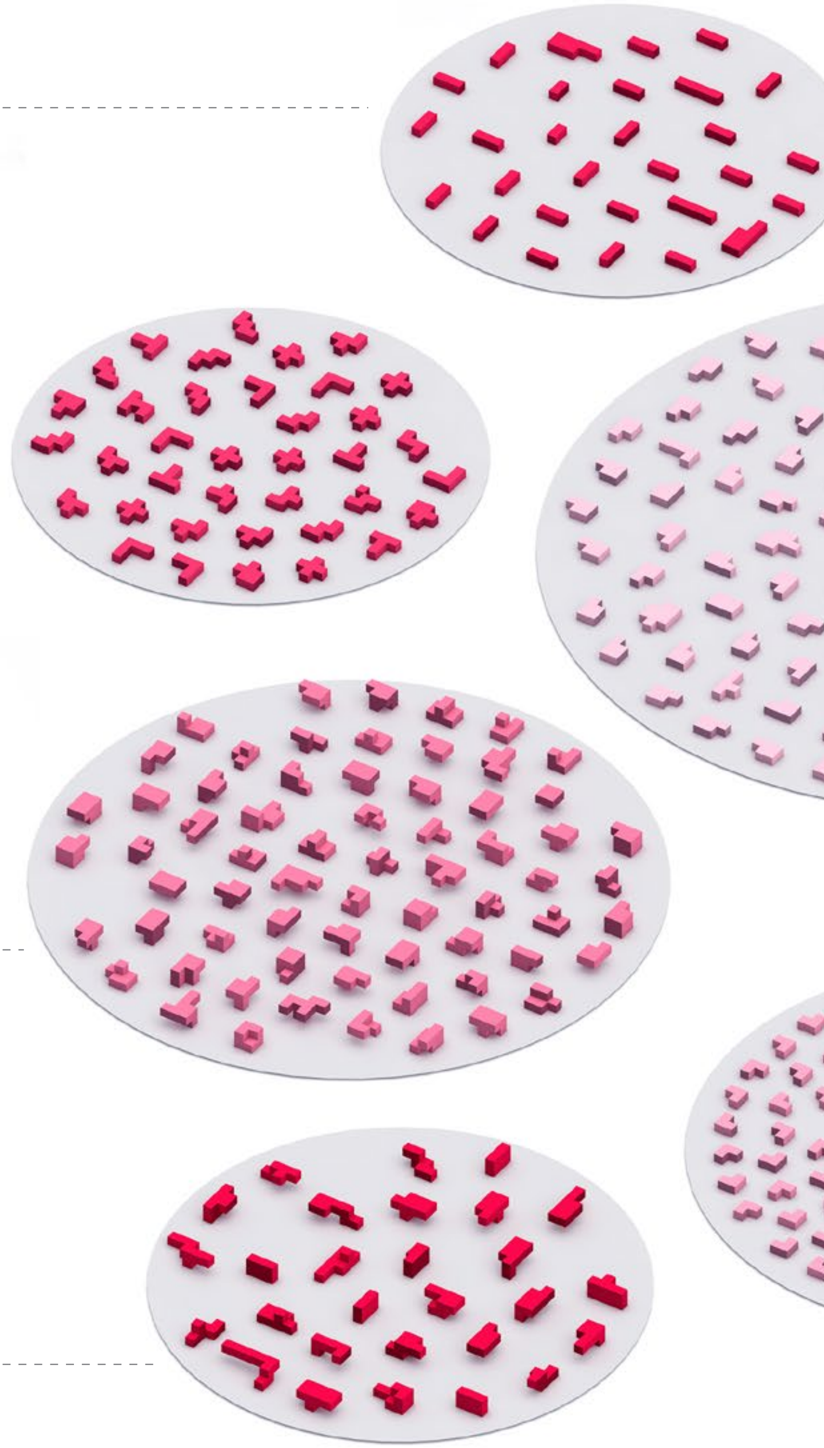


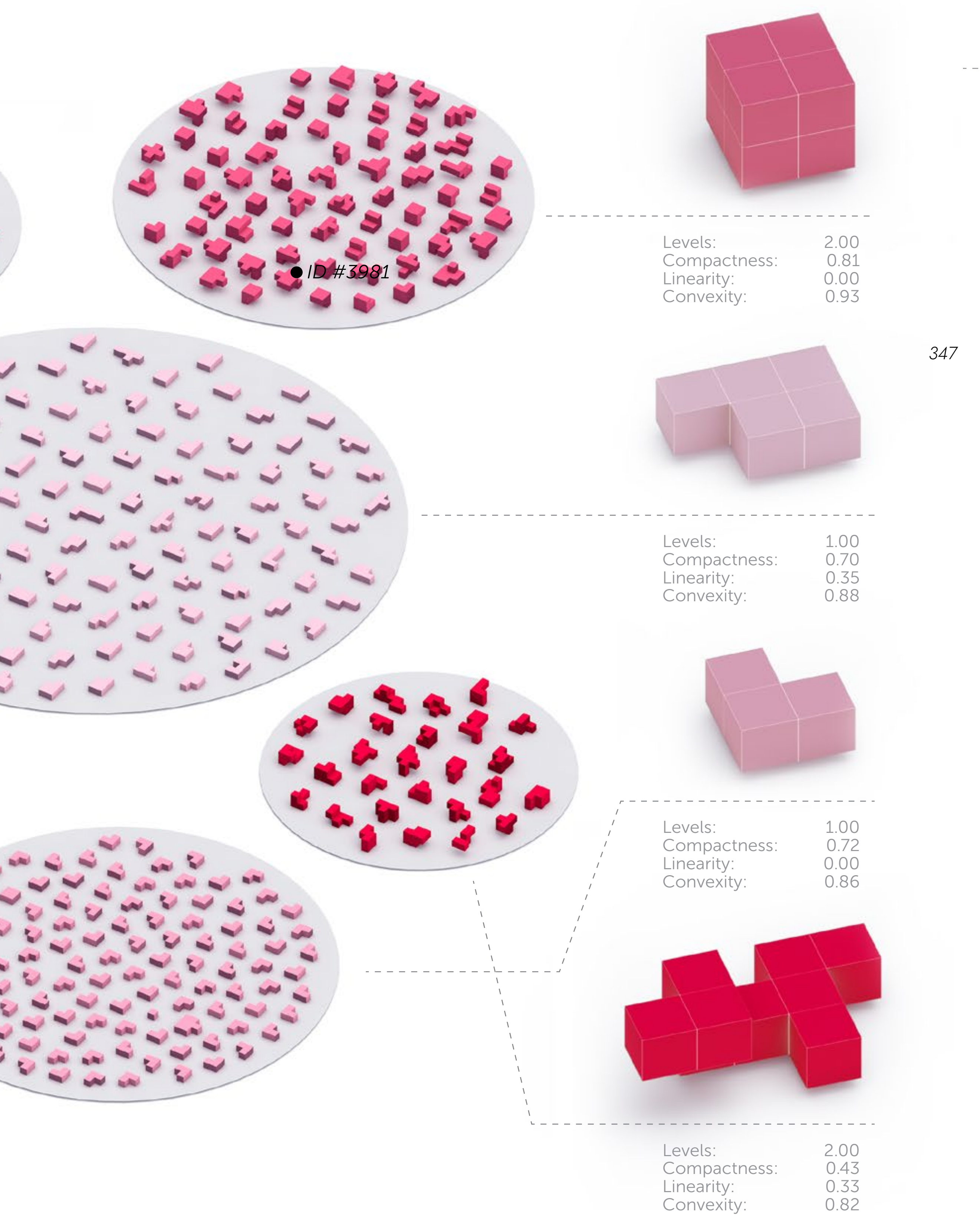
Levels: 1.00
Compactness: 0.51
Linearity: 0.73
Convexity: 0.99

Levels: 1.00
Compactness: 0.41
Linearity: 0.00
Convexity: 0.72

Levels: 2.00
Compactness: 0.54
Linearity: 0.32
Convexity: 0.95

Levels: 2.00
Compactness: 0.65
Linearity: 0.61
Convexity: 0.94




● ID #3981
Levels: 2.00
Compactness: 0.81
Linearity: 0.00
Convexity: 0.93
Levels: 1.00
Compactness: 0.70
Linearity: 0.35
Convexity: 0.88
Levels: 1.00
Compactness: 0.72
Linearity: 0.00
Convexity: 0.86
Levels: 2.00
Compactness: 0.43
Linearity: 0.33
Convexity: 0.82

SURFACE ANALYSIS

Analysis at the surface level performs basic analysis for each desired parameter at the level of each voxel surface, both horizontal and vertical. It is the most important analysis of all as it is fundamental for the further materialization of the aggregation into a building. Through analysing the aggregation a dataset is created which is later used as a design driver for a procedural design process which distributes a series of spatial and programmatic elements to different parts of the building according to their requirements and the performance of the building at that point in space. This enables the partial automation of the design process and eases the challenges posed by the complexity of the aggregation.

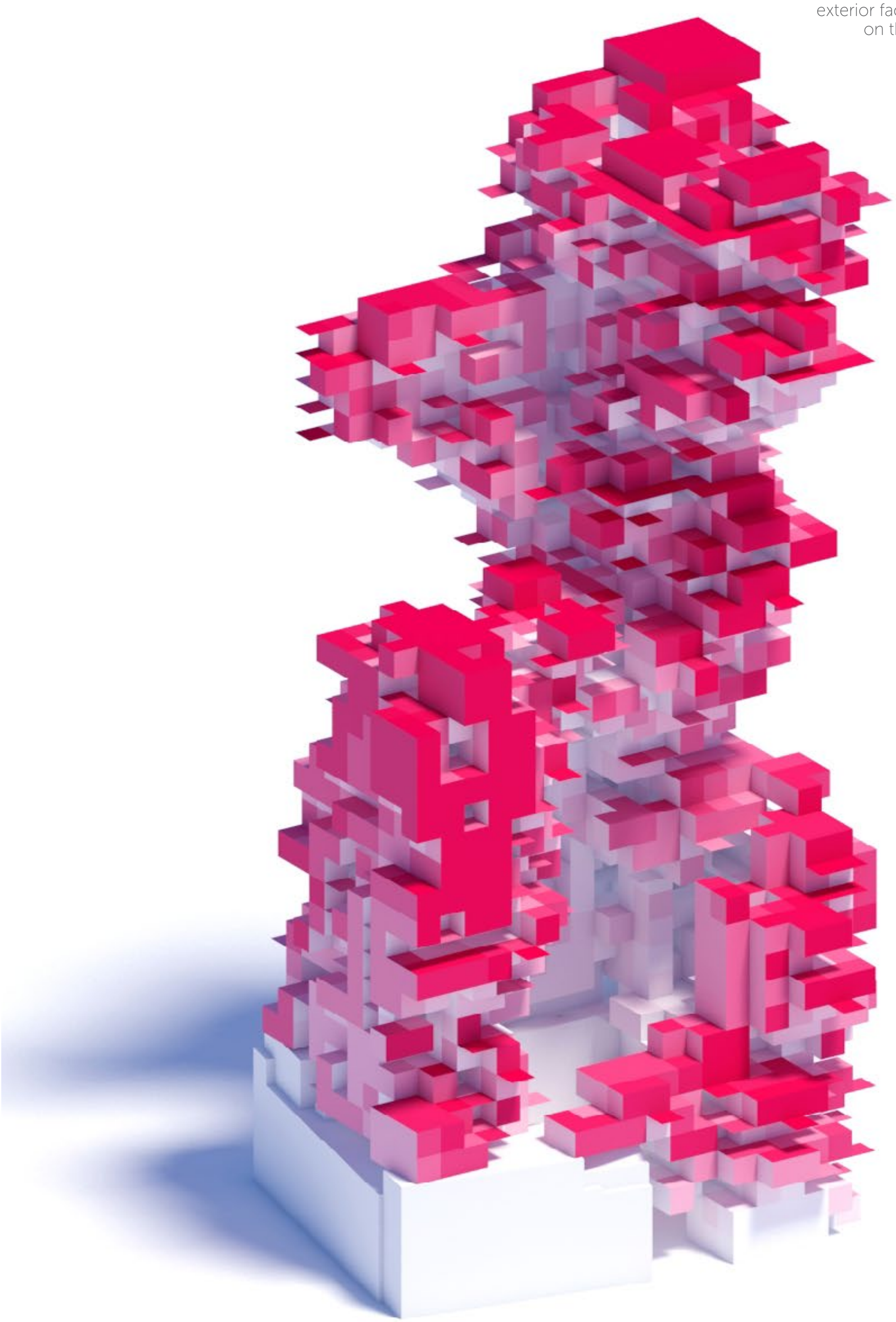
Group ID	Cluster ID	Cluster Type	Cluster Voxels	Connected Clusters	Area	Floors	Geometry
0	0	0	231;631;1031	1;10;27;200	27	3	interior
0	1	1	211;210;209	0;17;151;6;7;9	27	1	exterior
0	6	4	610;609;589;569;588;568;608;549	1	72	1	interior
0	7	2	189;169;168	1	27	1	interior
0	9	3	230;250;251;271;270;290	1	54	1	interior
0	10	0	1431;1831;2231	0;11;218;237	27	3	interior
0	11	1	1451;1450;1449	);183;192;92;94;35	27	1	exterior
0	17	1	208,207,206	1,19,36,998	27	1	exterior
0	19	1	205;204;203	17;33;20;1039	27	1	exterior
0	20	5	5;1025;1026;1006;1046;1045;1027;10	19	90	2	interior
0	27	1	651;650;649	0;44;103;31;40	27	1	exterior
0	31	3	671;691;690;670;710;711	27	54	1	interior
0	33	1	202	19;119	9	1	exterior
0	36	3	226;225;245;244;264;263	17	54	1	interior
0	40	2	1049;1069;1070	27	27	1	interior

Group ID	Cluster ID	Voxel ID	Type ID	Adjacent Voxels	Adjacent Faces	Voxel Area	Geometry
0	149	2	2	3;1;22;402	0;1;3;4;5	9	interior
0	877	11	6	12;10;31;411	7;8;9;10;11	9	interior
0	877	12	6	13;11;32;412	14;16	9	interior
0	877	13	6	14;12;33;413	19;21	9	interior
0	877	14	6	15;13;34;414	23;24;26	9	interior
0	877	15	6	16;14;35;415	27;28;29;30;31	9	interior
0	174	16	3	17;15;36;416	27;34;35;36	9	interior
0	174	17	3	18;16;37;417	39;40;41	9	interior
0	174	18	3	19;17;38;418	42;44;45;46	9	interior
0	149	22	2	23;21;42;2;422	48;49;50;51	9	interior
0	149	23	2	24;22;43;3;423	52;53;54;55;56	9	interior
0	877	32	6	33;31;52;12;432	58;59;60;61	9	interior
0	877	33	6	34;32;53;13;433	62;63;65	9	interior
0	174	36	3	37;35;56;16;436	67;68;69;70	9	interior
0	174	37	3	38;36;57;17;437	72;73;74	9	interior

Face ID	Group IDs	Cluster IDs	Voxel IDs	Face Area	Face Type	Face Is Vertical	Face Is Solid	Face Is Connecting	Sun t
0	0	149	2	9	int-ext	TRUE	TRUE	FALSE	5
1	0	149	2	9	int-ext	TRUE	TRUE	FALSE	5
3	0	149	2	9	int-ext	TRUE	TRUE	FALSE	11
4	0	149	2	9	int-ext	FALSE	TRUE	FALSE	11
5	0	149	2	9	int-ext	FALSE	TRUE	FALSE	11
7	0	877	11	9	int-ext	TRUE	TRUE	FALSE	5
8	0	877	11	9	int-ext	TRUE	TRUE	FALSE	0
9	0	877	11	9	int-ext	TRUE	TRUE	FALSE	11
10	0	877	11	9	int-ext	FALSE	TRUE	FALSE	8
11	0	877	11	9	int-ext	FALSE	TRUE	FALSE	8
14	0	877	12	9	int-ext	TRUE	TRUE	FALSE	11
16	0	877	12	9	int-ext	FALSE	TRUE	FALSE	5
19	0	877	13	9	int-ext	TRUE	TRUE	FALSE	11
21	0	877	13	9	int-ext	FALSE	TRUE	FALSE	5
23	0	877	14	9	int-ext	TRUE	TRUE	FALSE	[illegible]

SOLAR ANALYSIS

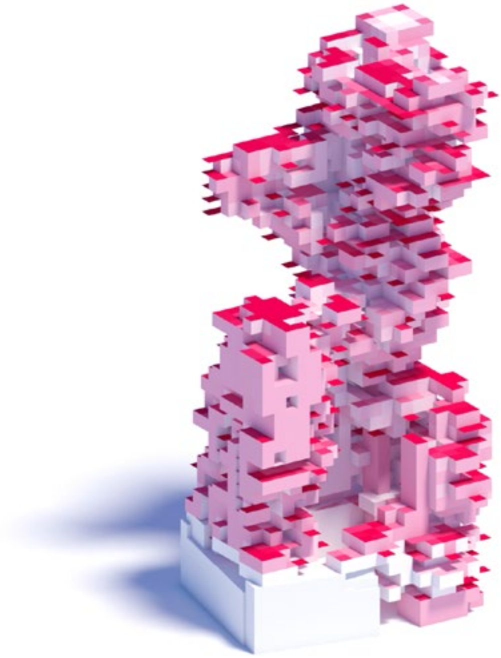
Solar access analysis of each exterior face in the building on the 21st of March.



SPATIAL ANALYSIS

Analysis of spatial conditions at the level of a voxel face, together generating a performance database.

Sunlight



Views

Access

Facade

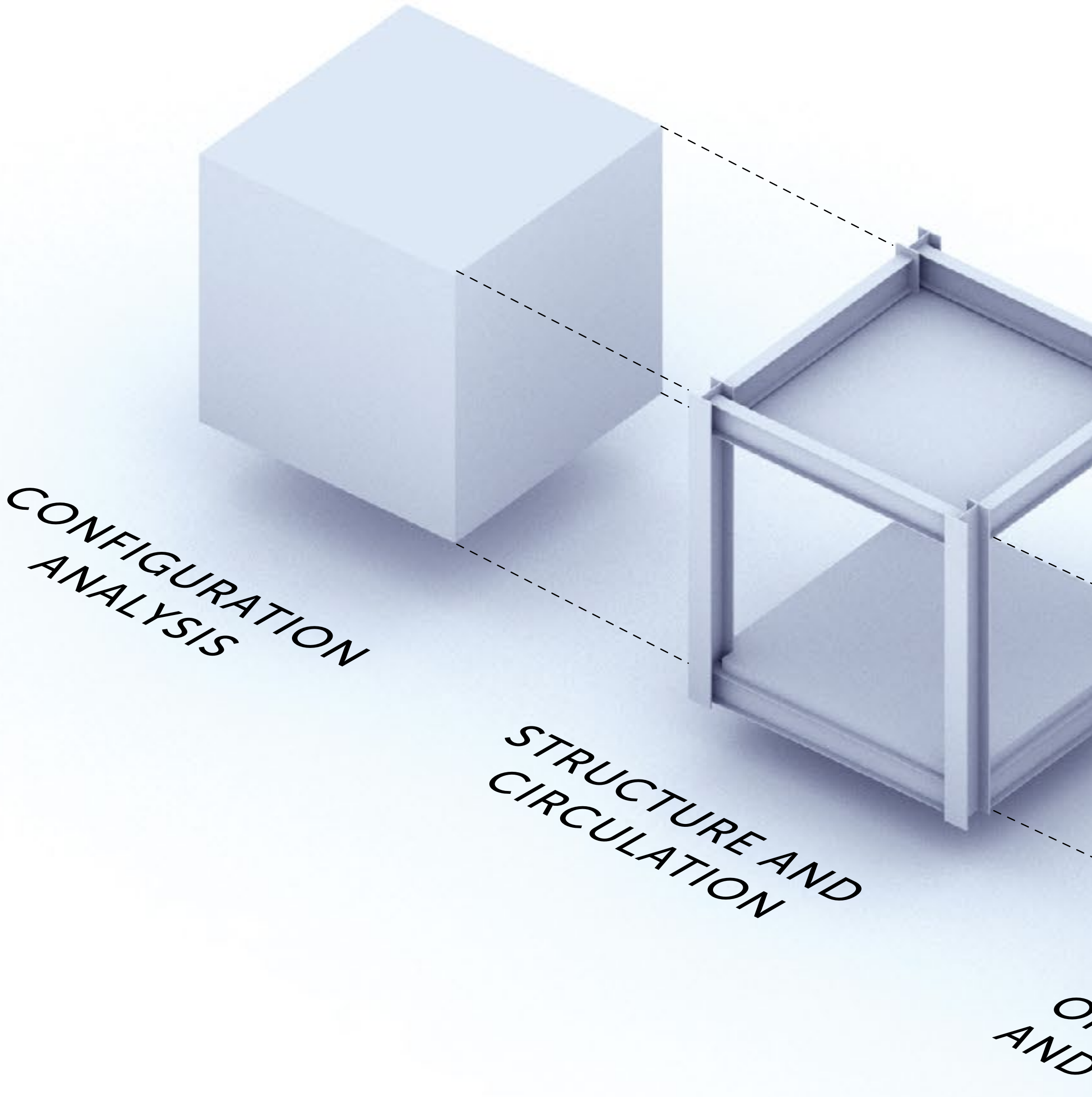
Privacy

Height

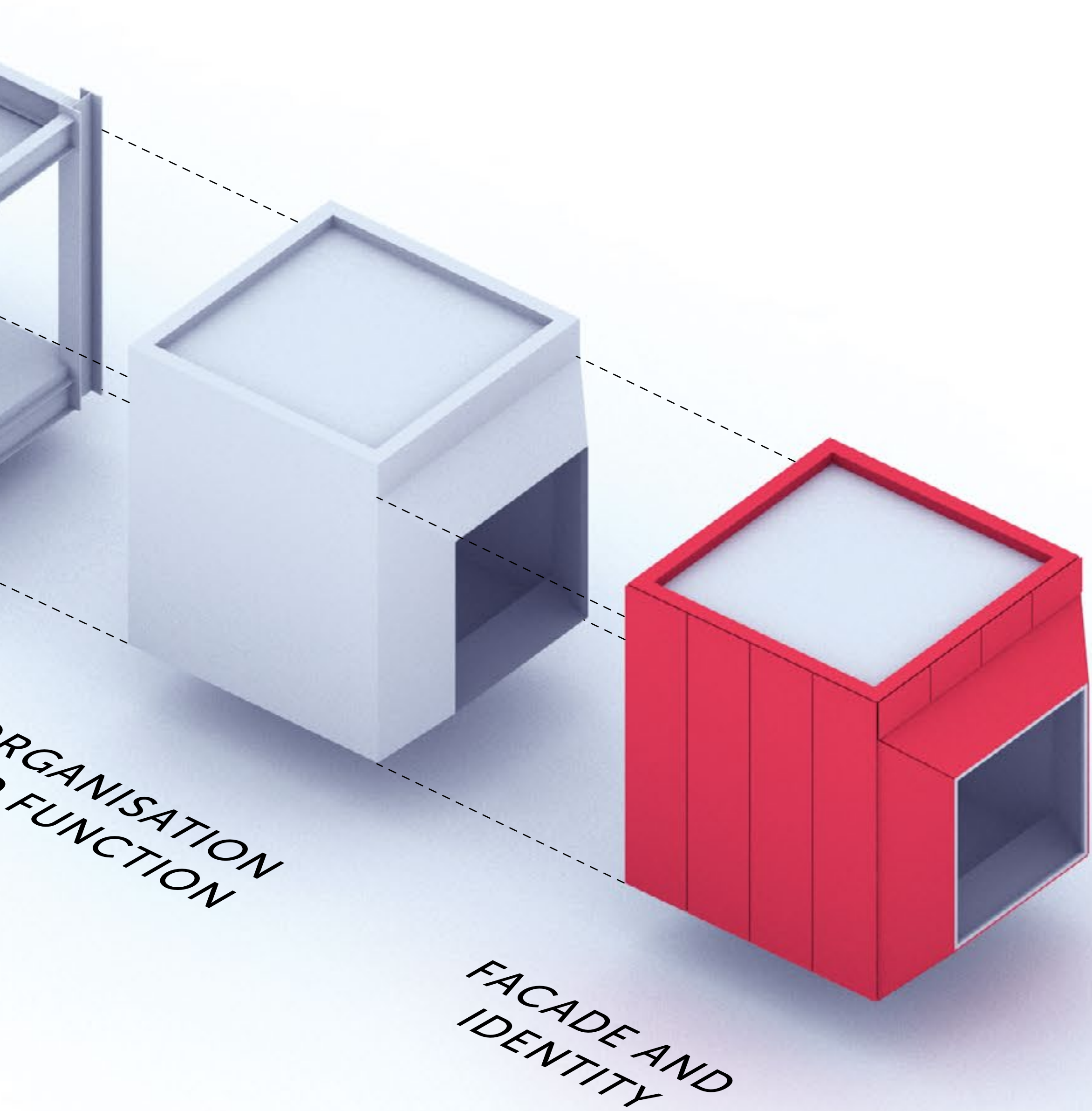
Interior walls

Connecting walls

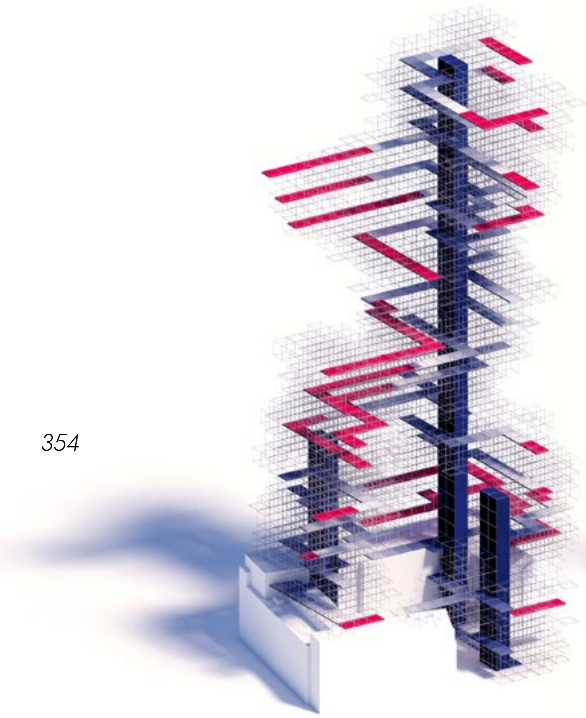
MATERIALISATION



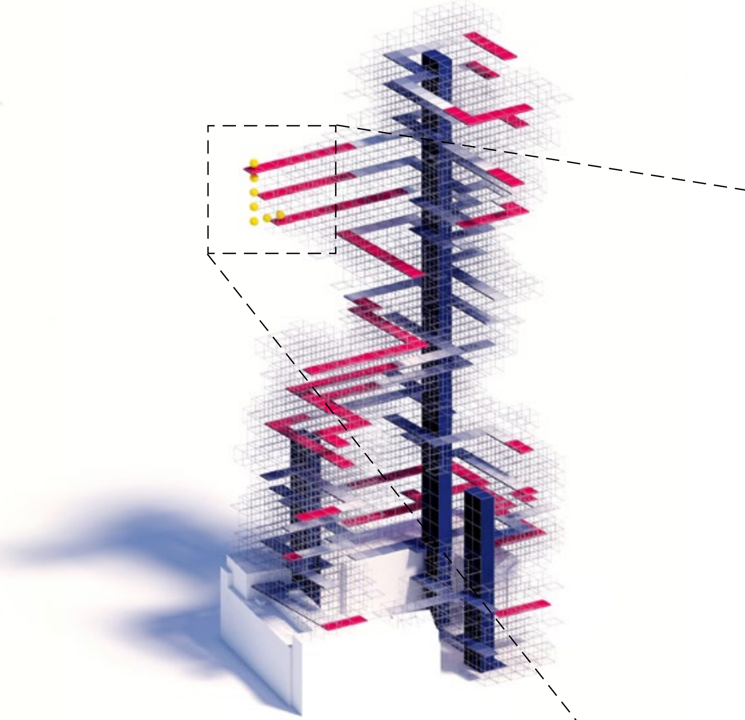
MATERIALISATION of the project is conceptualised as a step-by-step process in which the aggregation starting as abstract voxels representing spatialised information is gradually transformed into a building. The process is strongly supported by automated and semi-automated algorithms which enable the architect to not only be more effcient while designing a 50.000 m2 highly customized building but crucially to productively channel the complexity within and design the interior end exterior spaces in a way that maximises their inherent potential not always visible at first glance. Through the use of analytical algorithms, augmented design interfaces and procedural design the project showcases the strong spatial qualities of the proposal, the feasibility of its construction and the potential of automation for improving both the quality and efficiency of architectural design.


ORGANISATION
D FUNCTION
FACADE AND
IDENTITY

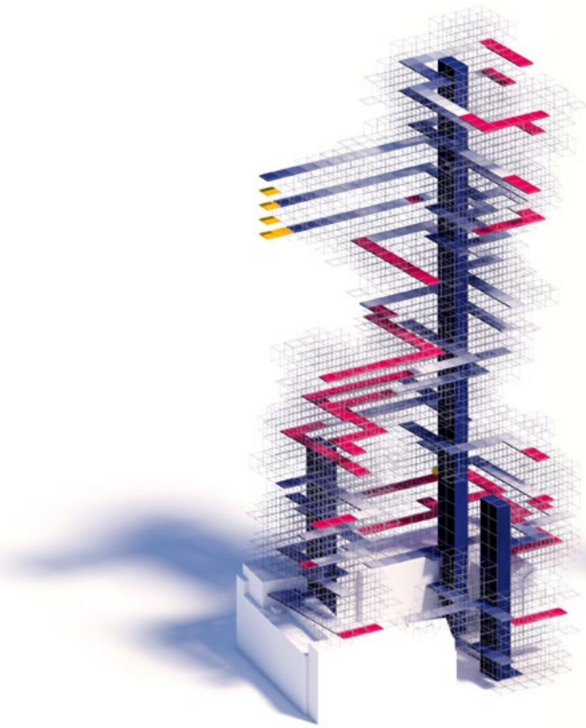
CIRCULATION



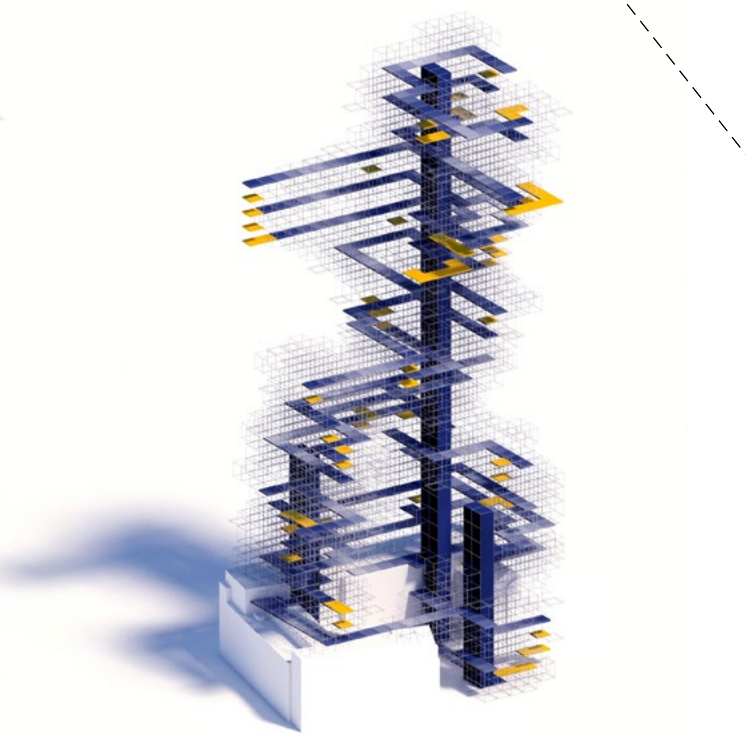
Analyze circulation distances



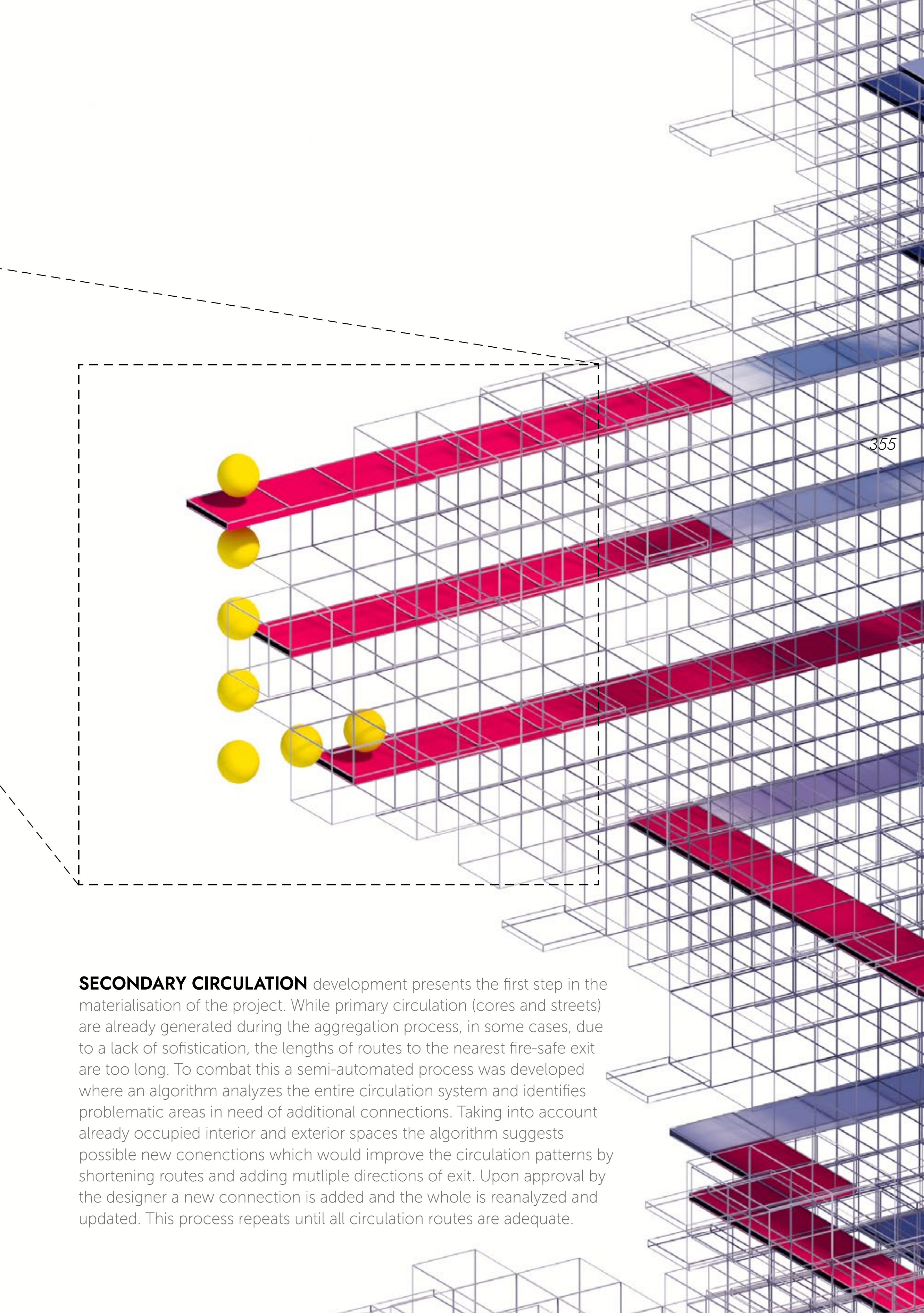
Suggest possible connections



Add connection and recalculate



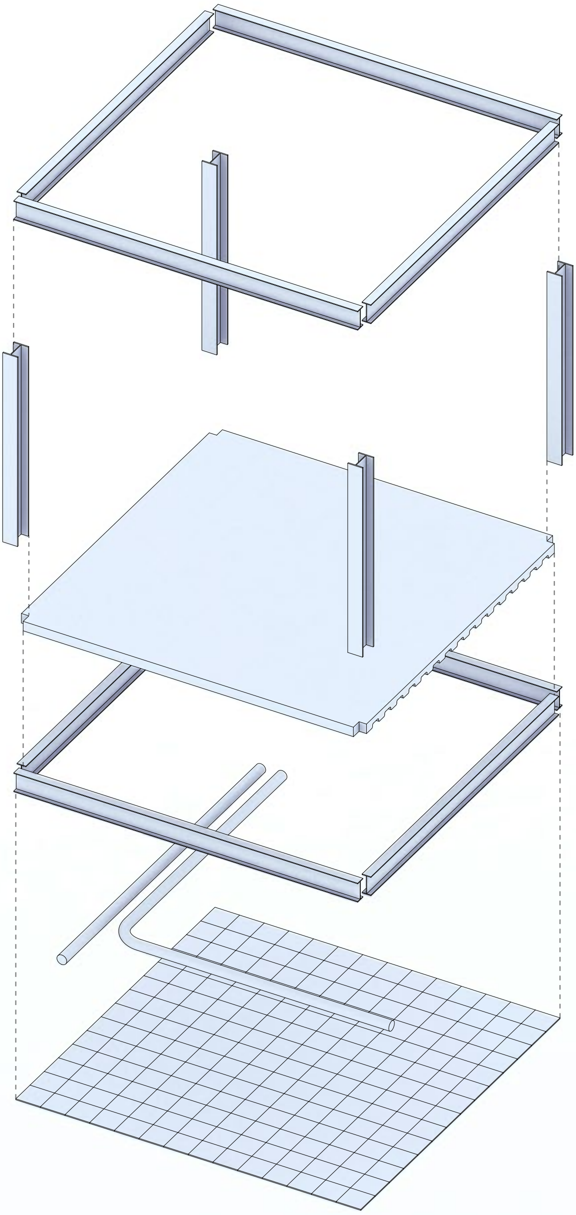
Repeat for entire structure



SECONDARY CIRCULATION development presents the first step in the materialisation of the project. While primary circulation (cores and streets) are already generated during the aggregation process, in some cases, due to a lack of sofistication, the lengths of routes to the nearest fire-safe exit are too long. To combat this a semi-automated process was developed where an algorithm analyzes the entire circulation system and identifies problematic areas in need of additional connections. Taking into account already occupied interior and exterior spaces the algorithm suggests possible new conenctions which would improve the circulation patterns by shortening routes and adding mutliple directions of exit. Upon approval by the designer a new connection is added and the whole is reanalyzed and updated. This process repeats until all circulation routes are adequate.

STRUCTURE

From a structural perspective the proposed aggregation materialization is based on a steel grid framework construction system used in Timmerhuis by O.M.A. in Rotterdam. The 3d Vierendeel truss structure combined with prefabricated composite concrete floor slabs offers exellent adaptability both as a structural system as well as a built space with minimal obstructions such as walls and beams. It is this flexibility that enables the building to behave as a vertical multiplication of the ground plane on which multiple programmes can take place; from housing to offices or even retail. In the case of the project the steel truss grid is applied in a hybrid raster of 7x7m and 3,5x3,5m to maximise spatial flexibility and is vertically reinforced by three concrete cores which also contain the main elevators, utility shafts and emergency stairs.



Main structural elements

TIMMERHUIS

Modular structural system of the Timmerhuis by O.M.A. in Rotterdam

Only primary structure
9.960 elements - 100%

Primary and secondary struct
11.175 elements - 112%

STRUCTURAL RASTER OPTIMIZATION

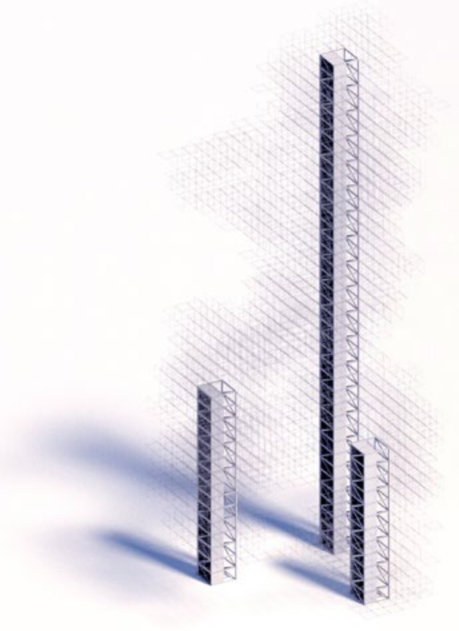
Comparing three variations of structural rasters and their efficiency; 7x7 m (left), 3.5x3.5 m (right), computationally optimized hybrid (center) offering a baalnce between efficiency and spatial flexibility

ure mix

Only secondary structure
16.390 elements - 164%

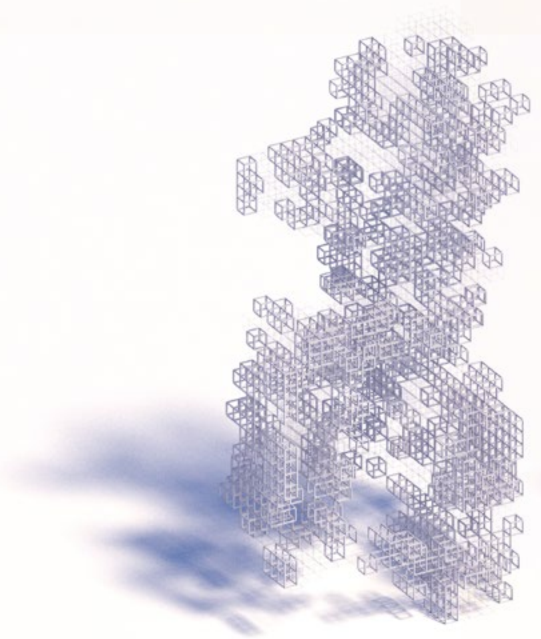
STRUCTURAL COMPOSITION

Below: Exploded axonometry of the main structural elements.
Opposite: The building on site; aflexible megastructure framework.



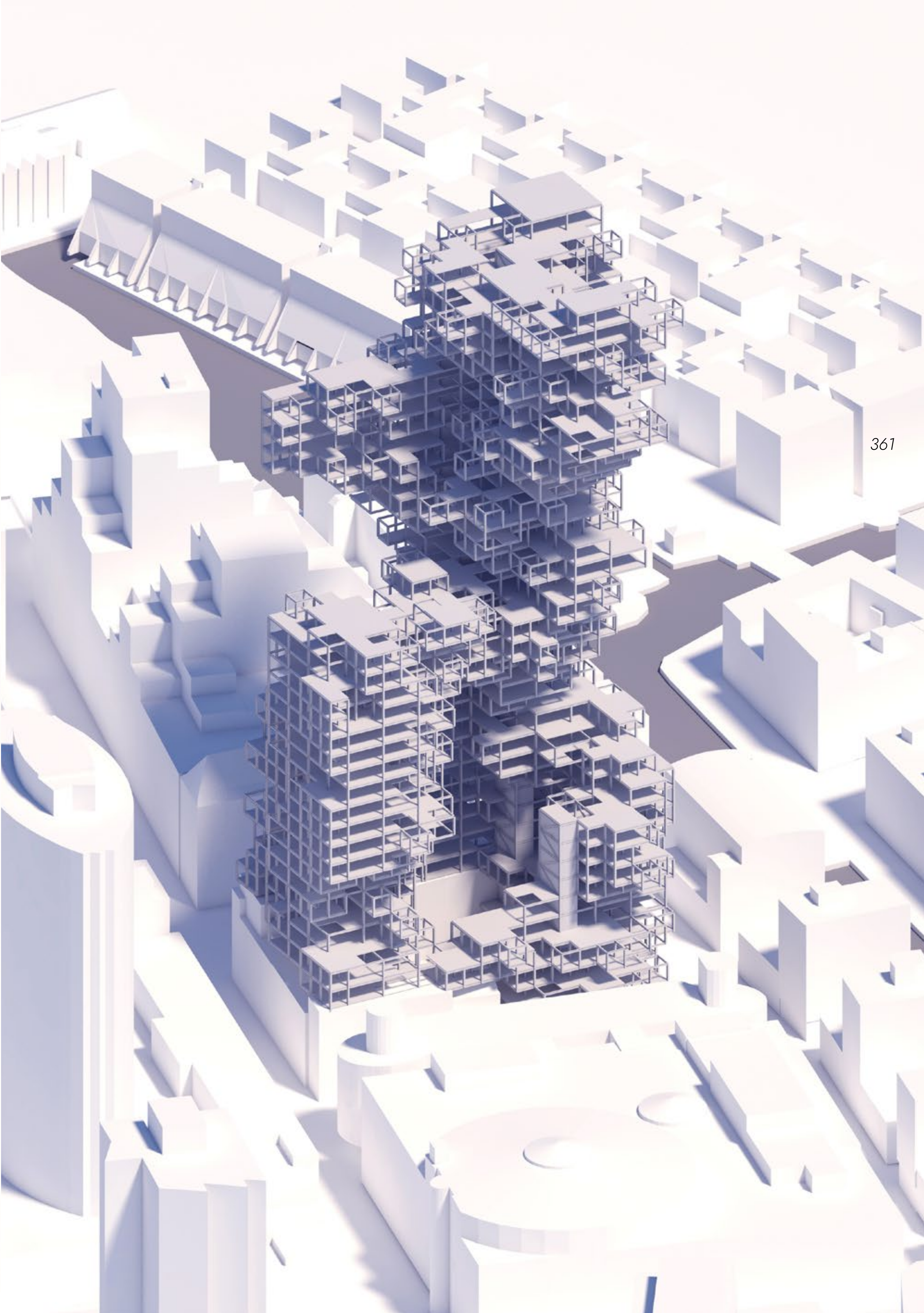
Steel & concrete circulation cores

Primary steel structure



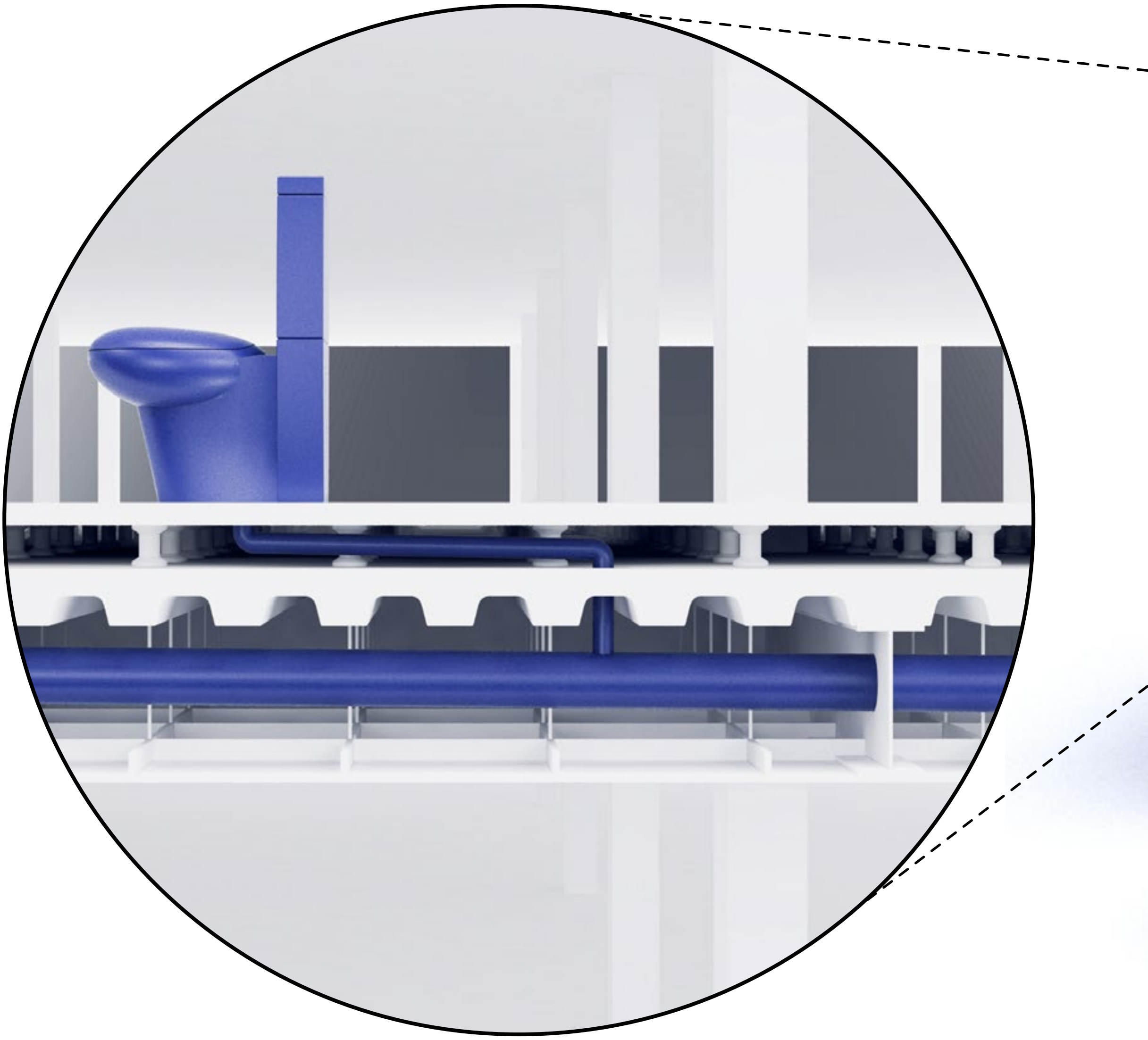
Secondary steel structure

Concrete modular floor panels



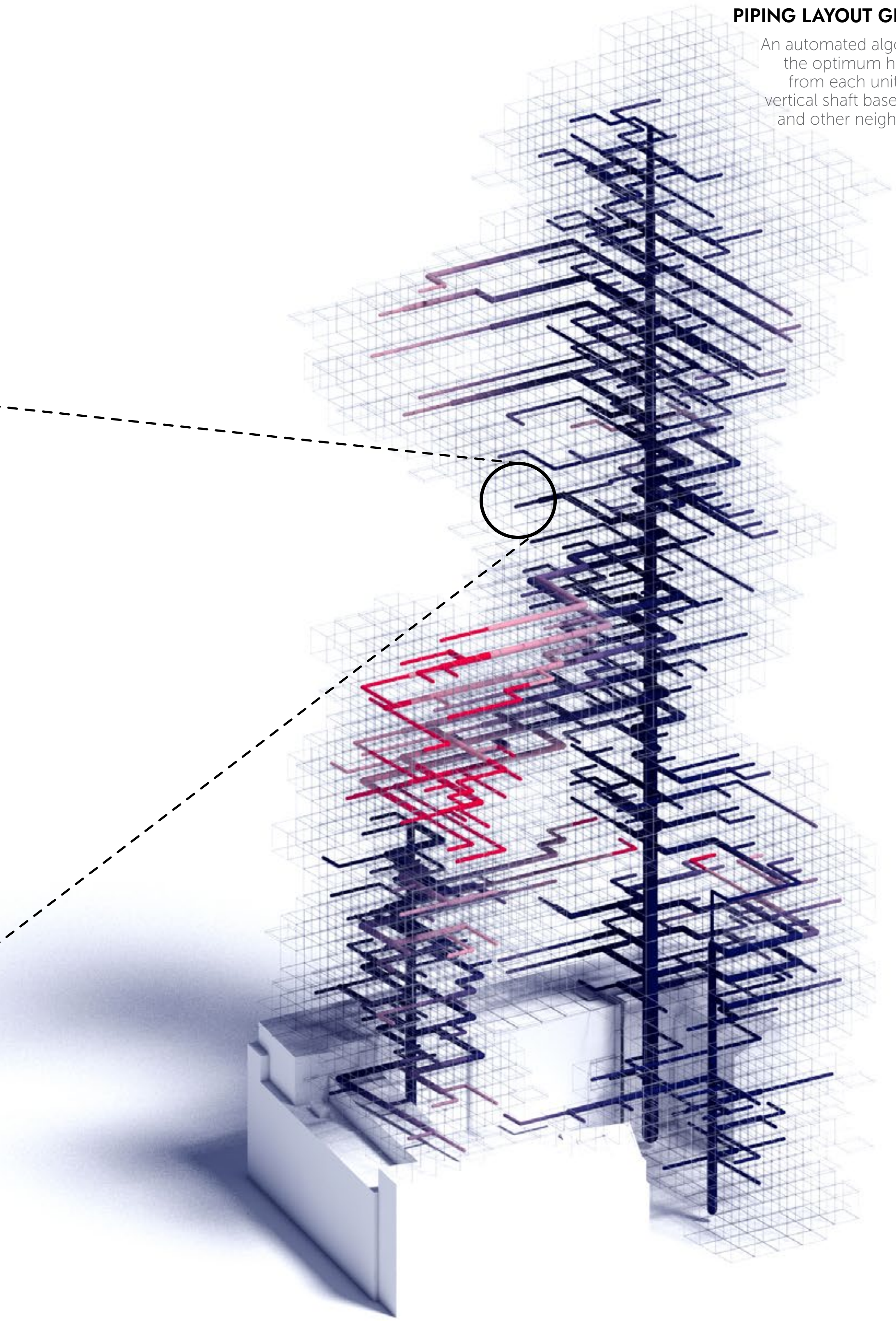
SERVICES

To ease planning of the layout of piping for services such as water, electricity, and wastewater a custom algorithm has bees developed capable of automating this procedure. The software automatically maps the most efficient layout of pipes within the suspended ceiling of the structure thus ensuring the most efficient path to the nearest vertical shaft. The layout is generated by taking into account both the closest distance as well as bundling together pipes from nearby apartments and prefering positioning below the public streets for ease of maintenance. When applied to our building the algorithm shows an area of concern (in red) where the distance to the nearest core is too long due to a core not extending vertically enough to service the area. This issue could be solved by extending only the utility shaft of said core vertically so the distances become adequate.



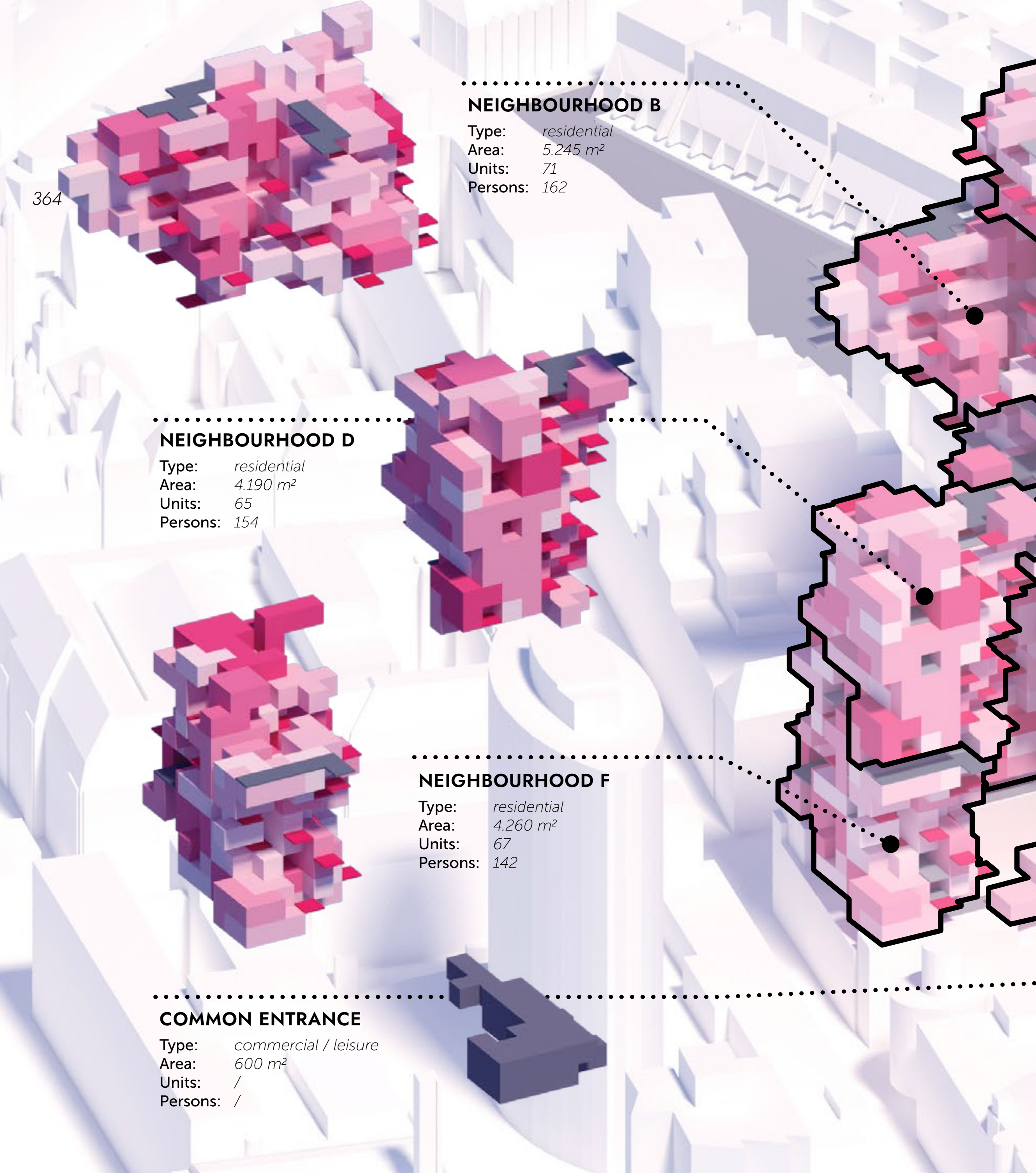
PIPING LAYOUT GENERATION

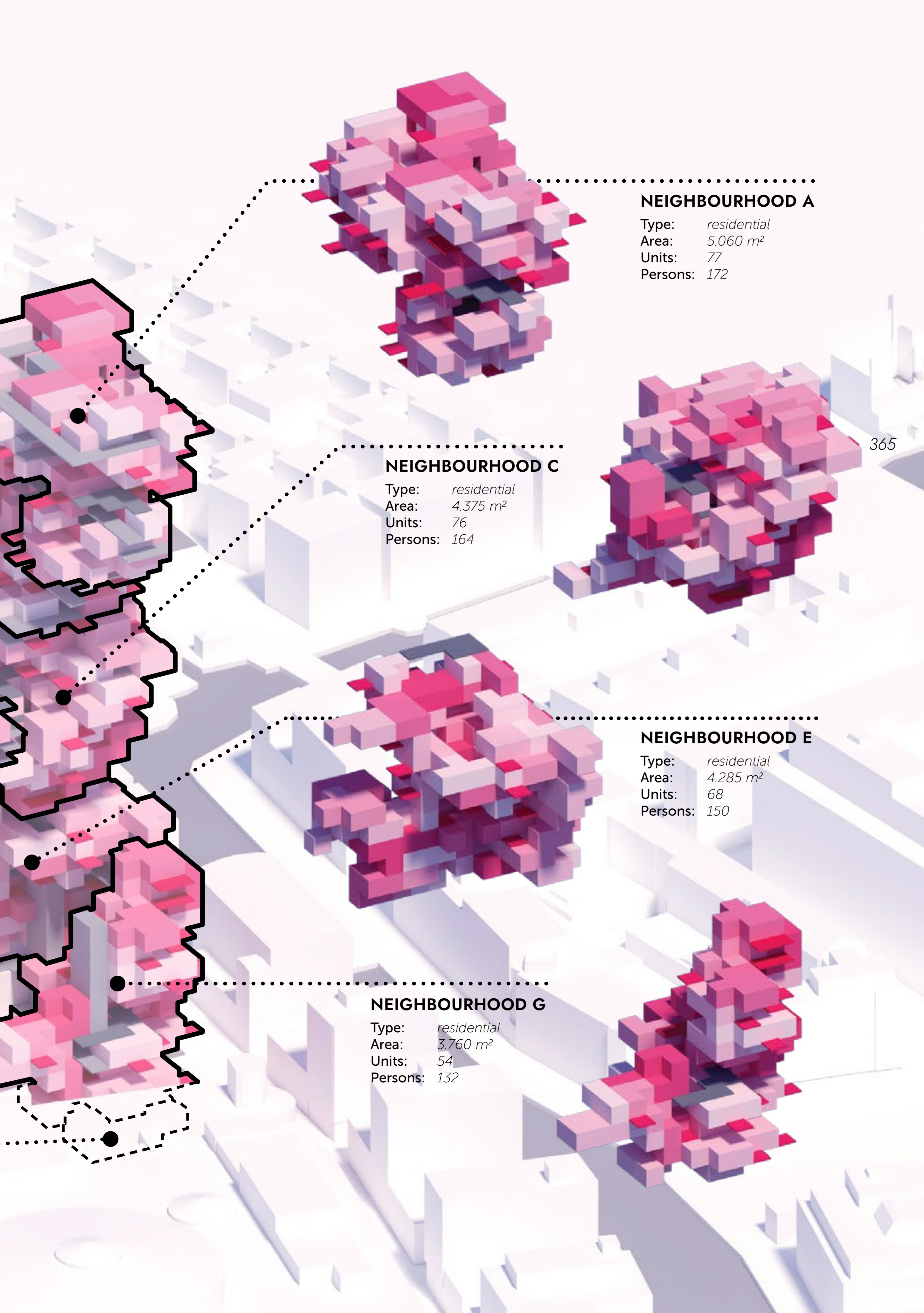
An automated algorithm finding the optimum horizontal path from each unit to its nearest vertical shaft based on distance and other neighbouring units.



ORGANISATION

Due to the size of the buidling - around 50.000 m2 - it is too large to be considered a single organisational entity due to reasons of identity, wayfinding and the sheer number of inhabitants. To segment the building into smaller clusters a statistical approach is utilised where the entire aggregation is divided into neighbourhoods of approximately 150 people, an amount known as the Dunbar number used as a rough estimate of the size of a persons' social circle. While this metric is undoubtedly flawed in some ways it provides a good departure point for the formation of communities and their respecitve spatial borders.




NEIGHBOURHOOD A
Type: residential
Area: 5.060 m²
Units: 77
Persons: 172
NEIGHBOURHOOD C
Type: residential
Area: 4.375 m²
Units: 76
Persons: 164
NEIGHBOURHOOD E
Type: residential
Area: 4.285 m²
Units: 68
Persons: 150
NEIGHBOURHOOD G
Type: residential
Area: 3.760 m²
Units: 54
Persons: 132

FUNCTION

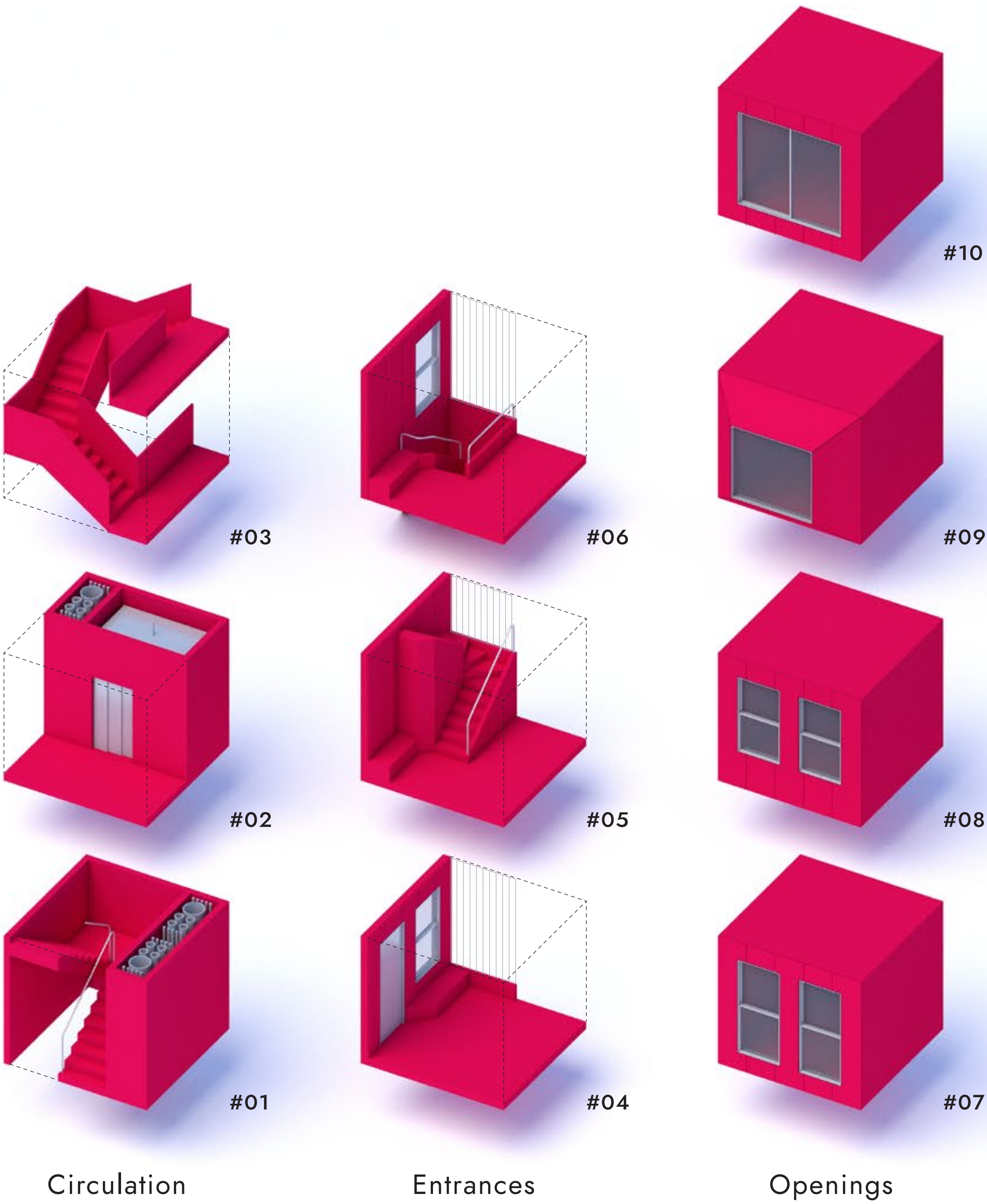
ROTTERDAM FRAGMENTS

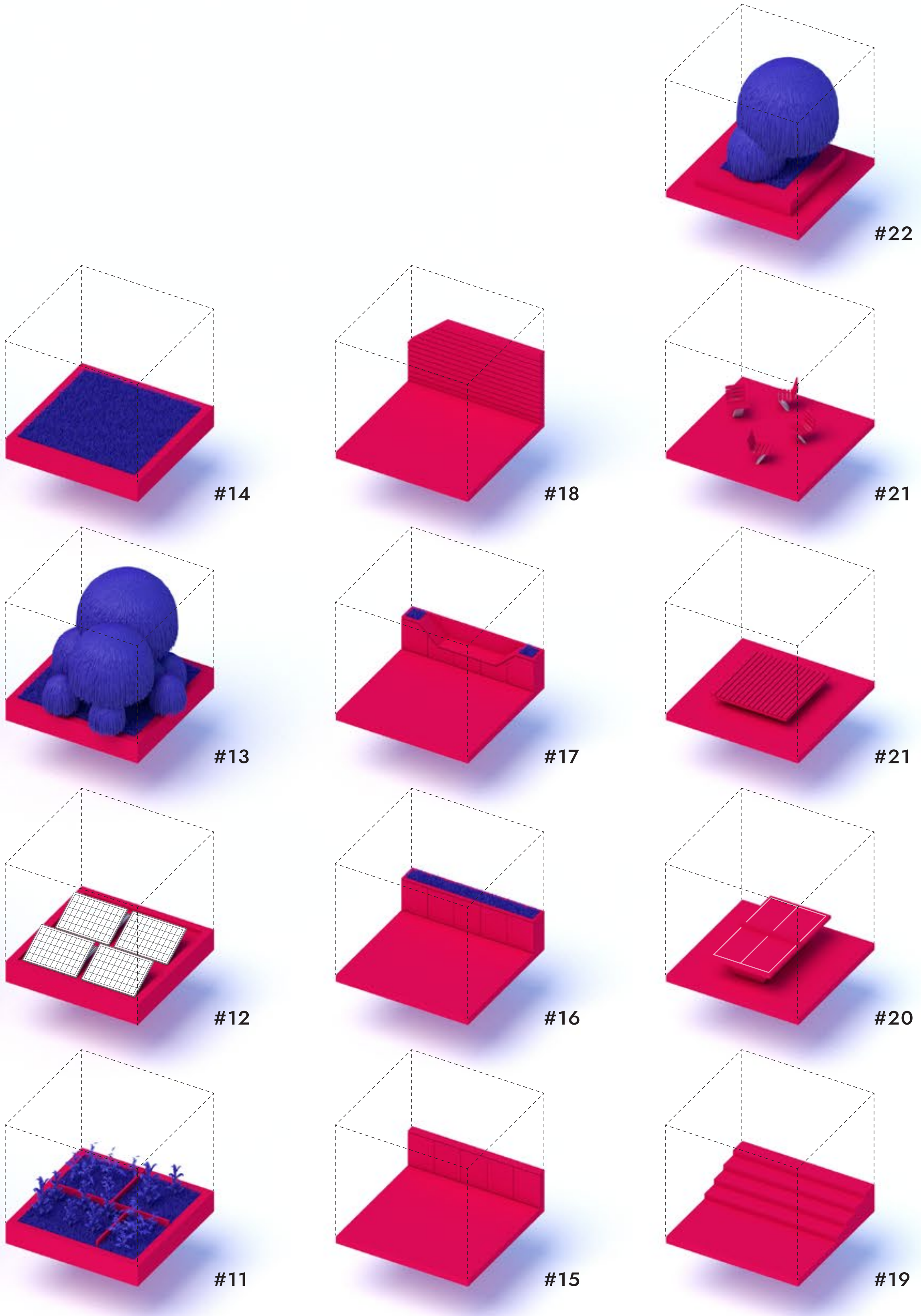
A series of urban space fragments from Rotterdam representing the predominant spatial elements constituting the existing city.

ROTTERDAM FRAGMENTS is a sequence of defining spatial features of Rotterdam and, in addition to describing its dominant characteristics, also acts as the basis for selection and development of new spatial elements for the project. Through the process of abstraction of existing elements a new catalogue of functional modules is created, which attempt to traslate the abstract voxelized aggregation into a true vertical extension of the Rotterdam urban fabric complete with "buildings", squares, streets, urban furniture and vegetation.

URBAN MODULES CATALOGUE

A catalogue of designed urban modules derived from existing characteristics of Rotterdam and used as building blocks in a procedural design process transforming the abstract aggregation into urban space.

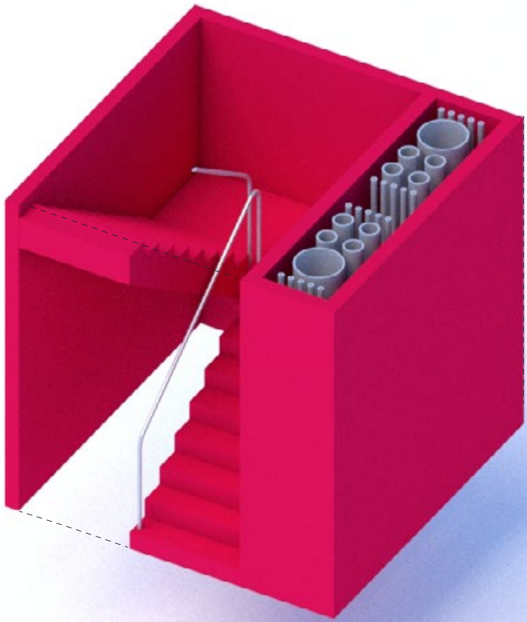




Public terraces

Railings

Common space



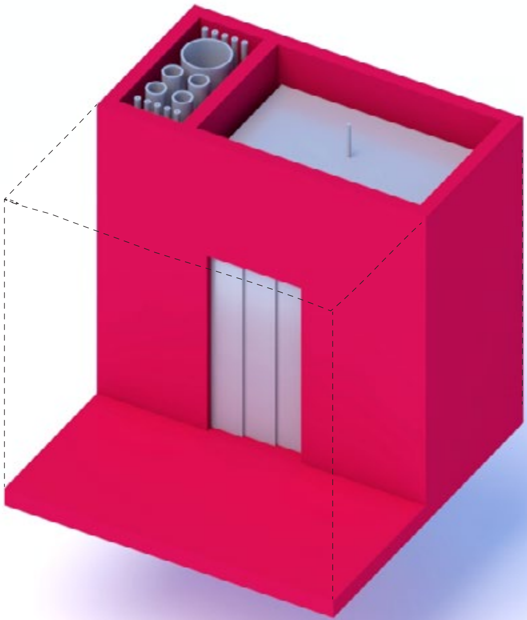
#01 | CORE STAIRS

CATEGORY: *Circulation*

ABOUT: *Primary means of vertical circulation in the building, also acting as a crucial fire-safe emergency exit. Also, a vertical shaft for utility piping such as electricity, water and sewage.*

CONDITIONS:

- *Vertically connected to same module type*
- *Combined with Core Elevator module*



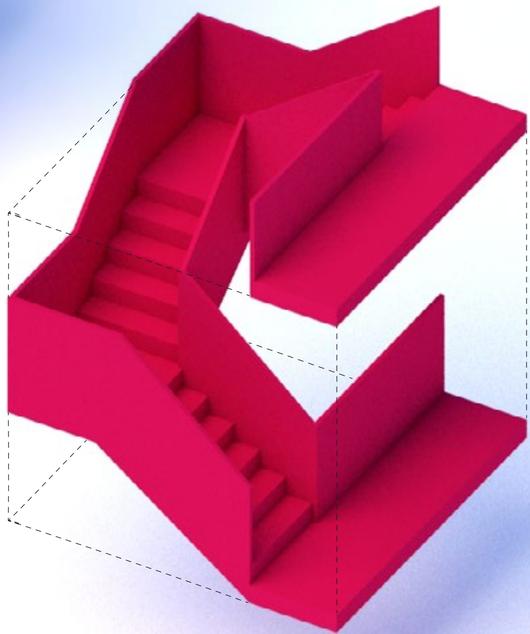
#02 | CORE ELEVATOR

CATEGORY: *Circulation*

ABOUT: *Primary means of vertical circulation in the building, also appropriate for disabled persons. Large dimensions of 2.0 x 1.4 m enable transport of goods and furniture. Also, a vertical shaft for utility piping such as electricity, water and sewage.*

CONDITIONS:

- *Vertically connected to same module type*
- *Combined with Core Stairs module*



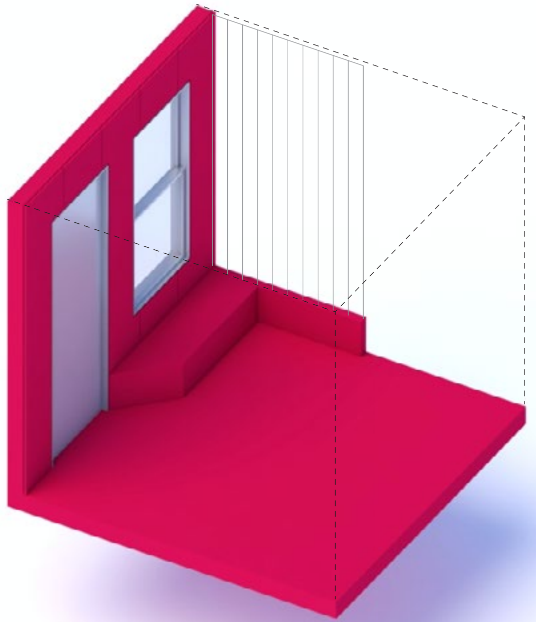
#03 | SECONDARY STAIRS

CATEGORY: *Circulation*

ABOUT: *Secondary vertical circulation applied in cases where the distance to the vertical core is too large for safe escape. Through creating two-way escape routes the secondary stairs also increase connectivity and flexibility in circulation.*

CONDITIONS:

- *Combined with circulation voxel*

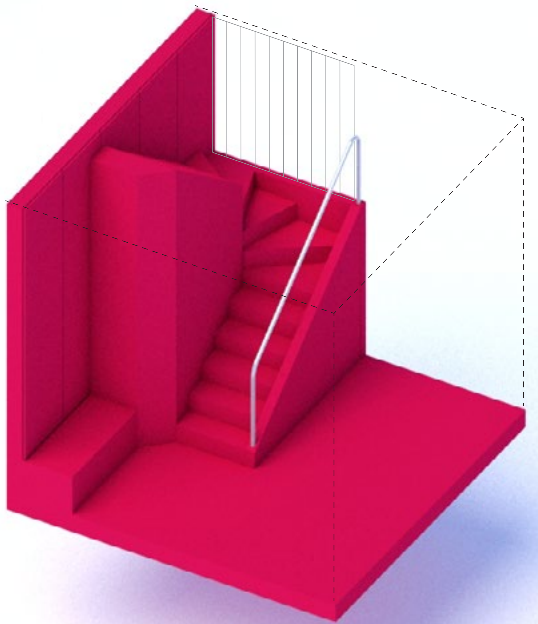


#04 | STREET ENTRANCE

CATEGORY: *Entrances*

ABOUT: *Derived from traditional row houses in which every unit has a direct entrance to the public street. Its immediate vicinity is considered an extension of the unit; a space to be occupied and approapriated with seating, plants and more.*

CONDITIONS:
- *Maximum one per unit*
- *Combined with circulation voxel*

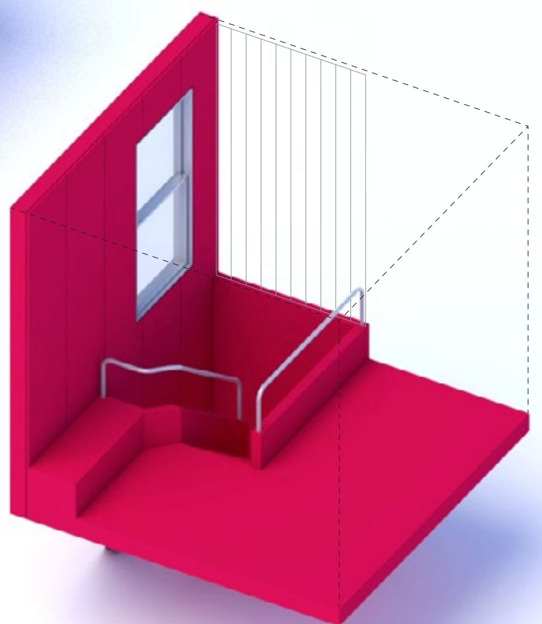


#05 | STOOP ENTR. UP

CATEGORY: *Entrances*

ABOUT: *Inspired by the traditional Dutch stoop present in a large number of row houses, this entrance area combining stairs and an area for sitting creates a semi-private zone increasing the possibilty for appropriation by occupants.*

CONDITIONS:
- *Maximum one per unit*
- *Combined with circulation voxel*



#06 | STOOP ENTR. DOWN

CATEGORY: *Entrances*

ABOUT: *Inspired by the traditional Dutch stoop present in a large number of row houses, this entrance area combining stairs and an area for sitting creates a semi-private zone increasing the possibilty for appropriation by occupants.*

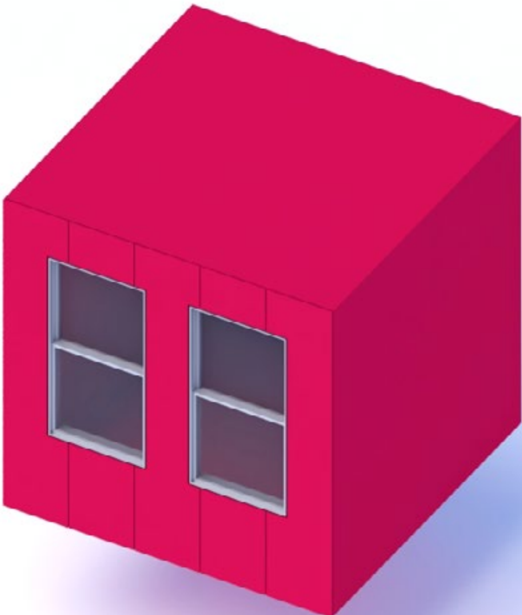
CONDITIONS:
- *Maximum one per unit*
- *Combined with circulation voxel*

#07 | TRAD. WINDOW

CATEGORY: *Openings*

ABOUT: *Modeled after traditional Dutch row house windows with a large height-to-width ratio to maximise the daylighting depth. These qualities are emphasised in this floor to ceiling version which maximises the connection to exterior.*

CONDITIONS:
- Where other window types are not possible
- When facing an empty voxel.

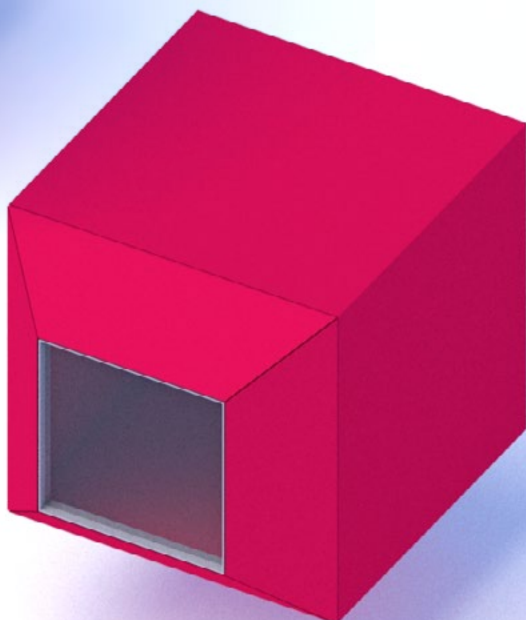


#08 | STREET WINDOW

CATEGORY: *Openings*

ABOUT: *Modeled after traditional Dutch row house windows with a large height-to-width ratio to maximise the daylighting depth. This smaller version is specifically designed for positioning next to circulation streets to limit privacy conflicts as well as positioning of bench elements on its exterior side.*

CONDITIONS:
- Where other window types are not possible
- When facing directly a circulation voxel.



#09 | BAY WINDOW

CATEGORY: *Openings*

ABOUT: *A reinterpretation of the typical row house bay window, once acting as a symbol of wealth and prosperity. It acts as a focal point of a unit's identity and extends its interior space outwards.*

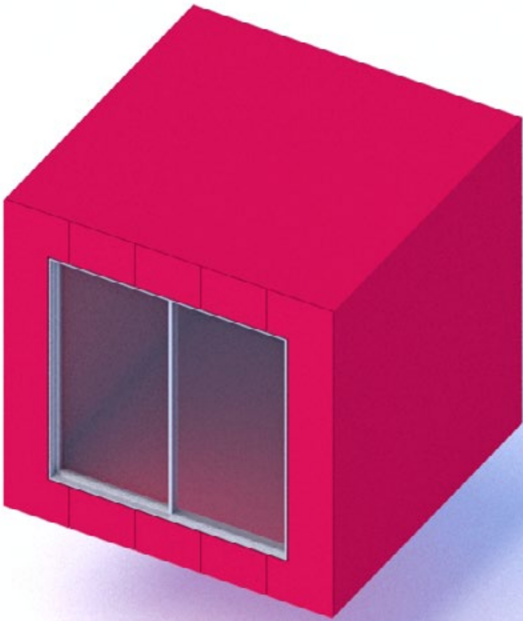
CONDITIONS:
- Maximum one per unit
- Its neighbour voxel must not be occupied
- Neighbour voxel is not circulation

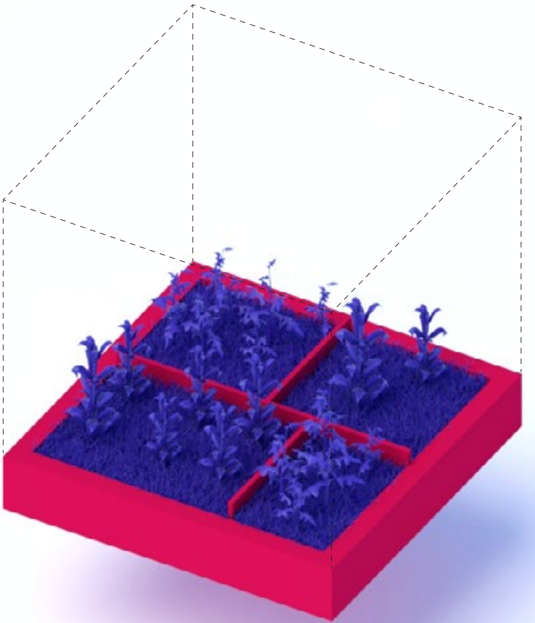
#10 | LARGE WINDOW

CATEGORY: *Openings*

ABOUT: *A translation of the large, often north-facing windows in modern Dutch housing. Maximises view and valuable sunlight at the cost of privacy, eliminated by its positioning rules. Can be transformed to a french balcony.*

CONDITIONS:
- *Neighbour voxel is not circulation*
- *No privacy conflicts on this facade*
- *Maximum of 2 hours of sun*





#11 | COMMUNITY GARDEN

CATEGORY: *Public terraces*

ABOUT: *Community gardens are intended for small-scale local food production, also acting as social generators, water management and retention systems, improving insulation and creating pleasant microclimates.*

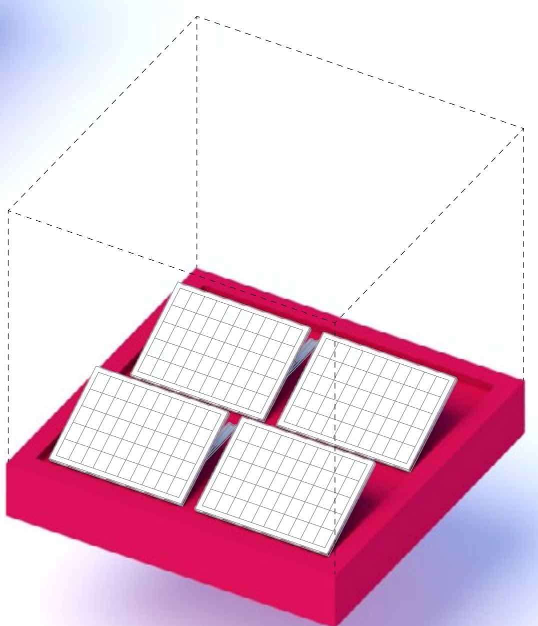
CONDITIONS:
- *Rooftop must be accessible from circulation.*
- *Minimum 3 hours sunlight*
- *Roof must have rainwater access*

#12 | SOLAR COLLECTOR

CATEGORY: *Public terraces*

ABOUT: *Collectors in the form of solar PV-panels or solar thermal panels occupy the best-sunlit rooftops of the building and act as a source of renewable energy while putting excess porosity to good use.*

CONDITIONS:
- *Minimum 5 hours of direct sunlight daily*
- *Maximum 20% of total rooftops*

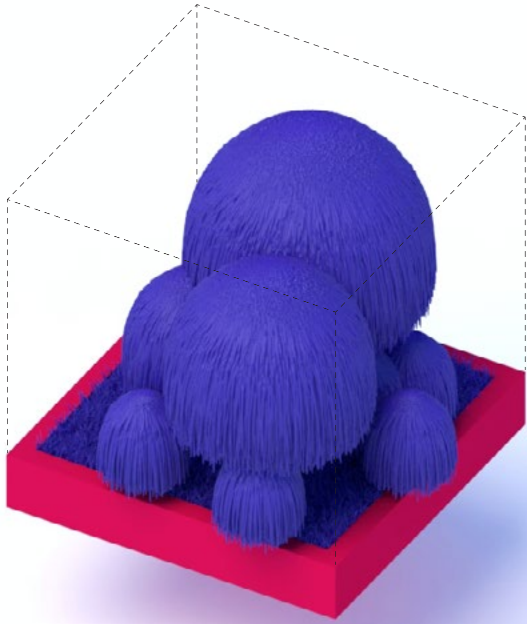


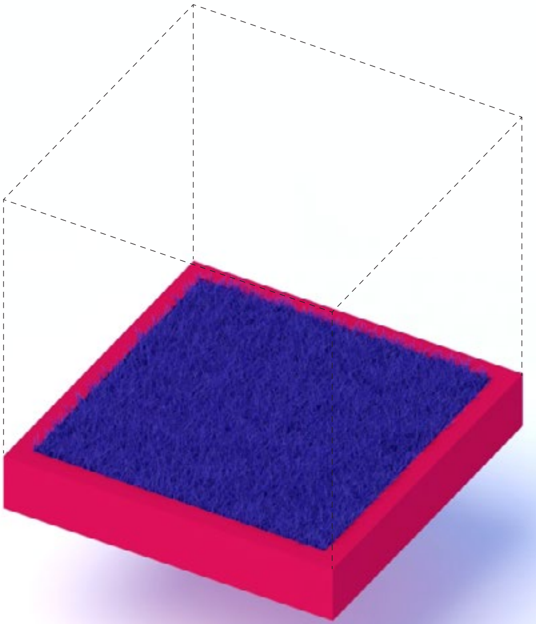
#13 | URBAN GARDEN

CATEGORY: *Public terraces*

ABOUT: *Urban gardens through their introduction of vegetation improve microclimate conditions while simultaneously acting as water collectors which can be used for plant watering or in-building use such as toilets or similar applications.*

CONDITIONS:
- *Minimum 3 hours sunlight*
- *Roof must have rainwater access*
- *Minimum 2 voxels height above rooftop*





#14 | GREEN ROOF

CATEGORY: *Public terraces*

ABOUT: *Green roofs occupy all residual roof spaces where other uses are not possible. By being covered with low-maintanence extensive vegetation they reduce the urban heat island effect, improve thermal insulation properties of the roof as well as acting as water collectors appropriate for various in-building uses.*

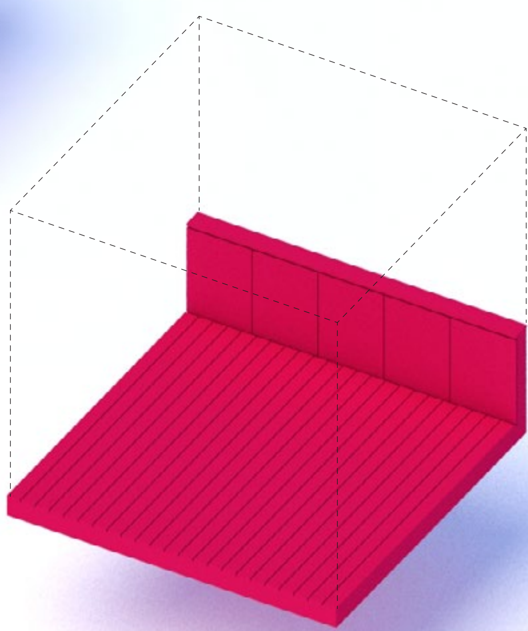
CONDITIONS:
- *Where no other roof types are possible*

#15 | TERRACE FENCE

CATEGORY: *Railings*

ABOUT: *The basic terrace fence is an efficient thin railing maximising space flexibility of private terraces while ensuring safety.*

CONDITIONS:
- *On edge of private unit terraces*

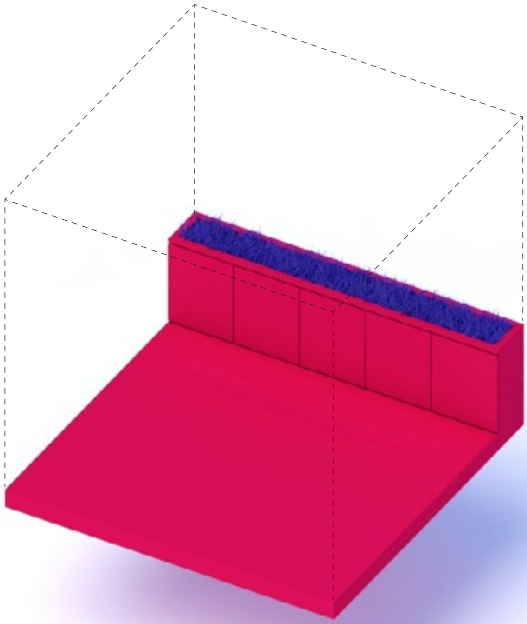


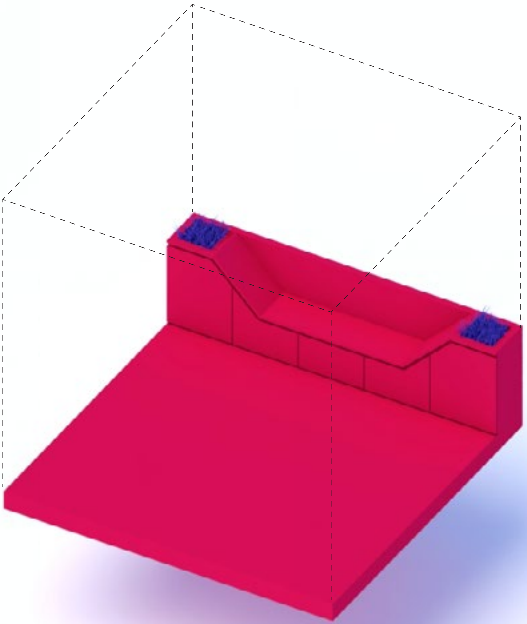
#16 | STREET PLANTER

CATEGORY: *Railings*

ABOUT: *A translation of urban planters often present in Dutch cities to the street in the sky. By combining a railing with a planter, safety is increased due to its increased width while additional value is brought by an element of nature otherwise absent in high-rise buildings.*

CONDITIONS:
- *Edges of public circulation streets and common squares*





#17 | STREET BENCH

CATEGORY: *Railings*

ABOUT: *Seating is a crucial element of urban furniture in any space. By being combined with a railing throughout the length of circulation streets, pockets of sociable spaces are created where residents and visitor can sit, talk, enjoy the view as well as the life passing by on the street.*

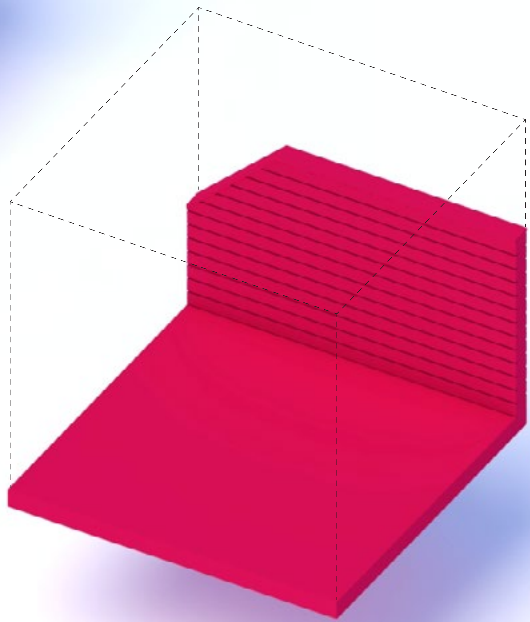
CONDITIONS:
- *Edges of public circulation streets and common squares*

#18 | PRIVACY BARRIER

CATEGORY: *Railings*

ABOUT: *The privacy barrier is a high fence intended to reduce privacy conflicts between exterior terraces while limiting views as less as possible. Due to its light wooden composition it is easily removable in cases of reprogramming*

CONDITIONS:
- *On edges between a private terrace and another occupied space (street/square/another private terrace)*

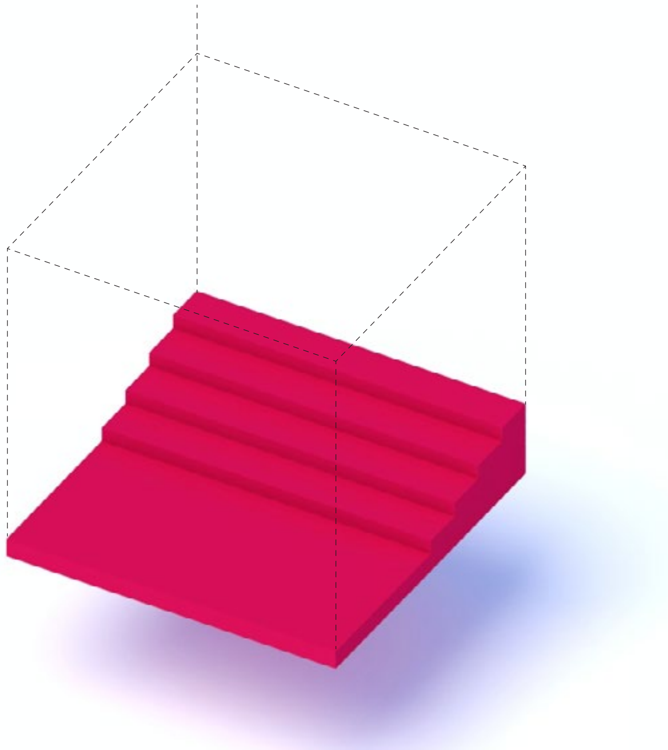


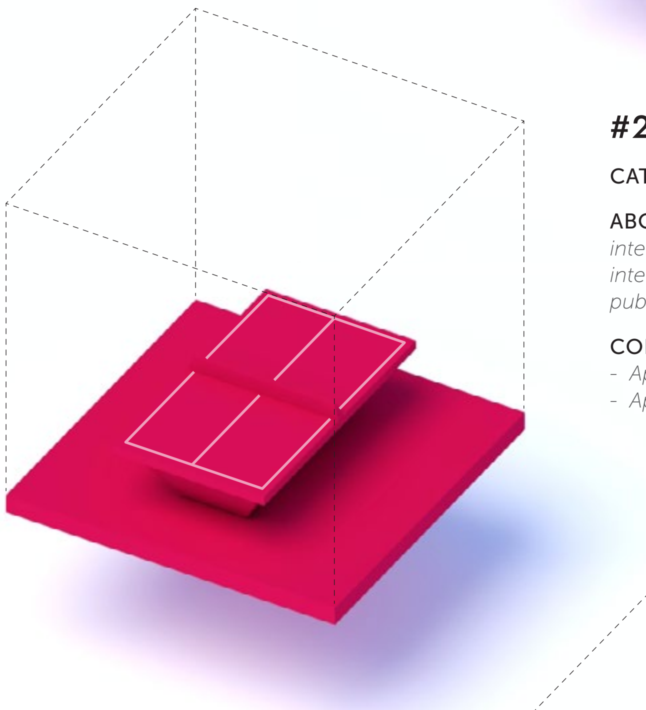
#19 | TRIBUNES

CATEGORY: *Common spaces*

ABOUT: *An urban furniture element intended to foster appropriation, social interaction and encourage diverse use of public spaces.*

CONDITIONS:
- *Applied to public common squares*
- *Applied to ground floor public courtyard*





#20 | TABLE TENNIS

CATEGORY: *Common spaces*

ABOUT: *An urban furniture element intended to foster appropriation, social interaction and encourage diverse use of public spaces.*

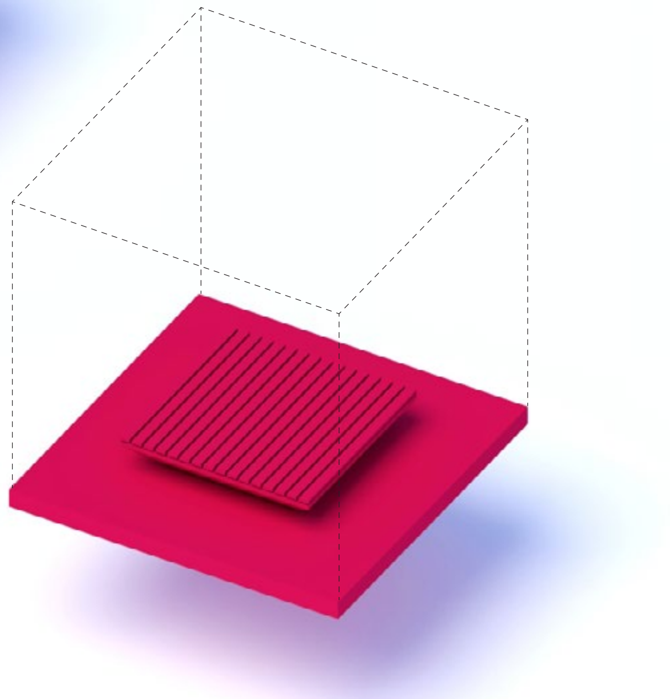
CONDITIONS:
- *Applied to public common squares*
- *Applied to ground floor public courtyard*

#21 | PLATFORM BENCH

CATEGORY: *Common spaces*

ABOUT: *An urban furniture element intended to foster appropriation, social interaction and encourage diverse use of public spaces.*

CONDITIONS:
- *Applied to public common squares*
- *Applied to ground floor public courtyard*



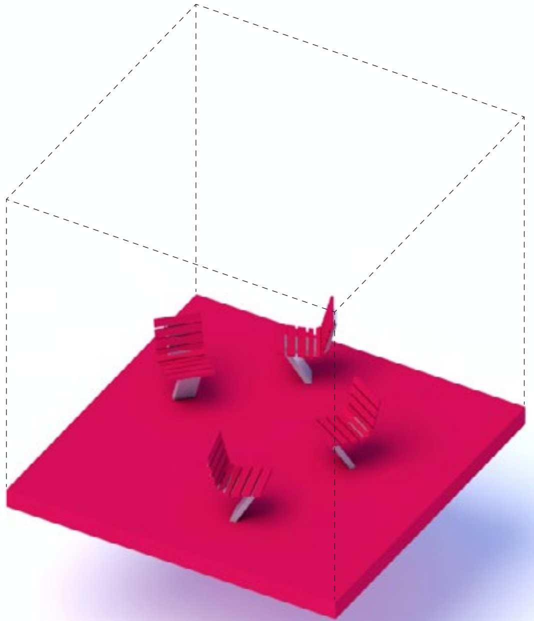
#22 | ROTTERDAM CHAIRS

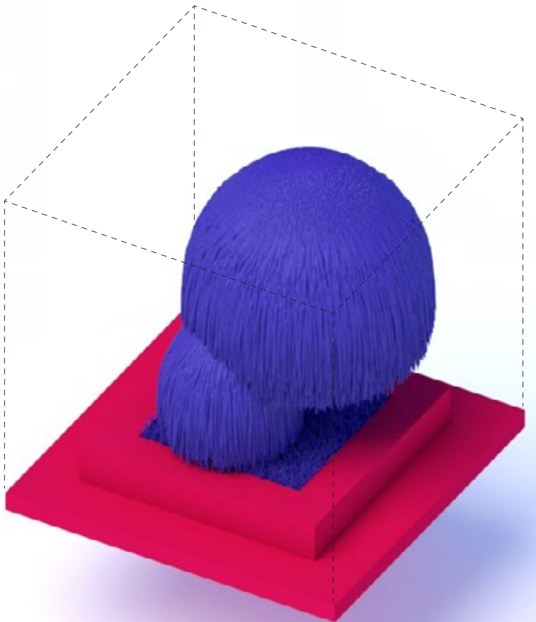
CATEGORY: *Common spaces*

ABOUT: *A distinct feature of urban furniture in Rotterdam, the swiveling chairs are a playful element providing seating in public space settings.*

CONDITIONS:

- *Applied to public common squares*
- *Applied to ground floor public courtyard*





#23 | GARDEN BENCH

CATEGORY: *Common spaces*

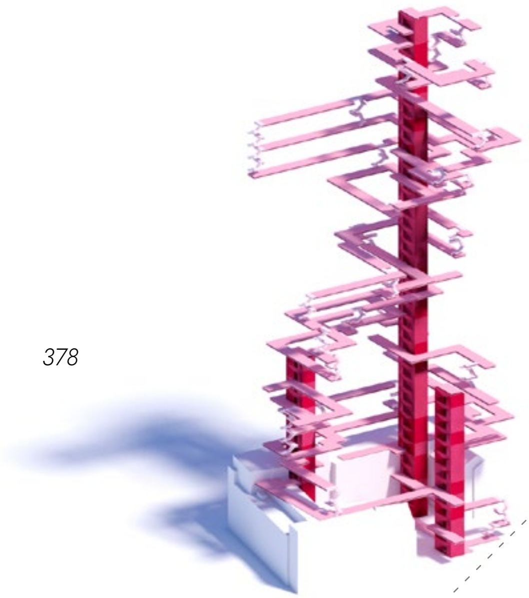
ABOUT: *An urban furniture element intended to foster appropriation, social interaction and encourage diverse use of public spaces.*

CONDITIONS:

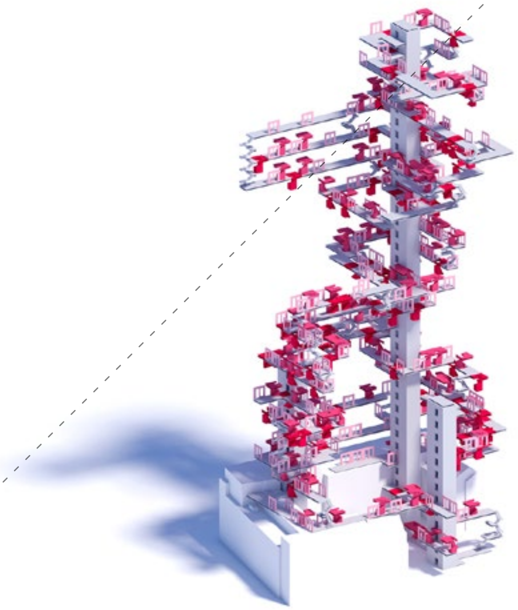
- *Applied to public common squares*
- *Applied to ground floor public courtyard*

PROCEDURAL DESIGN

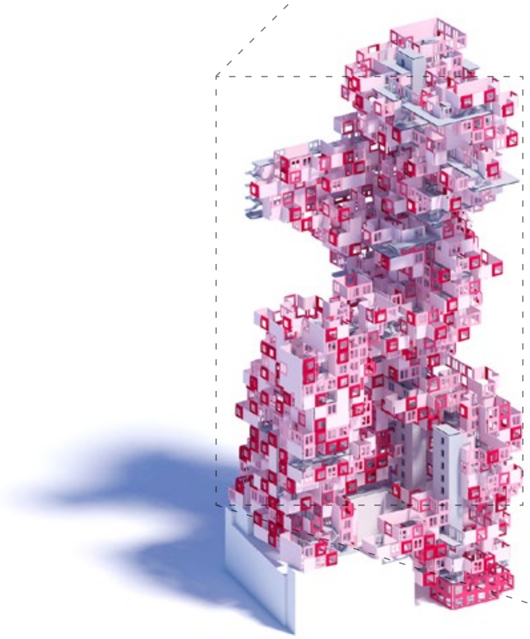
Based on the earlier analysis of spatial conditions the modular elements are procedurally assigned accross the structure according to individually defined rules. Continued on next page.



1. Circulation modules

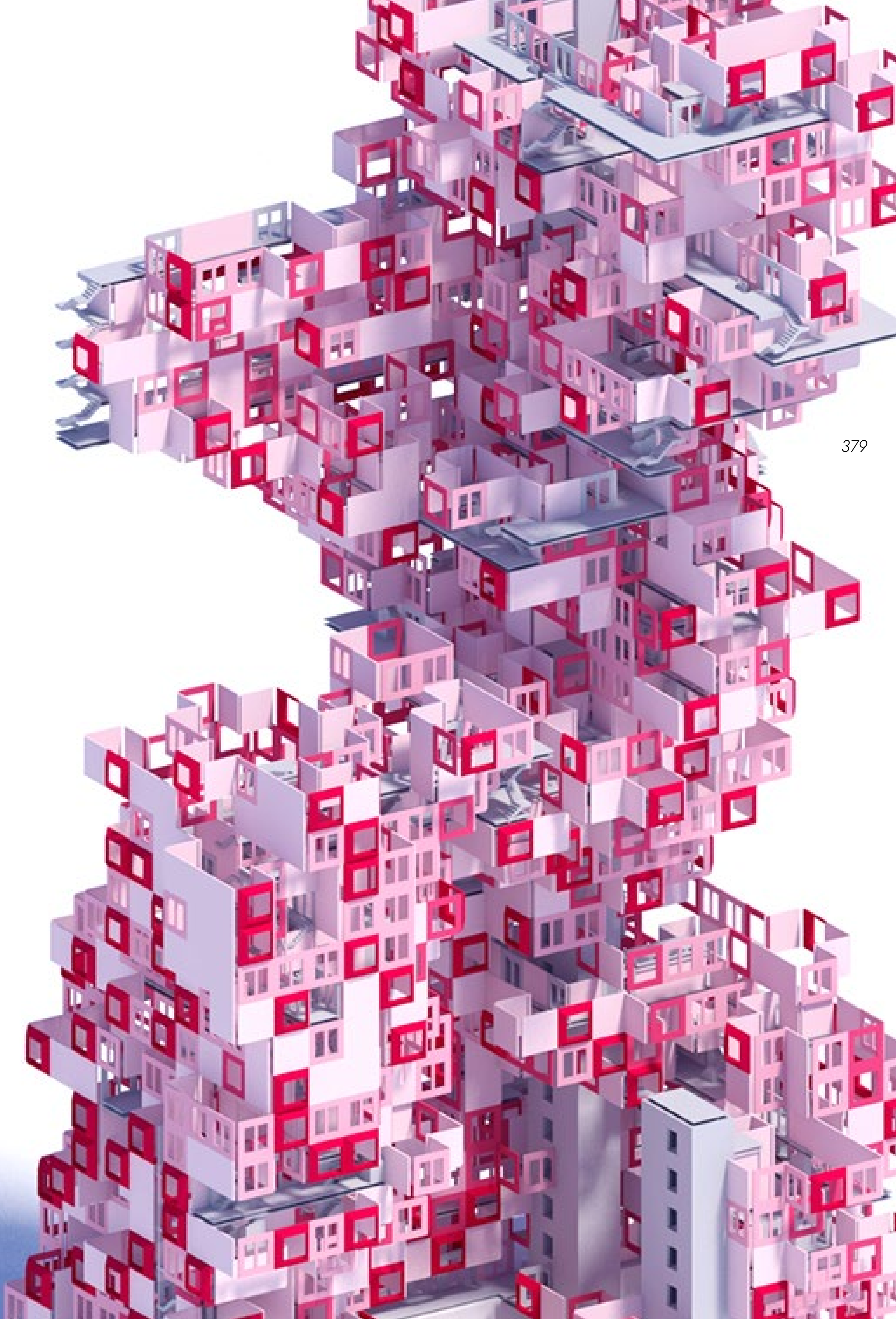


2. Entrance modules



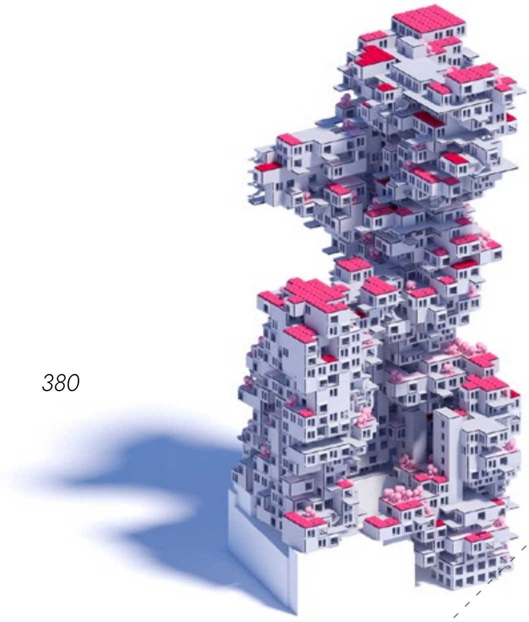
3. Window modules

4. Floors & interior walls

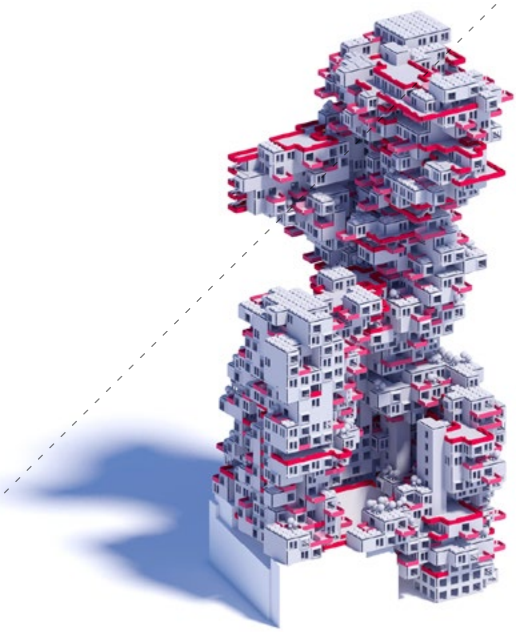


PROCEDURAL DESIGN

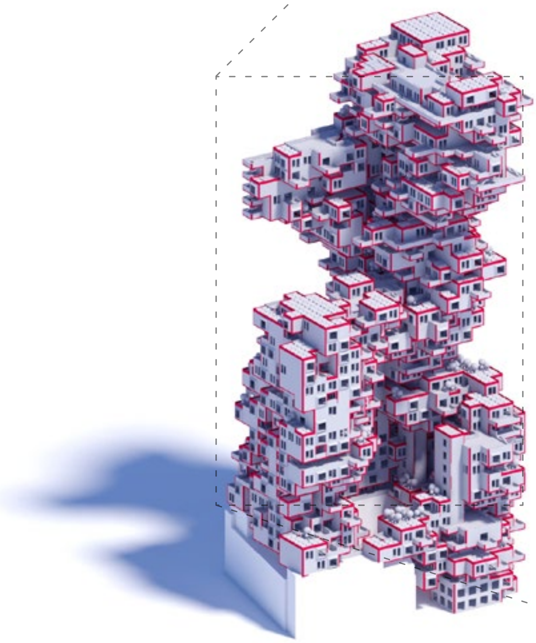
Based on the earlier analysis of spatial conditions the modular elements are procedurally assigned accross the structure according to individually defined rules.



5. Exterior space modules

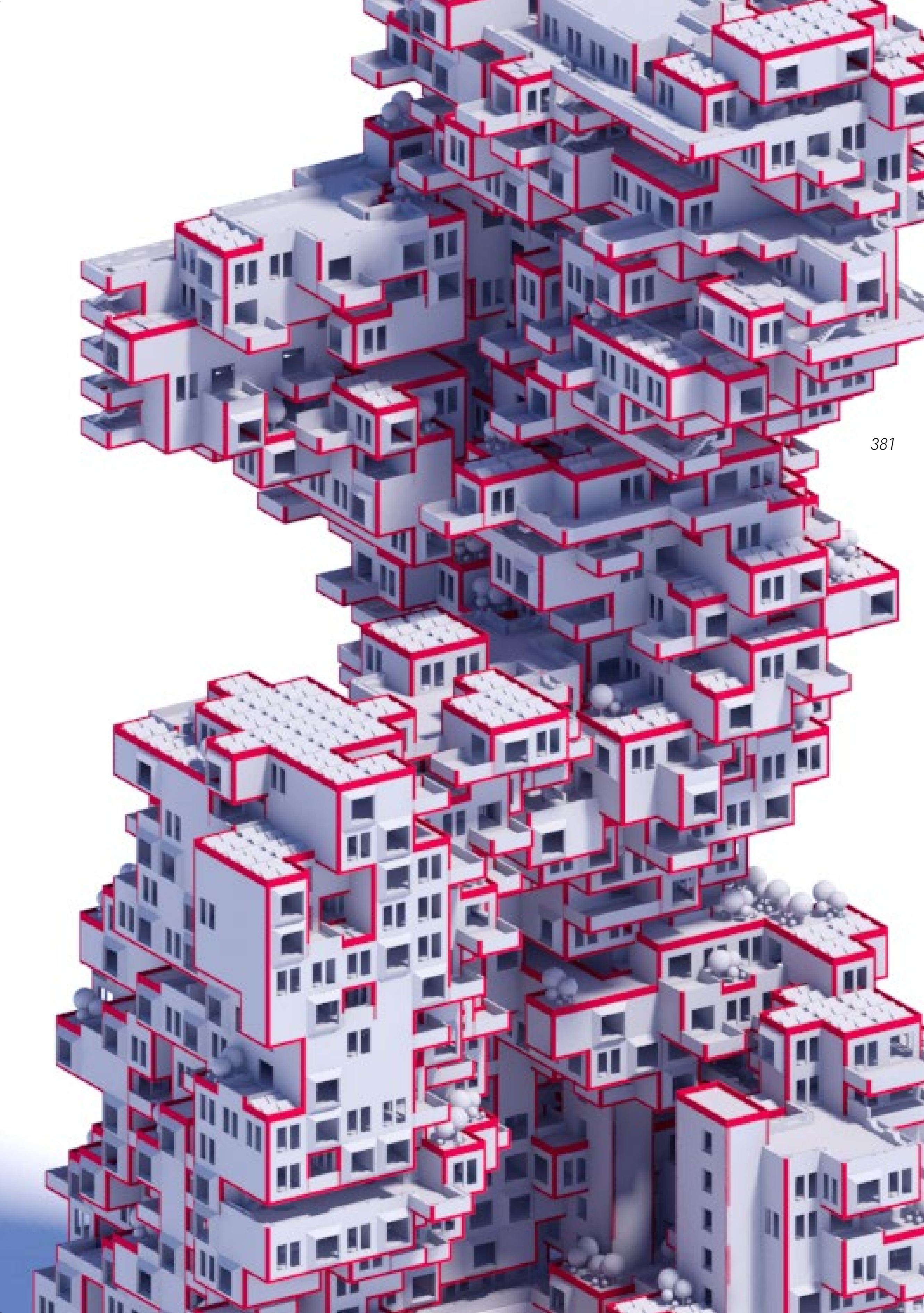


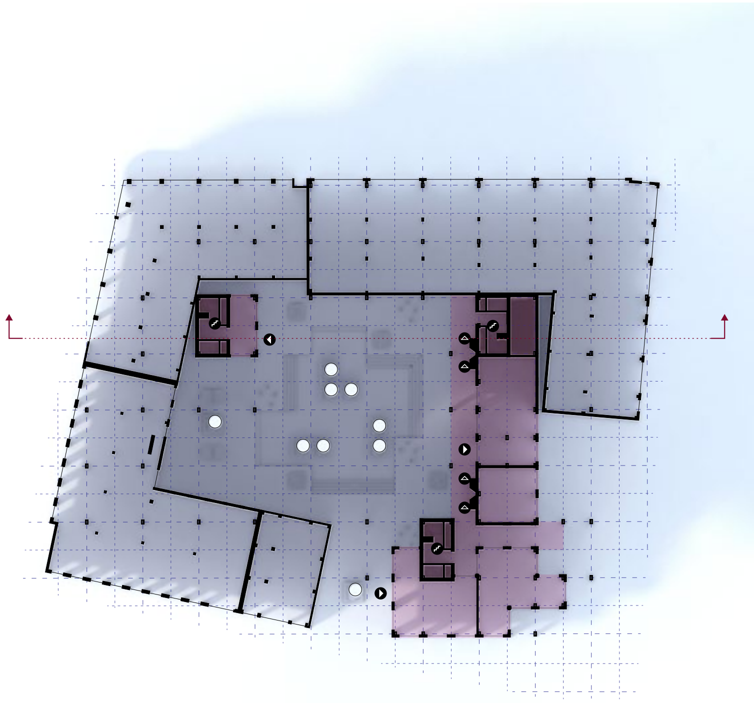
6. Fence modules



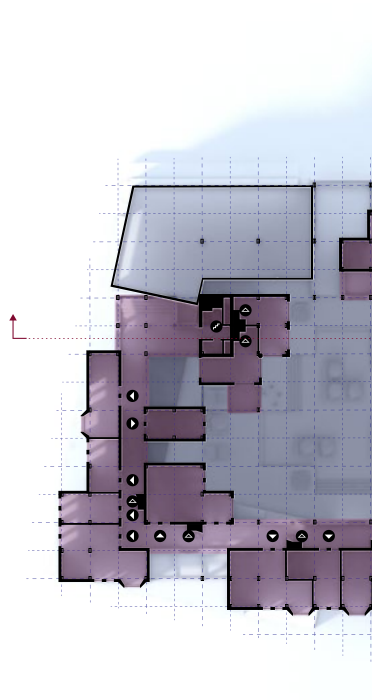
7. Facade corner details

8. Completed building



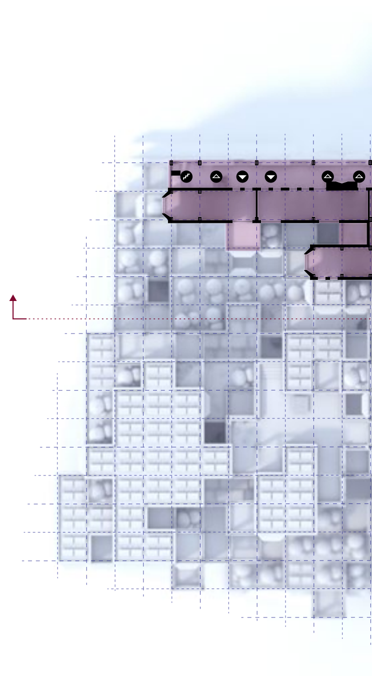


Plan | floor #0

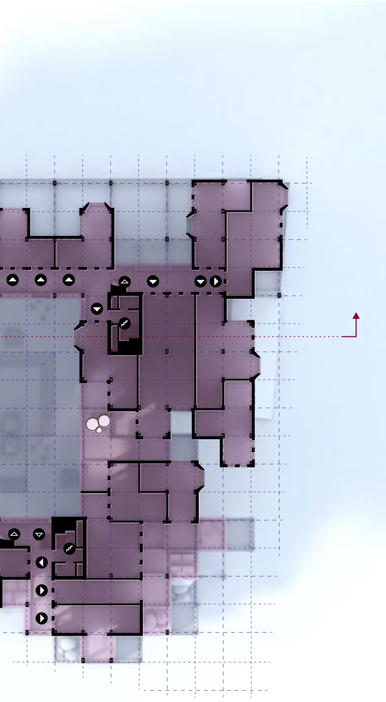


Plan | f

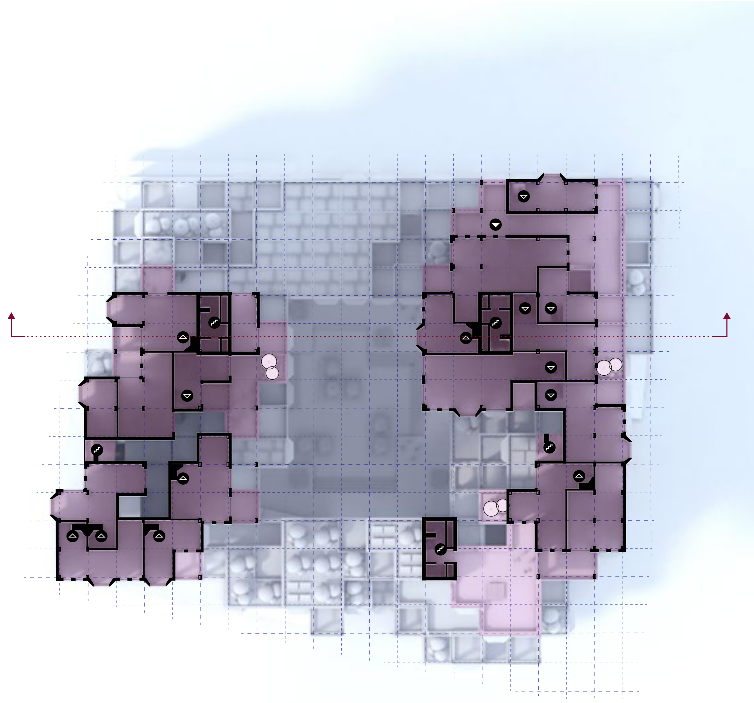
Plan | floor #23



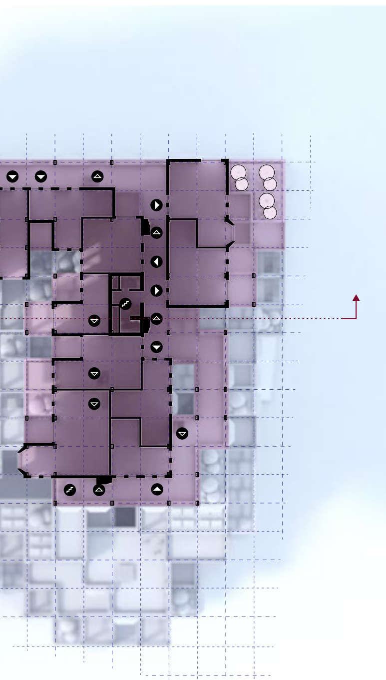
Plan | fl



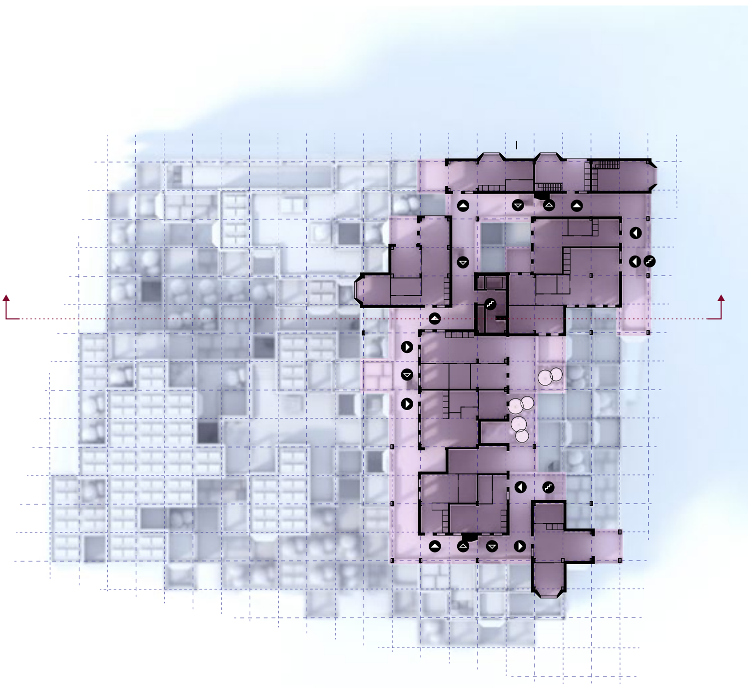
loor #7



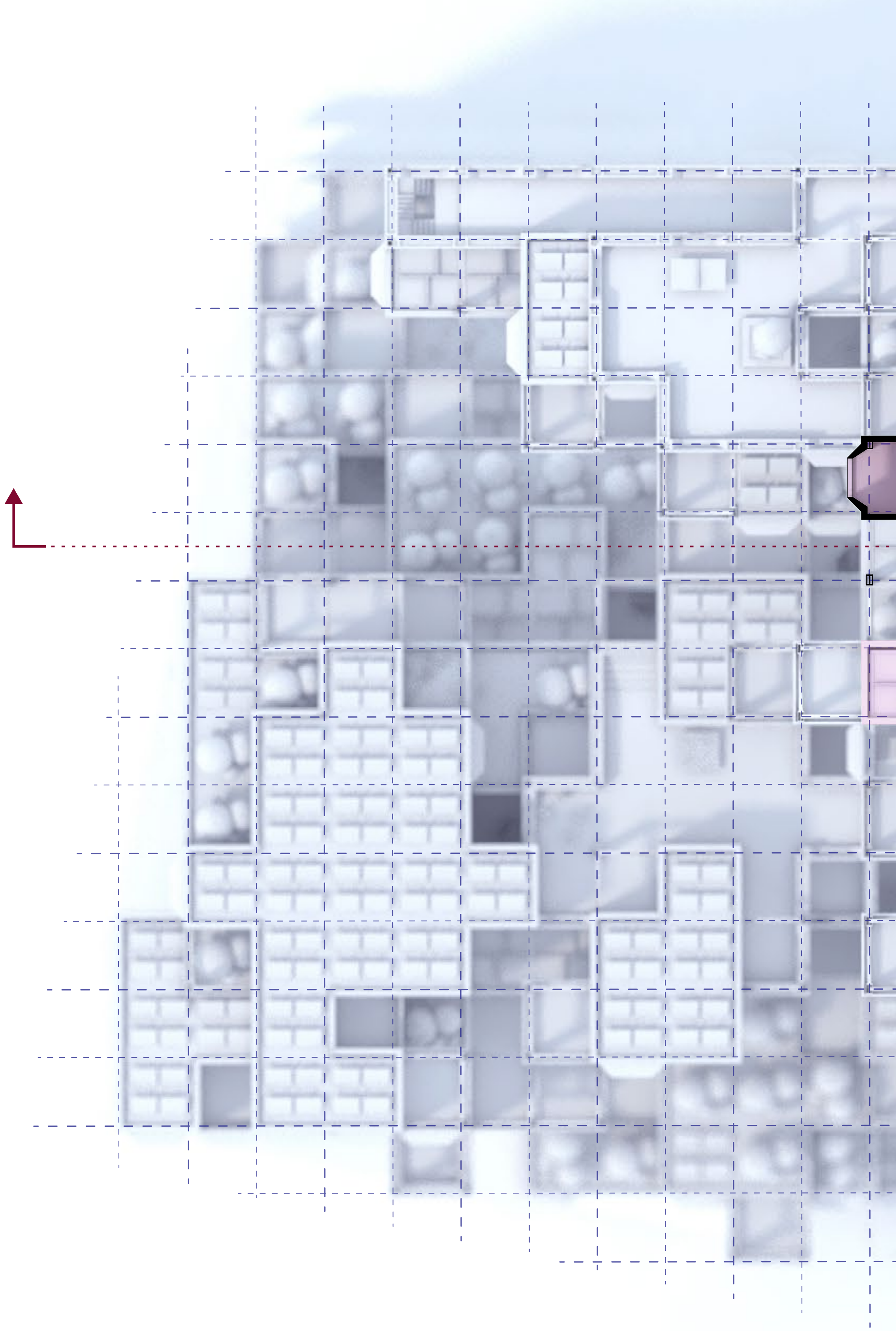
Plan | floor #13



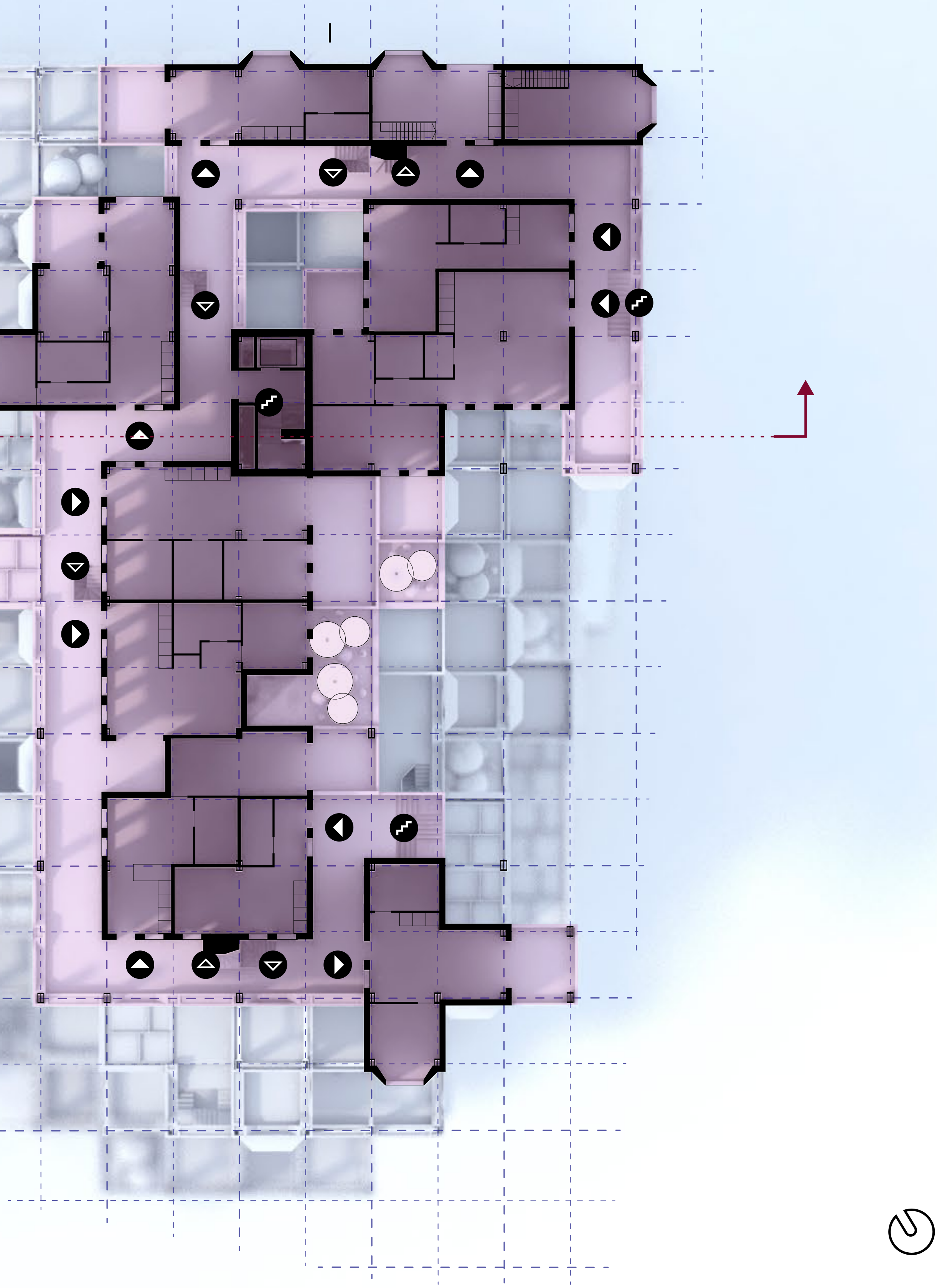
oor #31

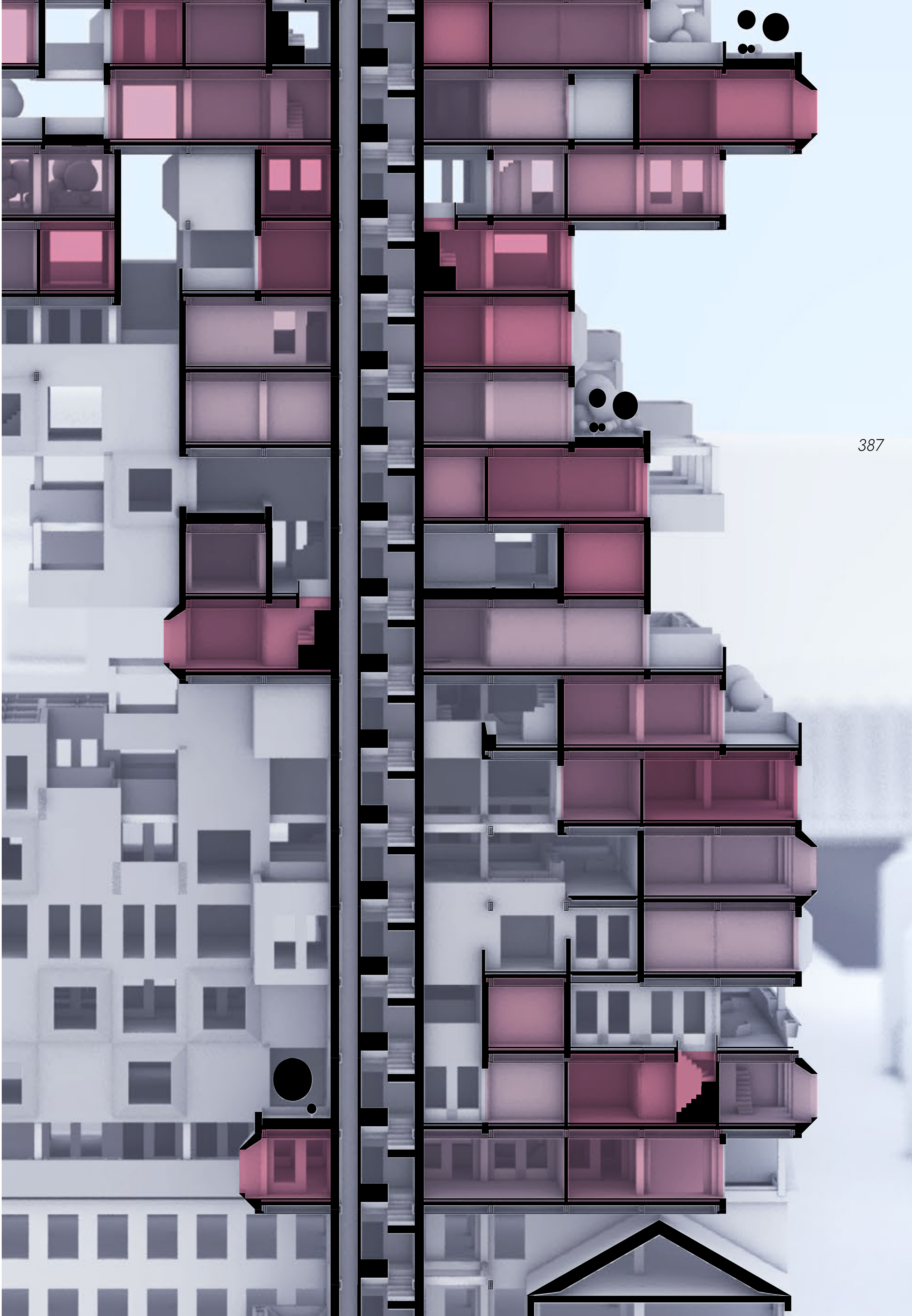


Plan | floor #39

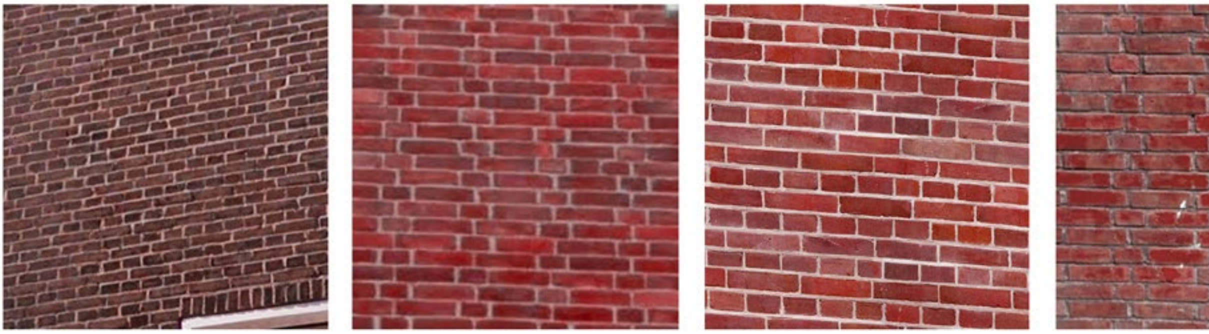


Floor plan | Ground floor | 1:250

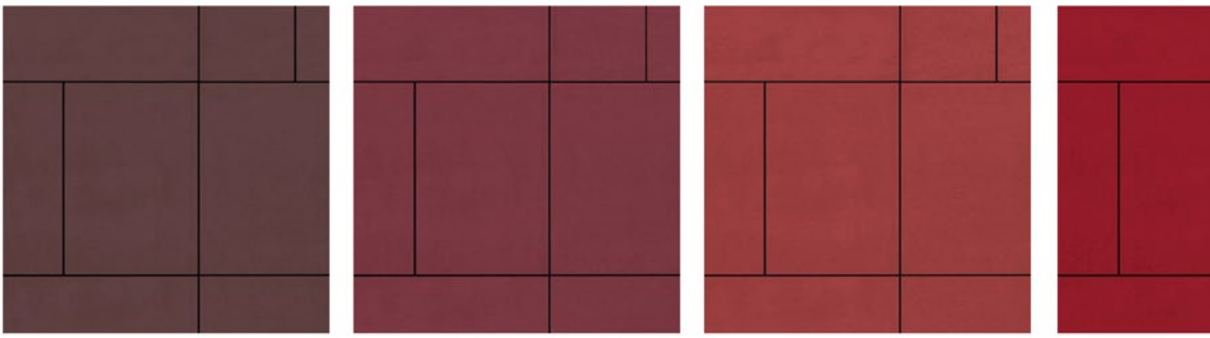




MATERIALITY



90	121	155	15
58	54	60	6
63	59	62	8



BRICKS are a defining material of Rotterdam and Dutch urban space and architecture in general. They are often present in many variations of color, size and pattern and can differ from building to building helping to establish a sense of place and identity. These qualities inspired an analysis of the surrounding brick patterns on Meent and their translation into both an appropriate facade material and its color. The chosen material is fiber-cement facade panels which in addition to posessing similar visual qualities of heaviness and solidity like brick also bring many other benefits such as a wide array of color tones, a minimalist aesthetic, light weight, ease of installation and replacement, possibility of a ventilated facade, modular assembly and low cost. As such they are used as an abstract equivalent of the all-present brick which is the defining feature of the area.

IDENTITY

To imrpove identity and legibility of the building the organisational clusters defined in the beginning are transformed into distinct neighbourhoods each with its own specific colour. These colours are then variated between adjacent units to ensure legibility and identity of each individual unit, whilst maintaining the coherenc of each neighbourhood as a whole.

Differentiated public spaces
Circulation and common spaces in raw concrete

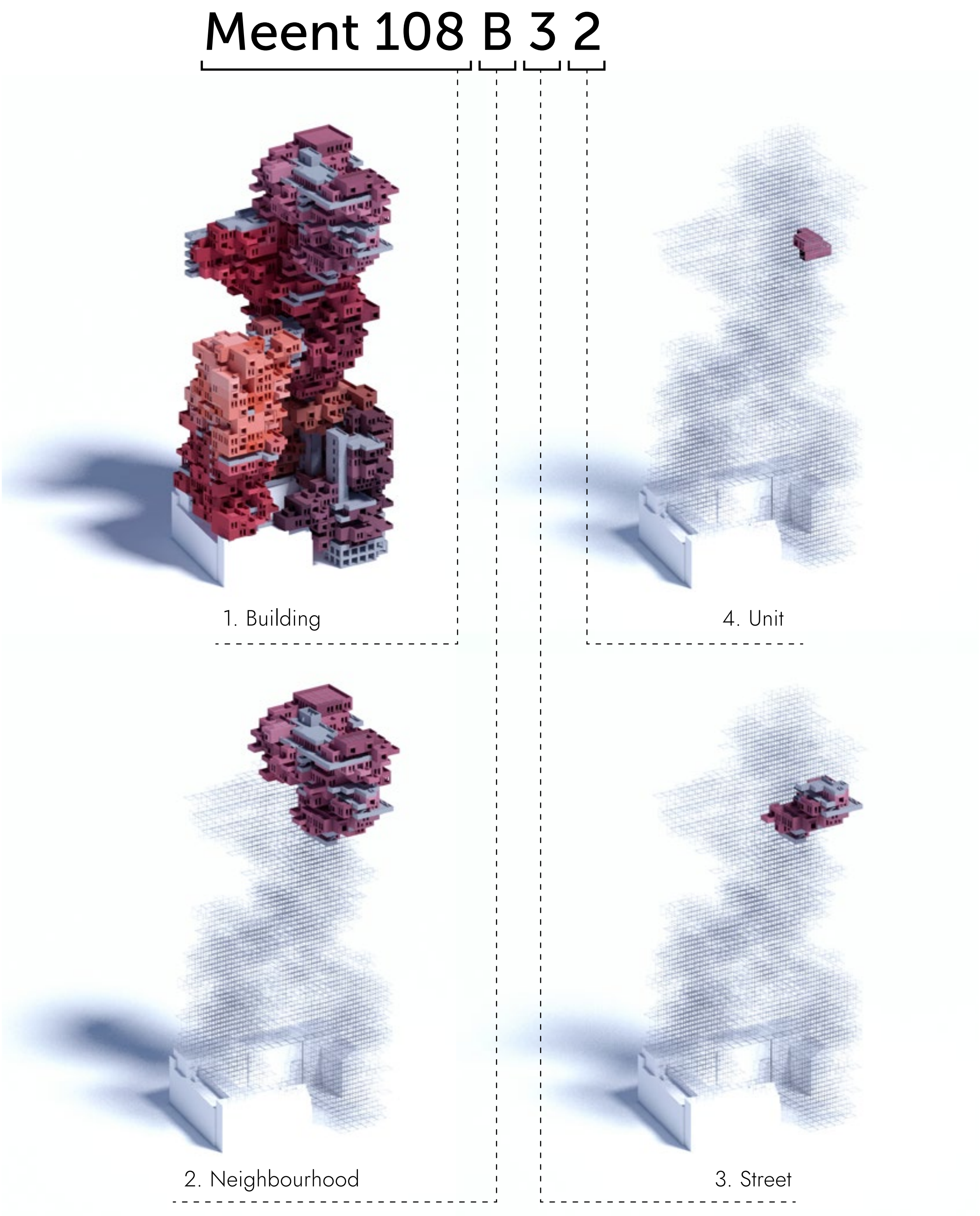
Private units; global identity
Seven residential clusters rep

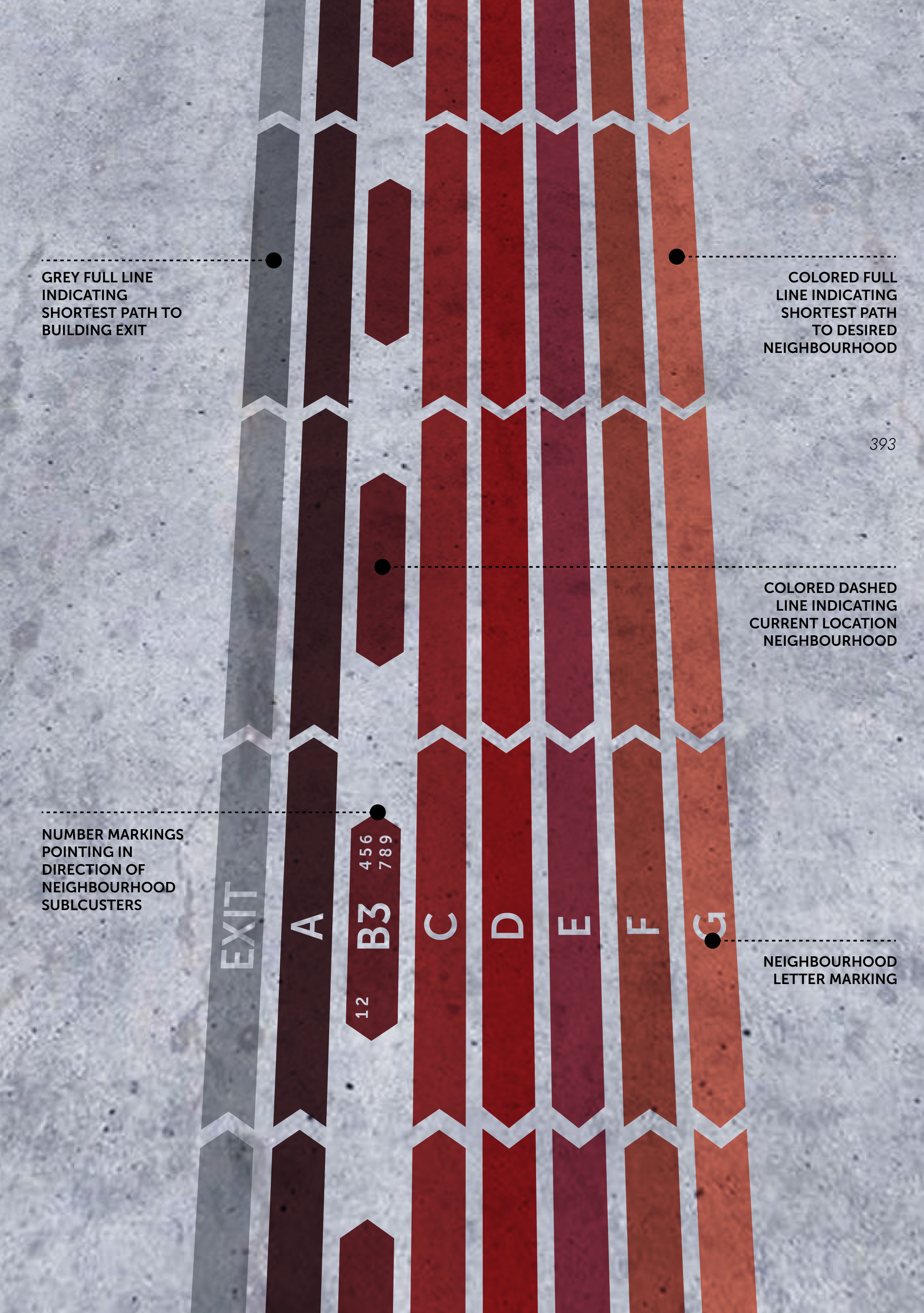
presenting comunities

Private units; local identity
Differentiated color shades of individual units

WAYFINDING

To enable effcient orientation in the complex new structure a simple graphic orientation system is developed and applied on the floor of all public streets. The building is organisationally divided into seven neighbourhoods, each marked with a letter (A, B, C,...). Further, each neighbourhood is divided into subclusters by number (1, 2, 3) , each of which contains a maximum of ten units. At each point in the building a person is pointed along the closest path towards all other neighbourhoods (A - G) by a solid coloured line. Upon reaching the desired neighbourhood its solid line changes into a dashed line indicating both the subcluster number (B3) in which the person is located, as well as the direction of other subclusters of this neighbourhood.



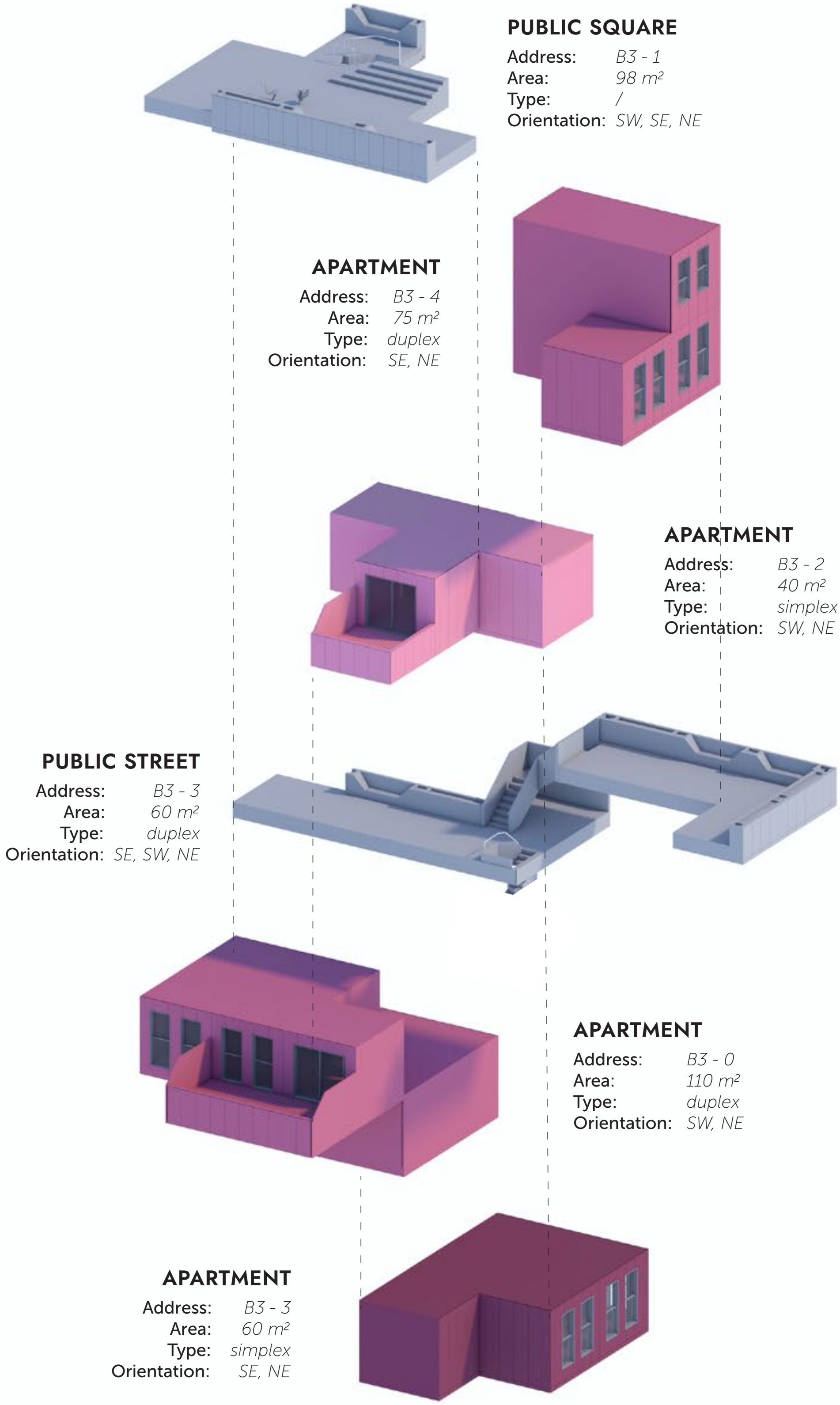

GREY FULL LINE INDICATING SHORTEST PATH TO BUILDING EXIT
COLORED FULL LINE INDICATING SHORTEST PATH TO DESIRED NEIGHBOURHOOD
COLORED DASHED LINE INDICATING CURRENT LOCATION NEIGHBOURHOOD
NUMBER MARKINGS POINTING IN DIRECTION OF NEIGHBOURHOOD SUBLCUSTERS
NEIGHBOURHOOD LETTER MARKING
EXIT
A
456
789
B3
12
C
D
E
F
G

ECOLOGY


COMMUNITY GARDENS
STREET IN THE SKY
OVERLOOKING TERRACES
VERTICAL CONNECTIONS
SOLAR COLLECTORS
NEIGHBOURHOOD SQUARE
TERRACE PARK
SCAN FOR 3D MODEL

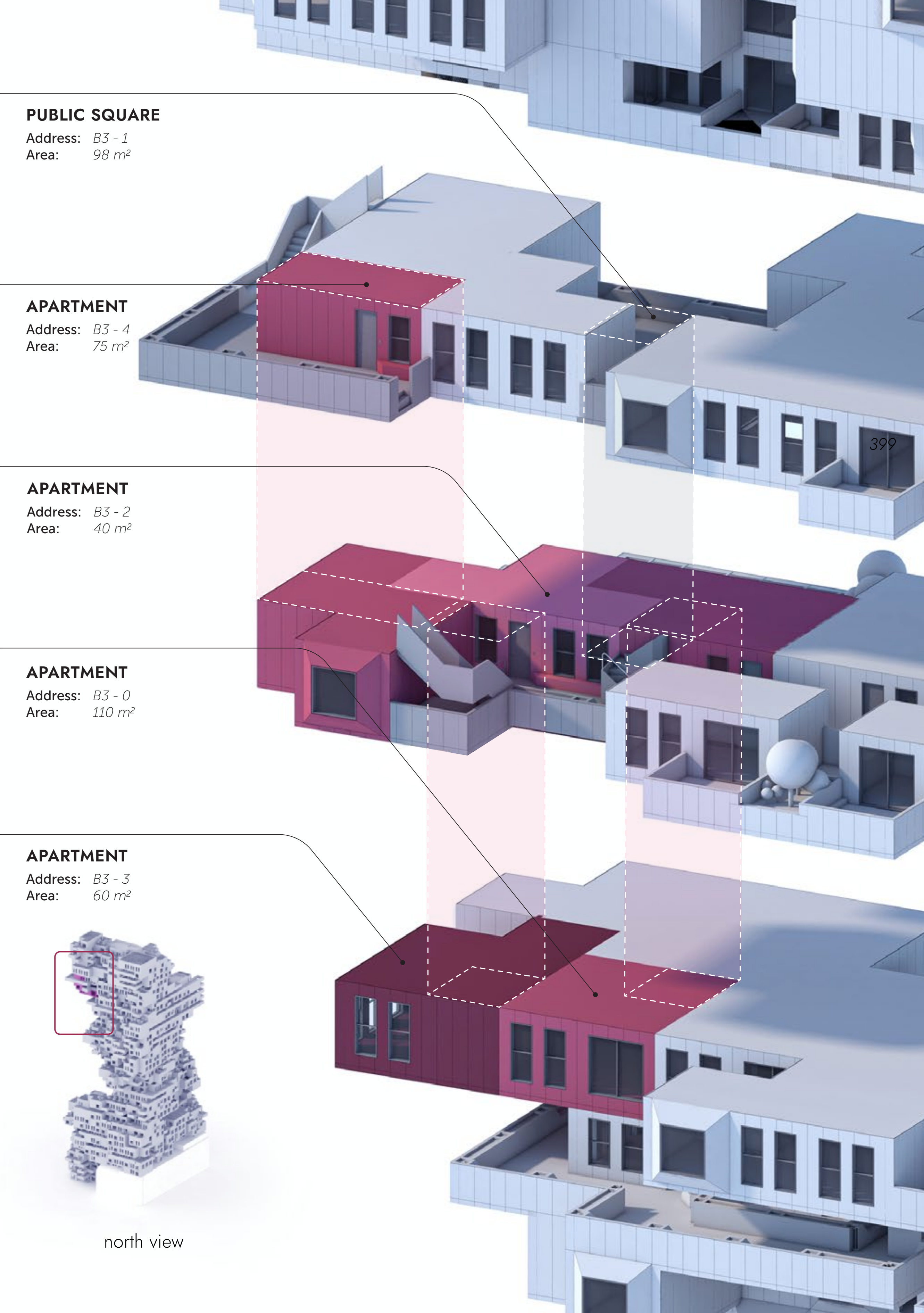
CLUSTER DESIGN

south view



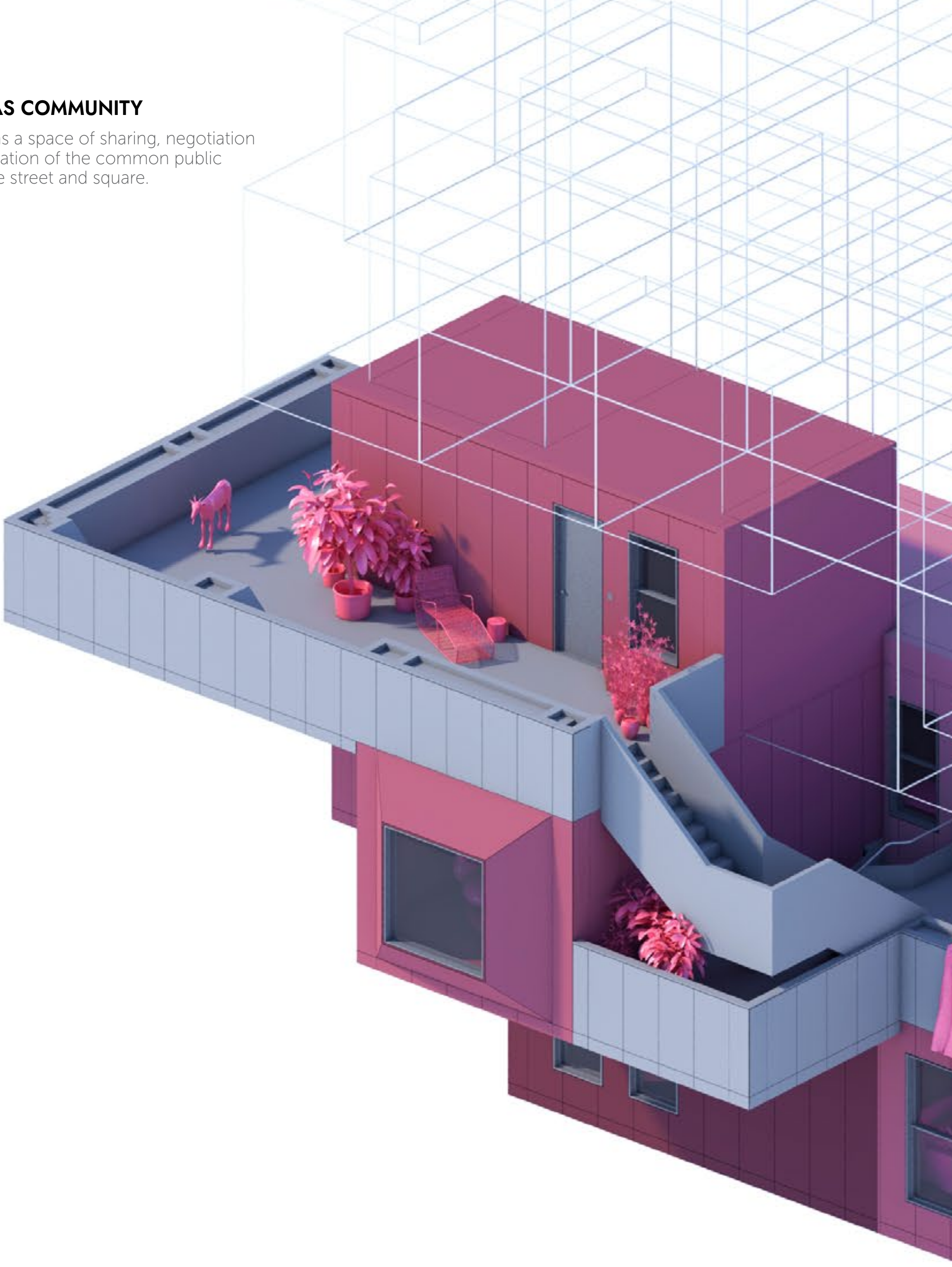
Subcluster B3 zoom-in and units

south view

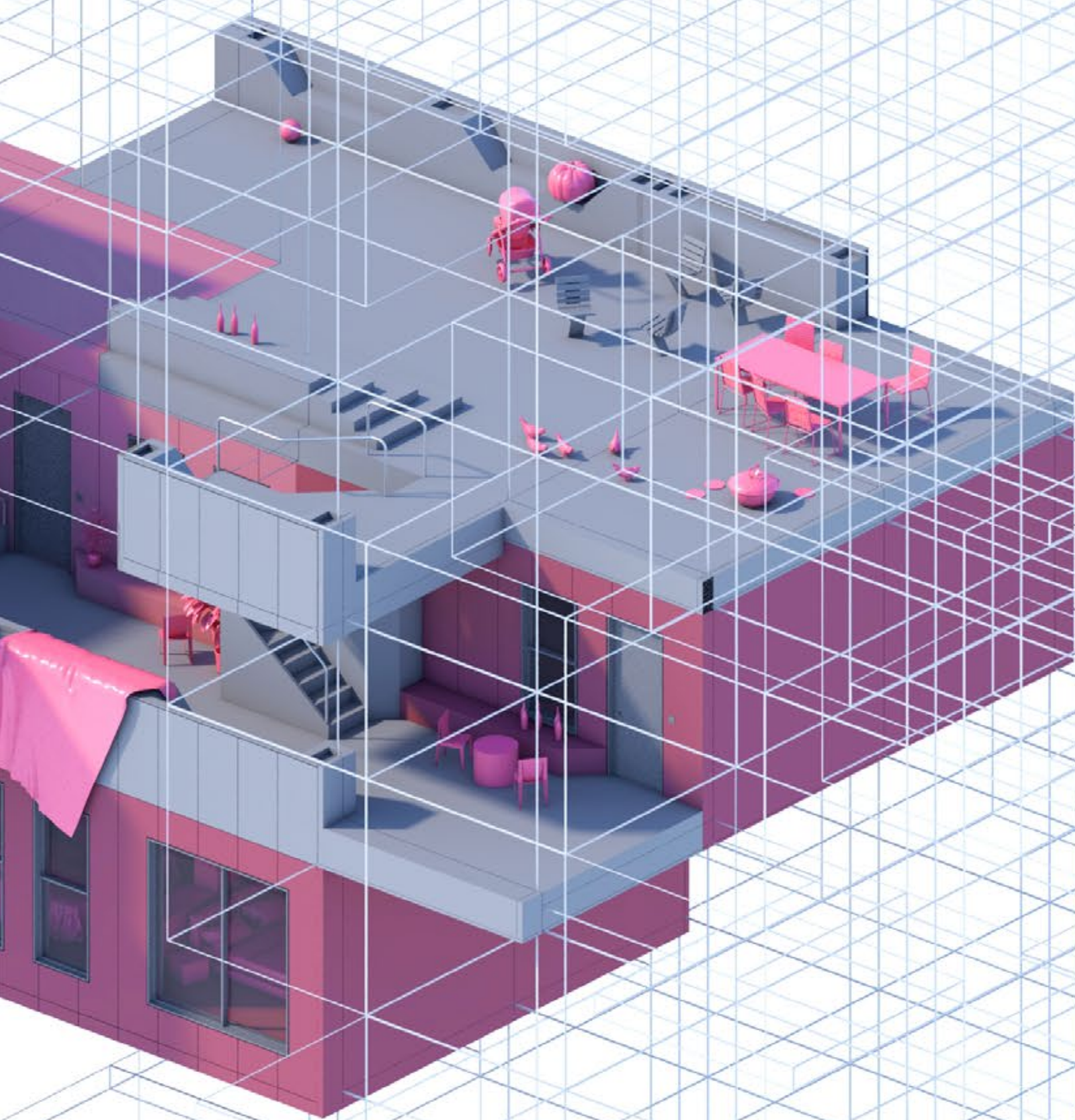

PUBLIC SQUARE
Address: B3 - 1
Area: 98 m²
APARTMENT
Address: B3 - 4
Area: 75 m²
APARTMENT
Address: B3 - 2
Area: 40 m²
APARTMENT
Address: B3 - 0
Area: 110 m²
APARTMENT
Address: B3 - 3
Area: 60 m²
north view

CLUSTER AS COMMUNITY

The cluster as a space of sharing, negotiation and appropriation of the common public spaces of the street and square.

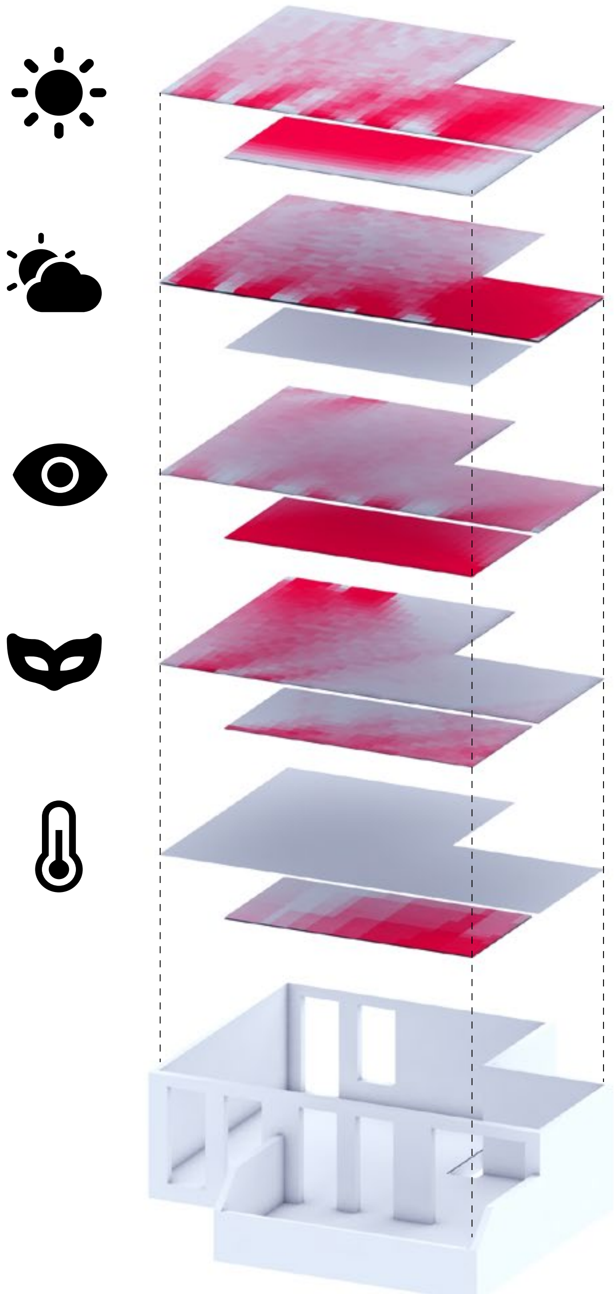


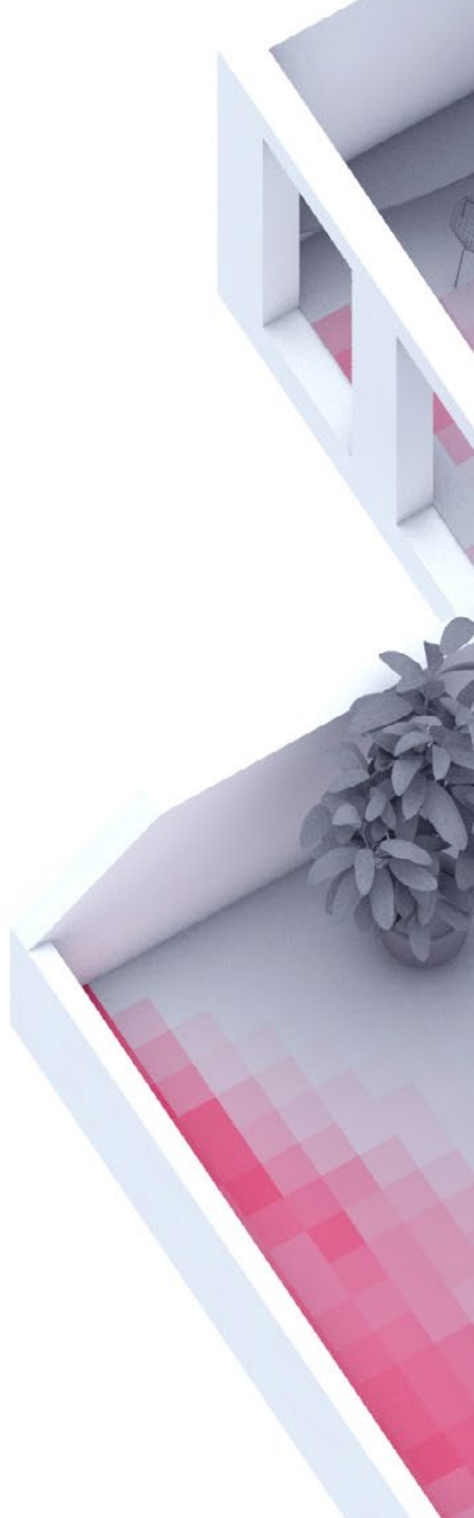
THE PUBLIC STREET beyond being the primary means of circulation, also acts as the main social gathering area. Due to its width providing ample space, the ambiguous urban furniture and the direct entrances to apartments it is a prime space for user appropriation. This can mean many things; from drying your sheets, sunbathing on a sunny day, sitting in front of your apartment drinking beer with friends, or simply placing plants and flowers to brighten up the space. Together with the community square the street space is an extension of the Rotterdam public ground plane and is key to extending the city vertically while maintaining its urban character and possibility for encounter and social interaction.



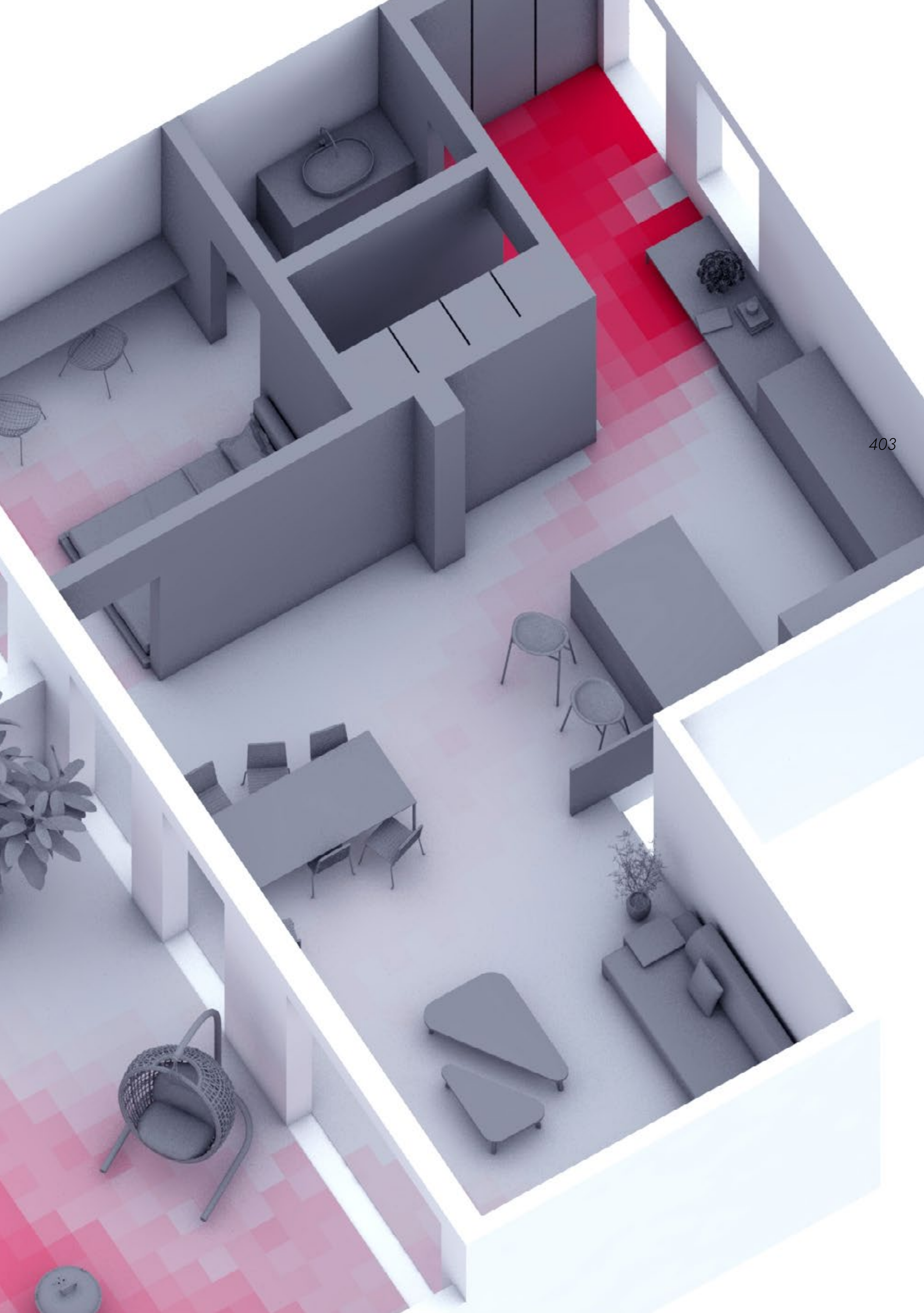
AUGMENTED LAYOUT DESIGN

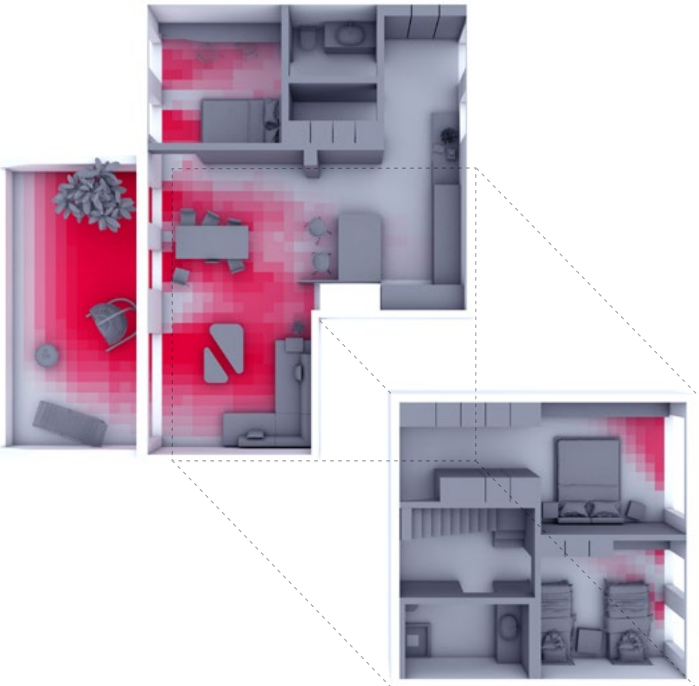
To ease development of unit floorplans within the complex spatial context of the aggregation, as well aa its surroundings, an digitally augmented plan design approach is proposed. Each unit plan is analysed accorcing to defined metrics such as sunlight access, daylighting, view quality, privacy and outdoor comfort, which create a multi-layered guide helping the architect identify advantages and issues and adapt the plan design accordingly. While this is now proposed as a method augmenting the human designer it can be imagined as an input for autonomous generative algorithms already under research and development. [66,67]



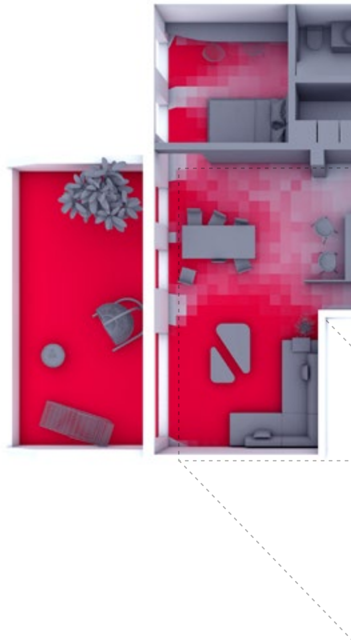


Multi-parameter plan analysis

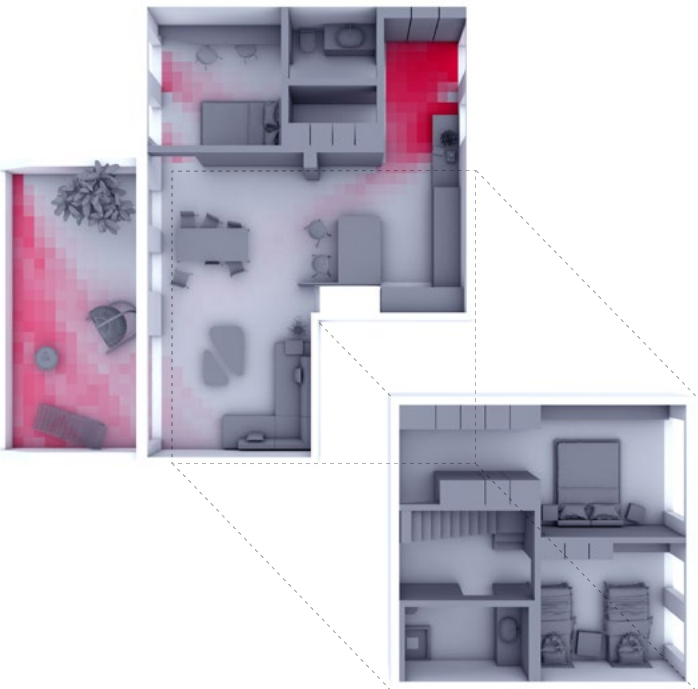




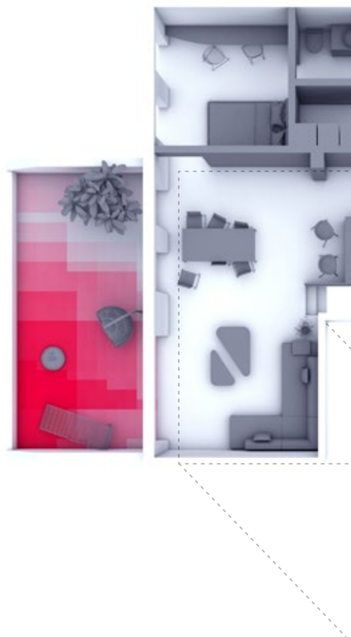
1. Sunlight access



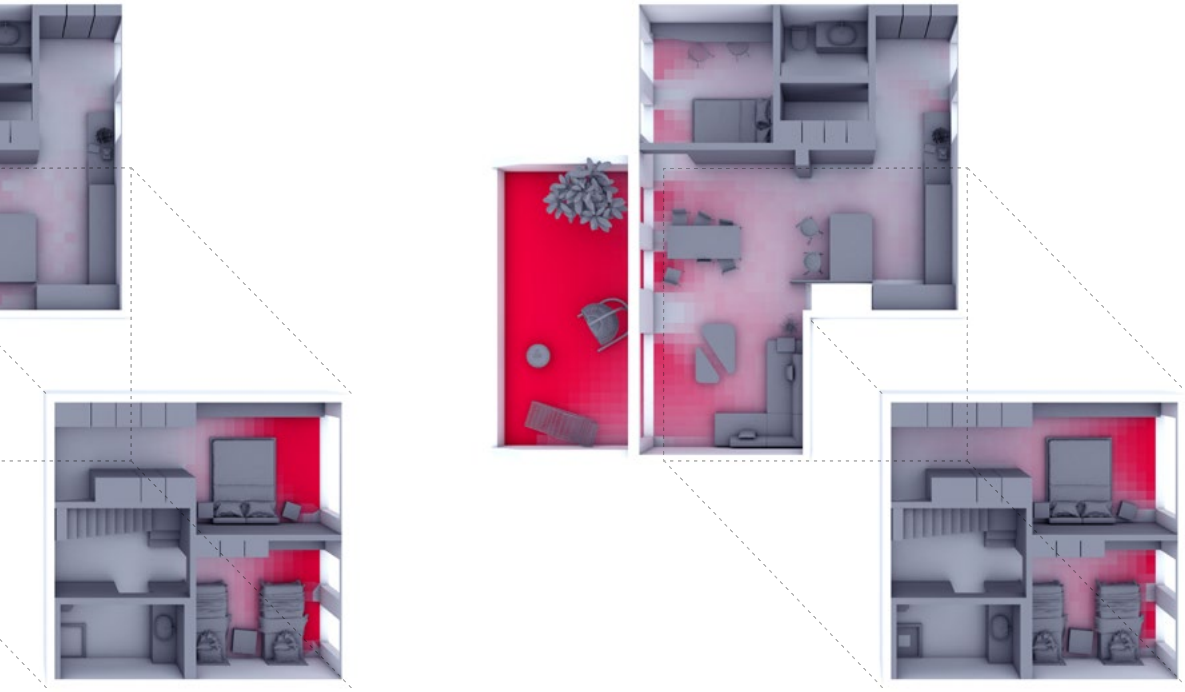
2. Daylight access



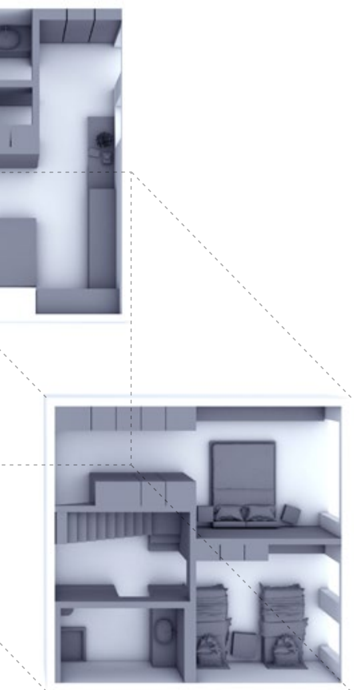
4. Degree of privacy



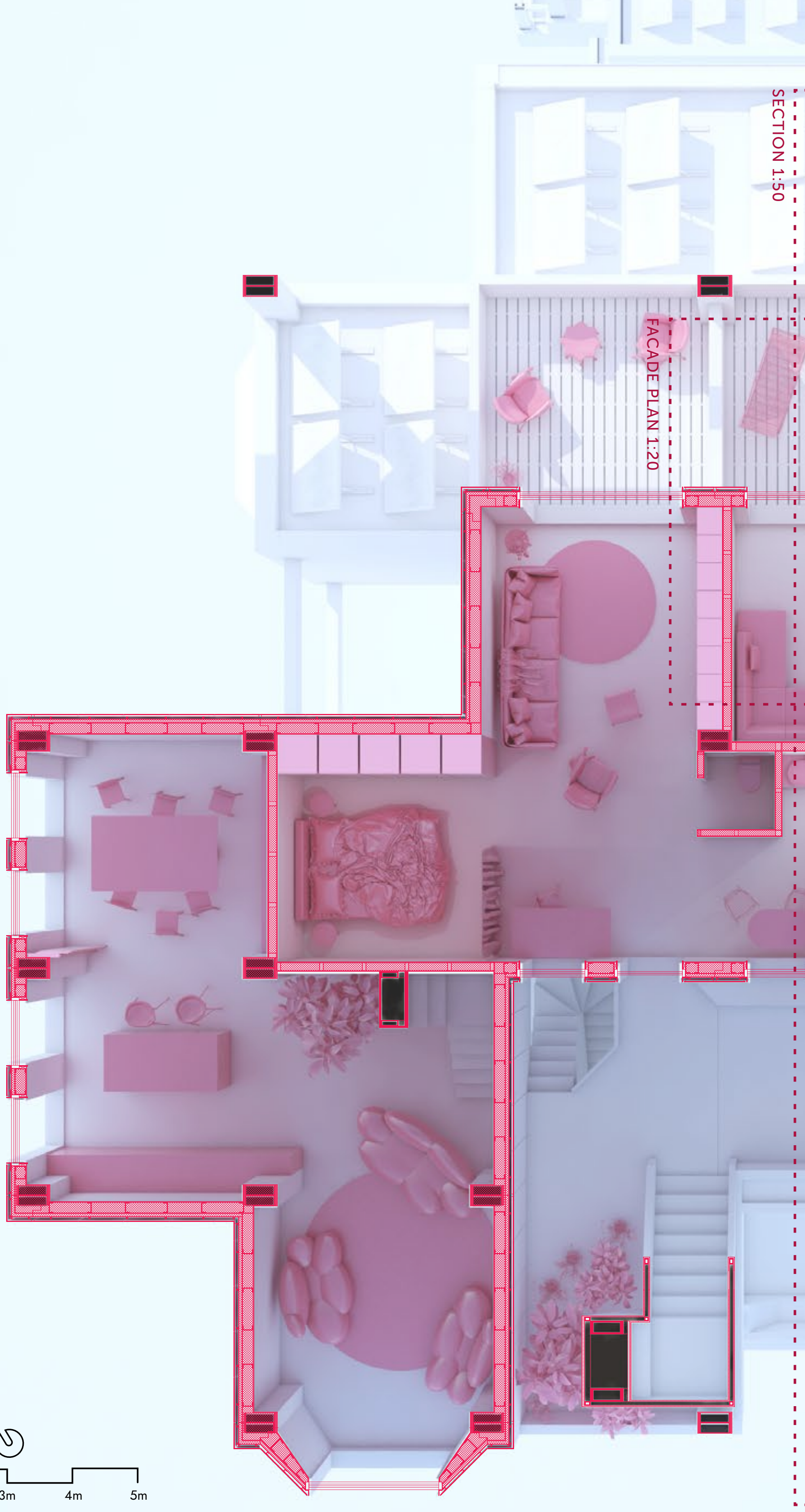
5. Outdoor comfort



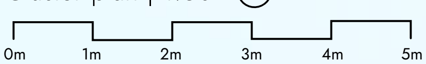
3. View angle

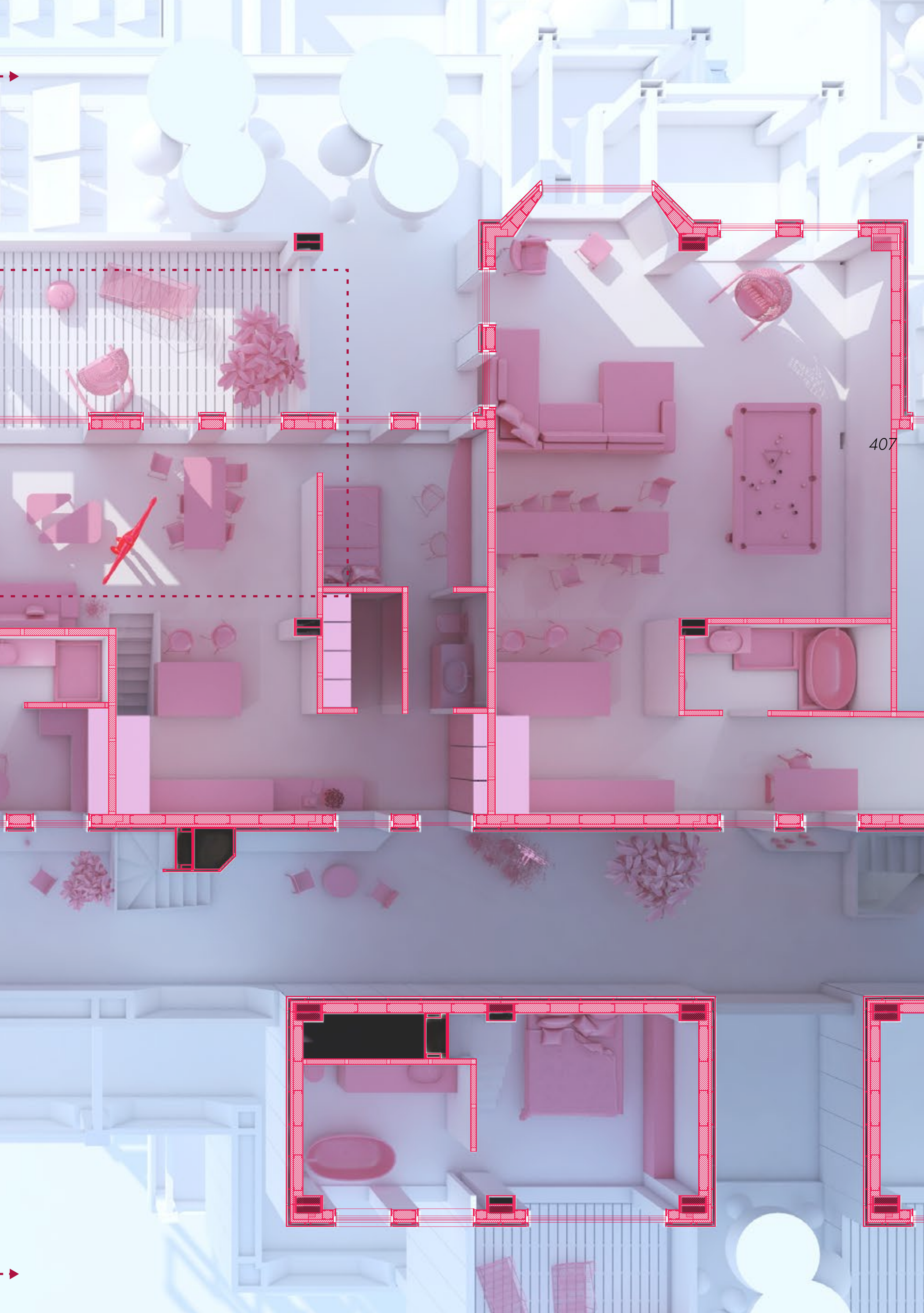


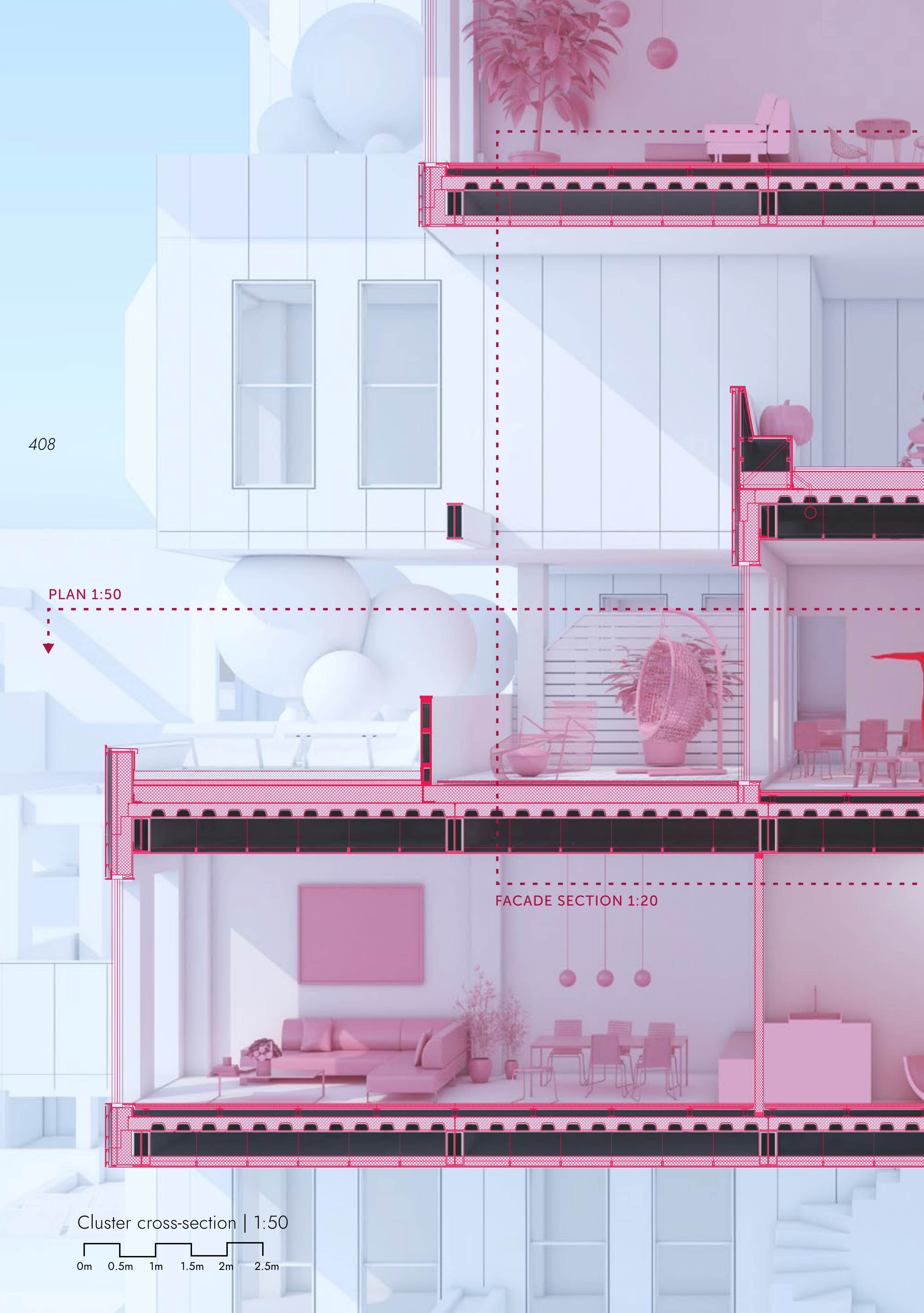
PLAN ANALYSIS was performed on a 110m2 duplex apartment intended for a four person family. Results of the analysis guided many design decisions in determining the spatial layout; first, the increased privacy of the lower floor implied it to be the best space for both the master bedroom - positioned on the side with a large window - as well as a smaller child bedroom and a bathroom. On the upper floor the positioning of the small bathroom and utility room solved the street privacy conflict, while the sunlight, view and daylighting parameters guided the positioning of the living and dining rooms. The kitchen acts as a connecting zone between the entrance and main living space, while the remaining room is used as a work room or a guest bedroom. The analysis was crucial to identify and solve all advantages and drawbacks in the default unit layout.

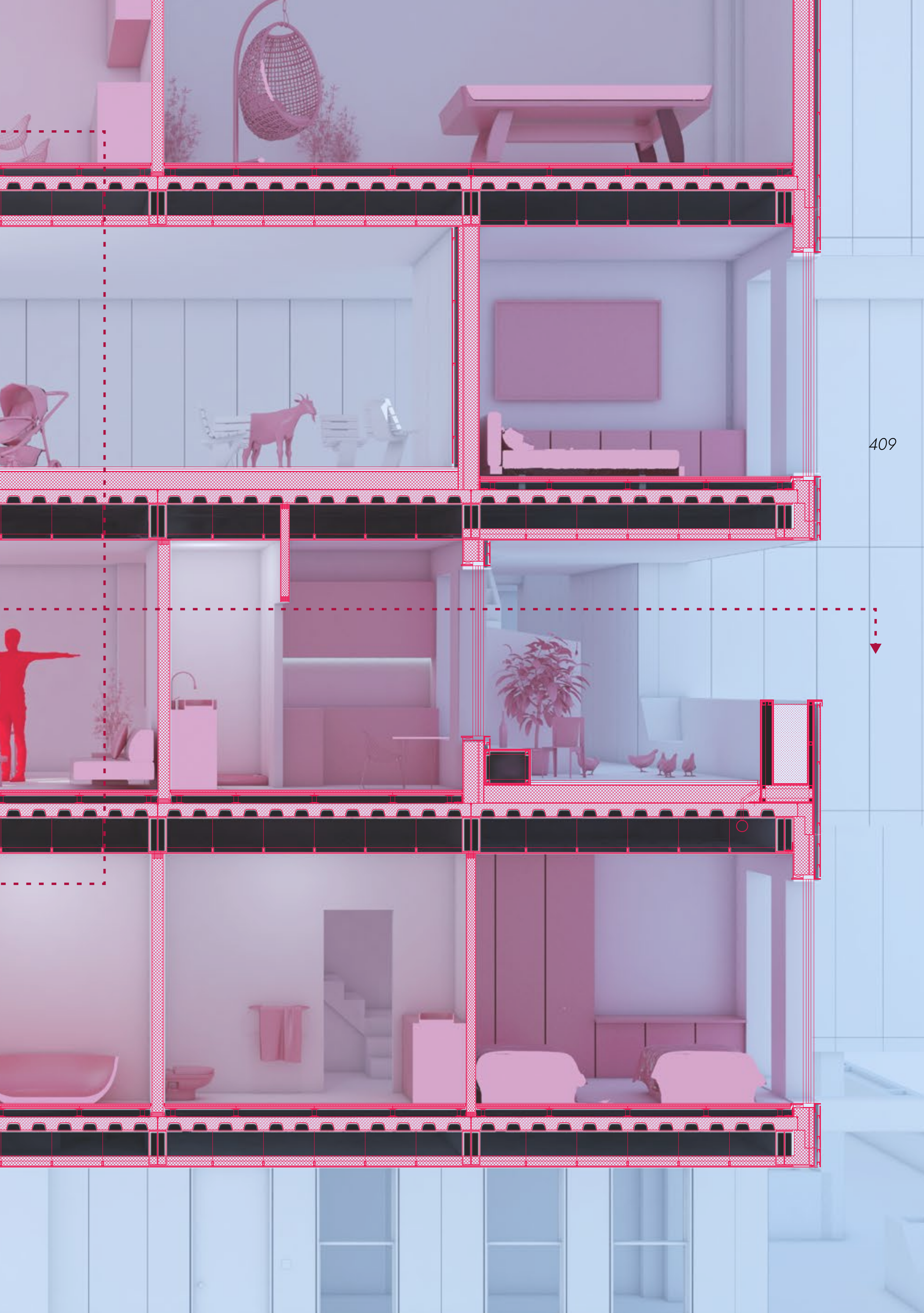


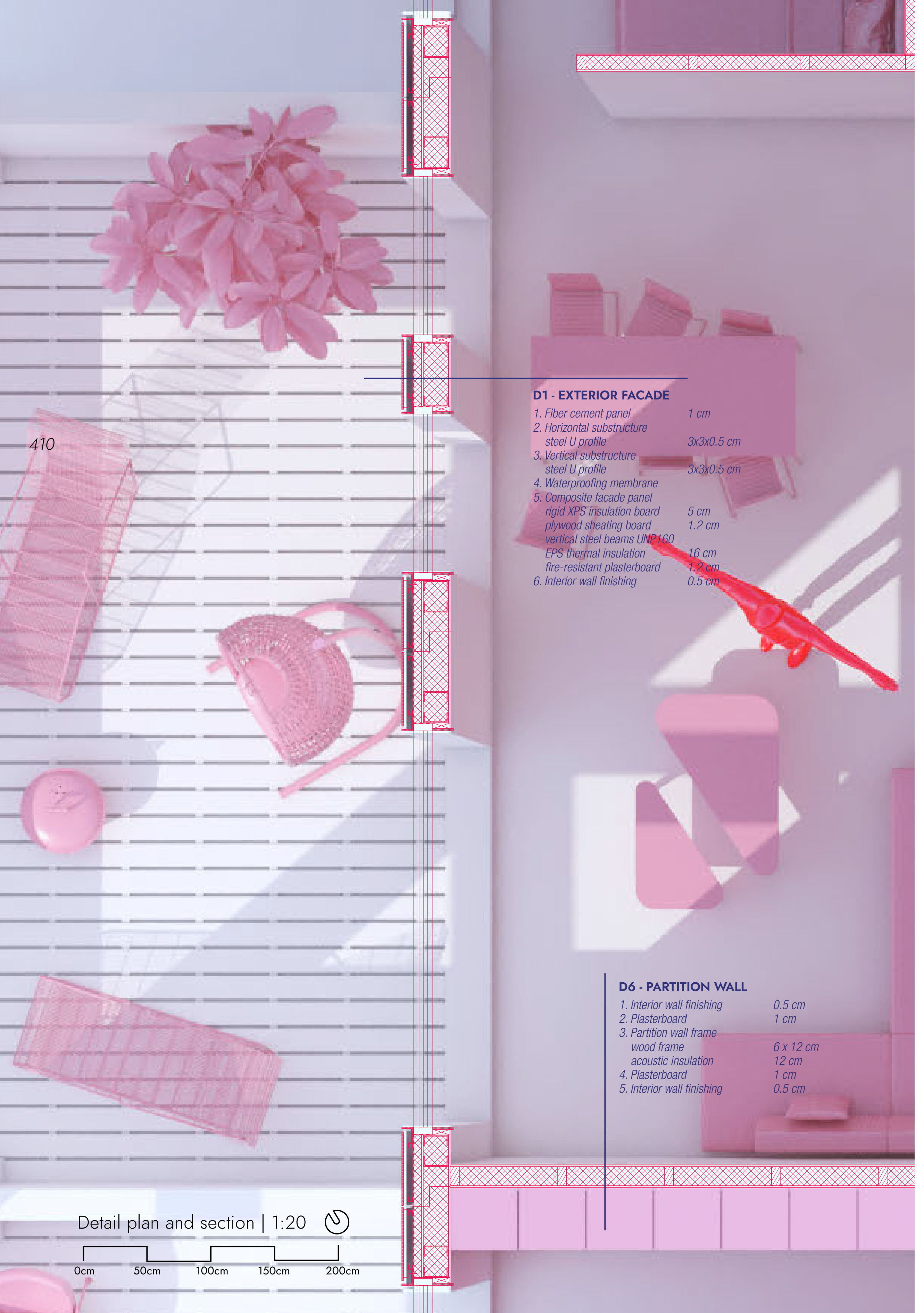
Cluster plan | 1:50






PLAN 1:50
FACADE SECTION 1:20
Cluster cross-section | 1:50
0m
0.5m
1m
1.5m
2m
2.5m





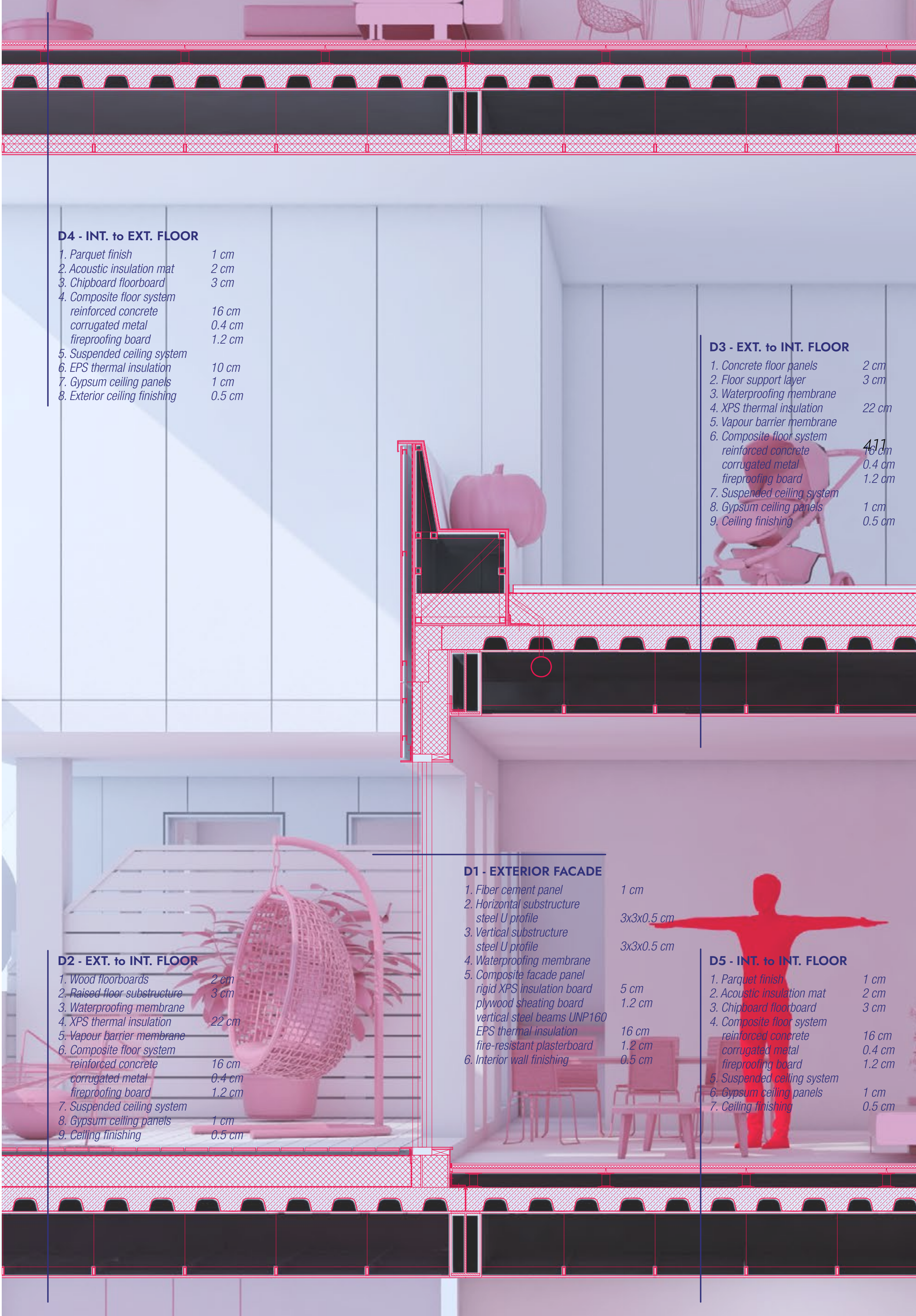
D1 - EXTERIOR FACADE

1. Fiber cement panel	*1 cm*
2. Horizontal substructure steel U profile	*3x3x0.5 cm*
3. Vertical substructure steel U profile	*3x3x0.5 cm*
4. Waterproofing membrane	
5. Composite facade panel	
rigid XPS insulation board	*5 cm*
plywood sheating board	*1.2 cm*
vertical steel beams UNP160	
EPS thermal insulation	*16 cm*
fire-resistant plasterboard	*1.2 cm*
6. Interior wall finishing	*0.5 cm*

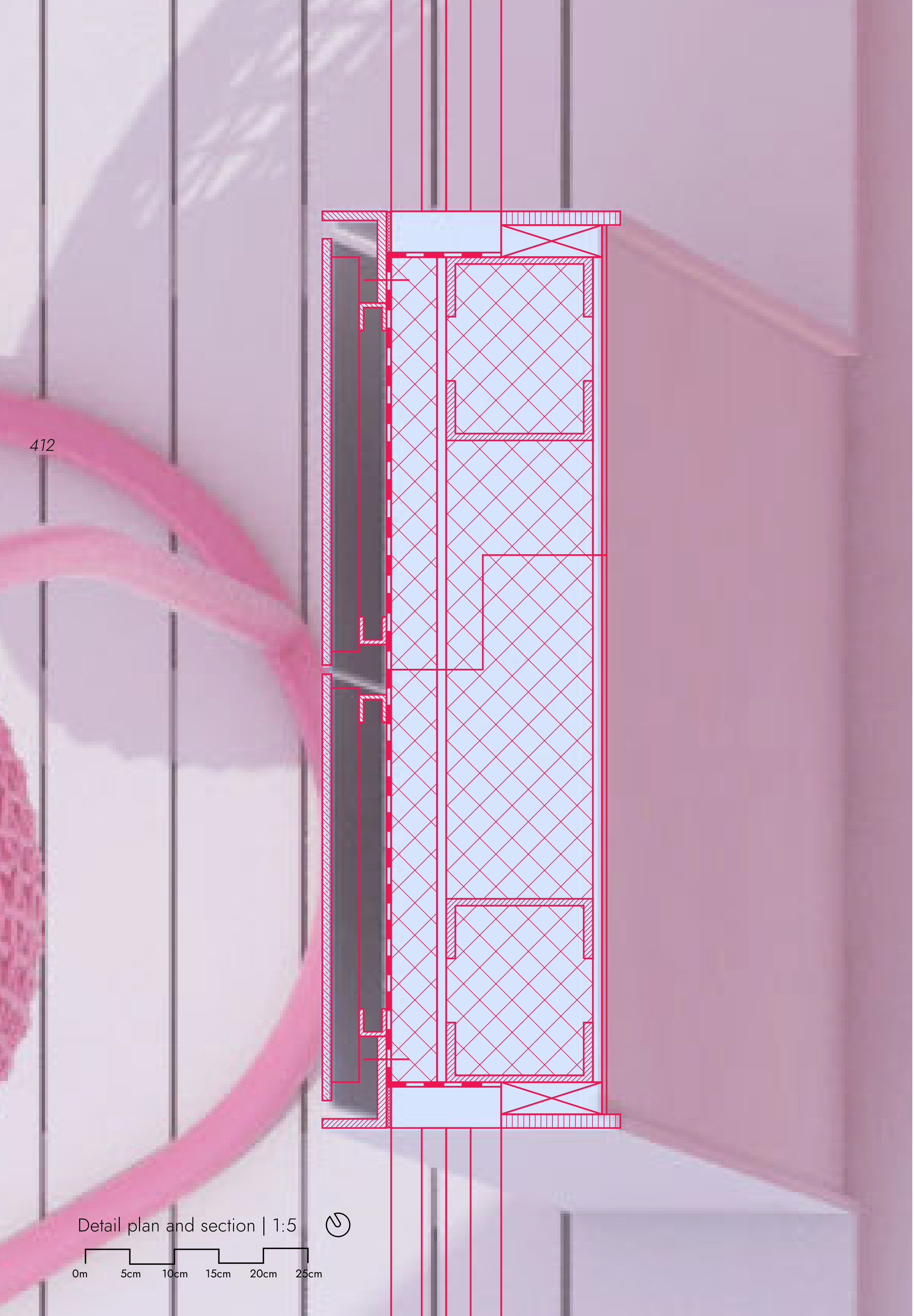
D6 - PARTITION WALL

1. Interior wall finishing	*0.5 cm*
2. Plasterboard	*1 cm*
3. Partition wall frame	
wood frame	*6 x 12 cm*
acoustic insulation	*12 cm*
4. Plasterboard	*1 cm*
5. Interior wall finishing	*0.5 cm*

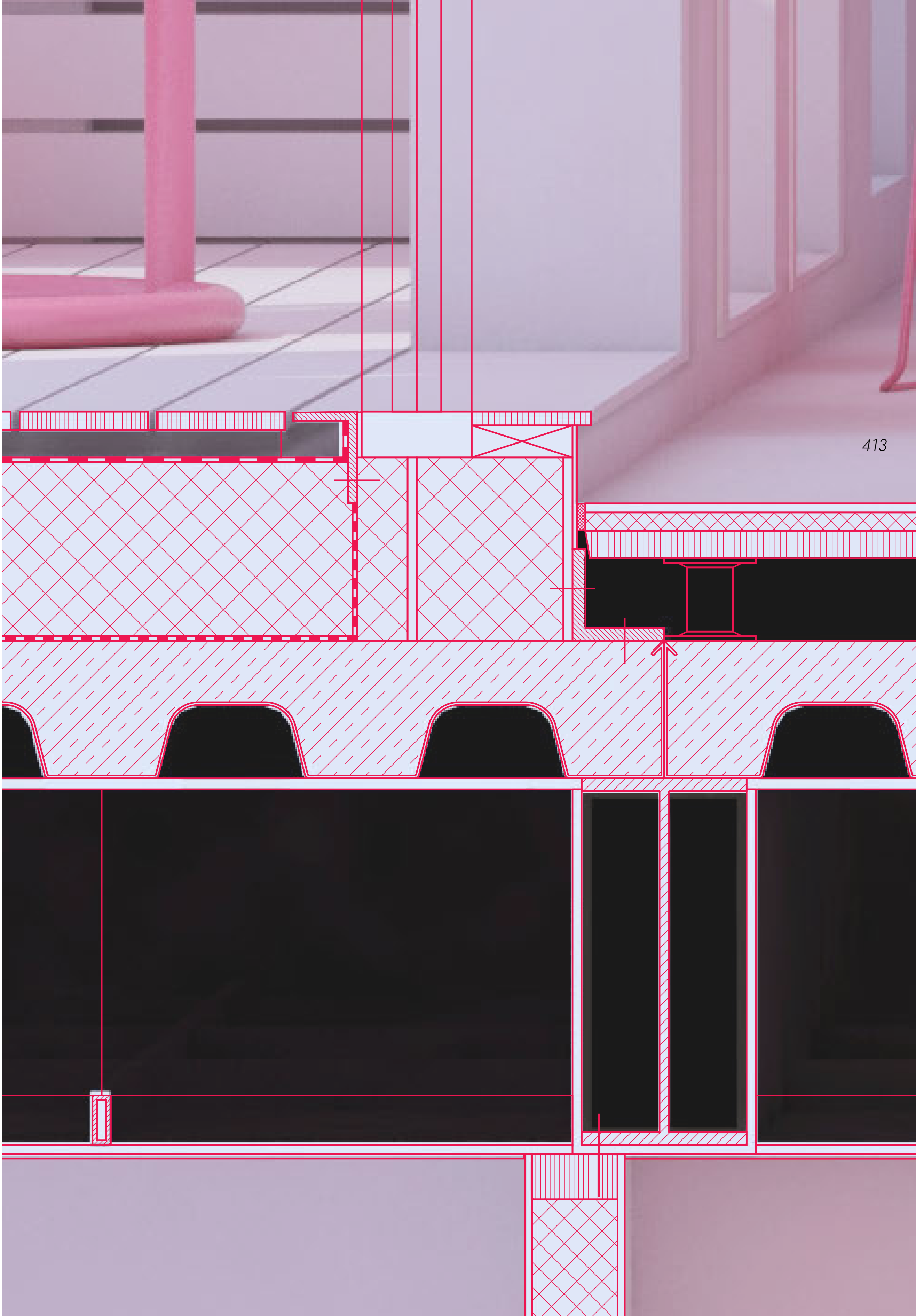
Detail plan and section | 1:20



D4 - INT. to EXT. FLOOR
1. Parquet finish 1 cm
2. Acoustic insulation mat 2 cm
3. Chipboard floorboard 3 cm
4. Composite floor system
reinforced concrete 16 cm
corrugated metal 0.4 cm
fireproofing board 1.2 cm
5. Suspended ceiling system
6. EPS thermal insulation 10 cm
7. Gypsum ceiling panels 1 cm
8. Exterior ceiling finishing 0.5 cm
D3 - EXT. to INT. FLOOR
1. Concrete floor panels 2 cm
2. Floor support layer 3 cm
3. Waterproofing membrane
4. XPS thermal insulation 22 cm
5. Vapour barrier membrane
6. Composite floor system
reinforced concrete 16 cm
corrugated metal 0.4 cm
fireproofing board 1.2 cm
7. Suspended ceiling system
8. Gypsum ceiling panels 1 cm
9. Ceiling finishing 0.5 cm
411
D1 - EXTERIOR FACADE
1. Fiber cement panel 1 cm
2. Horizontal substructure
steel U profile 3x3x0.5 cm
3. Vertical substructure
steel U profile 3x3x0.5 cm
4. Waterproofing membrane
5. Composite facade panel
rigid XPS insulation board 5 cm
plywood sheating board 1.2 cm
vertical steel beams UNP160
EPS thermal insulation 16 cm
fire-resistant plasterboard 1.2 cm
6. Interior wall finishing 0.5 cm
D2 - EXT. to INT. FLOOR
1. Wood floorboards 2 cm
2. Raised floor substructure 3 cm
3. Waterproofing membrane
4. XPS thermal insulation 22 cm
5. Vapour barrier membrane
6. Composite floor system
reinforced concrete 16 cm
corrugated metal 0.4 cm
fireproofing board 1.2 cm
7. Suspended ceiling system
8. Gypsum ceiling panels 1 cm
9. Ceiling finishing 0.5 cm
D5 - INT. to INT. FLOOR
1. Parquet finish 1 cm
2. Acoustic insulation mat 2 cm
3. Chipboard floorboard 3 cm
4. Composite floor system
reinforced concrete 16 cm
corrugated metal 0.4 cm
fireproofing board 1.2 cm
5. Suspended ceiling system
6. Gypsum ceiling panels 1 cm
7. Ceiling finishing 0.5 cm



Detail plan and section | 1:5



Streets

Squares

Terraces

Walking the streets, chatting to neighbours and having a glass of wine with friends...

...grabbing a cup of hot coffee and a doughnut before taking your bicycle and going to work...

...wandering the winding streets full of intimate spaces and little surprises...

...enjoying the nature on a warm spring day while your garden is blooming...

...having a good time with friends in the sun on a hidden patio only for yourselves...


...drinking a morning coffee while enjoying the views of Rotterdam on a clear morning...

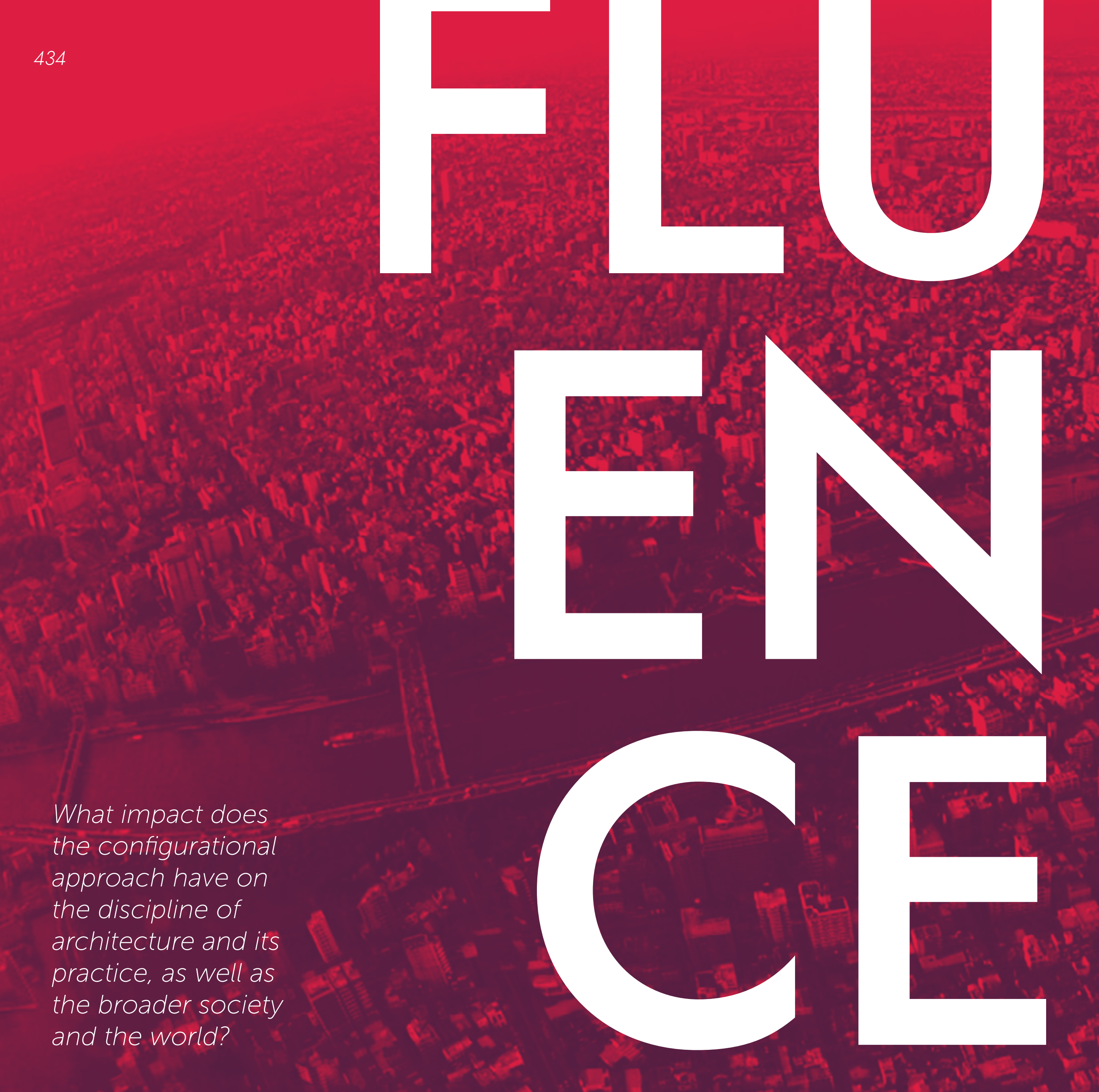
...going to tend your garden while children play ping pong on the communal square...

...celebrating a birthday with you loved ones while enjoying the summer evening sun...

...or simply having a picnic while the neighbourhood band practices under the lemon tree.

16 ON...

INFLUENCE



What impact does the configurational approach have on the discipline of architecture and its practice, as well as the broader society and the world?

After exploring both the theoretical and practical potentials of configurational design in architecture, this last chapter of Configurational Morphology will attempt to summarise the results, describe benefits and especially drawbacks, emphasise the limitations and point towards possible improvements. Through this reflection the starting questions about the viability of configurational design for designing responsive urban form are answered, whilst new ones are posed which will guide further research, its expansion and possibly real-world application.

Configurational Morphology combines general **theoretical principles** of configurational design with their **practical application** through specific experiments geared towards creating new **adaptive urban form**. This duality is crucial due to the breadth and importance of the topic in question - the architectural design process - which must simultaneously be conceptualised as a generalised approach as well as tested through practical real-world experiments. The project intentionally operates at an **intermediate scale** between architecture and urbanism; more than a building but not quite an urban plan, a no man's land for which everyone and no one is responsible, but has a strong influence on how our built environment looks, feels and performs. Through the reconnection of architecture and urbanism, Configurational Morphology aims to create a holistic **design process** in which the complex interdependencies between scales are acknowledged and productively channelled as parameters for generating new urban form.

Configurational Morphology examines the potentials of configurational design for designing responsive urban form in the scope of two activities crucial to the architectural design approach; **analysis** and **projective design**. Analytically, configurational design has proven a valuable tool for investigating and recording the **socio-spatial patterns** underlying the urban fabric of our cities by reducing three-dimensional space into abstract configurational **Spatial Networks.** These patterns in space are important not only because they govern how our cities are constructed, but also because they are a direct reflection of our society and way of life. Additionally, a configurational analysis of space enables the extraction of such patterns while separating them from physical form and making them ready for use as **design inputs** for the configurational generation of new urban form. The renewed focus on the configuration of space essentially enables a refocus on the social aspects of space allowing architects to consciously design in accordance with our ever-evolving society and behavioural patterns. Contrary to existing form based on aesthetics or formal precedents, this could lead to **socially responsive** and more sustainable architecture and urban form directly based on the way we live together and interact, consequently increasing our quality of life.

Projectively, configurational design has proven a capable design approach for generating designs organically growing out of local conditions and architect-defined constraints. In the case of **urban form**, configurations, especially when combined with **computation**, can enable the production of more responsive **site-specific urban form** better adapted to the site and environment in which it is placed. A top-down approach imposing rigid slabs and towers is replaced with a process of configurational aggregation where urban form emerges as the direct result of both **top-down** imposed configurations and spatial requirements, as well as complex **bottom-up** urban forces of local environmental conditions. Using Spatial Networks extracted from established urban types through configurational analysis such adaptivity can be channelled to extrapolate these types into new urban fabric better adapted to the forces of contemporary urban areas. The use of configurations as a generative design medium also entails a shift to a more scientific, **fact-based design approach** utilising urban datasets and digital analysis of urban conditions to guide the generation of design schemes. This systematism often leads to **increased building performance** in various categories such as density, sustainability or spatial quality as evident in the conducted morphological experiments. Through the theoretical and practical experiments conducted the viability of configurational design within architecture has been proven, especially for the production of responsive urban form adapted to site and context leading to more socially, economically and environmentally **sustainable** urban form.

While configurational design as a theoretical framework holds much promise for creating adaptive and sustainable architecture, its practical application explored throughout this project has been subject to numerous limitations imposed both by the restricted scope and time, as well as characteristics of the approach itself. These limitations open new questions that can guide further research into the viability of configurational design as a practical design approach for not only urban form but architecture in general. The most glaring limitation of the current research has been its focus on **generic urban tissue** such as residential urban fabric. While these indeed represent the vast majority of built space, the scope of architecture is far larger and includes complex public buildings such as schools, hospitals, museums, stadiums and shopping malls to name only a few. Theoretically and analytically the approach as presented can deal with all the above-mentioned building types, it is in the computational generative phase where this is harder to apply, mostly as a result of the increased complexity of topological connections within the configurational graph / Spatial network.

Next, the practical application of configurational thinking was currently restricted to a narrow **range of scales** of a building and an urban block, mostly as a consequence of the desired focus on urban form. As a result, the potential of configurational design as an analytical and projective approach needs to be further explored on smaller scales such as the unit or room, as well as larger scales ranging from the street to neighbourhood to the city. It is at these larger scales where the approach becomes similar to one of its precedents, the urban analysis tool **Space Syntax**, along with all of its benefits and issues. Similarly to other scales, the biggest challenge here remains how to translate the analytically capable configurations into an efficient and effective generative design driver for a new architecture.

To improve the practicality of configurations as a design medium the **digital design interface** would need to be further developed past the conceptual sketch presented as part of this project. This would make configurational design accessible to users irrespective of their programming skills whilst making it more time-efficient and intuitive. Concerning user experience, the currently implemented generative algorithms, whilst producing interesting designs, can often behave very unpredictably as a result of their complexity and difficulty in setting optimal parameters. Sometimes this can lead to frustrating and time-consuming behaviour where the algorithms produce large numbers of inefficient results purely as a result of poorly defined settings which the algorithm is unable to optimize. Consequently, an important step in development would be the implementation of machine learning or evolutionary optimization within the generative algorithm, allowing it to self-regulate thereby leaving the designer with more time to focus on the effects different configurations and their requirements have on the quality of generated schemes.

Lastly, there remains the dilemma of selecting **parameters** guiding both the generation of new designs, as well as their evaluation. Due to the systematic and logical nature of the configurational design process presented here, the developed generative algorithms operate exclusively through **quantitative metrics** such as sunlight hours, view degrees or privacy distance. Although such parameters are very successful at describing the economical, and environmental performance of a building, one could argue that spatial quality can never be fully described merely through simple metrics like sunlight access but is also affected by subjective perception. Further research is required (and ongoing) in this field to explore if qualities such as ambience are truly subjective, in addition to if and how they could be quantified. These new metrics must then complement existing ways of quantifying spatial features such as visibility or convexity used in Space Syntax and traditional parameters already used in the configurational approach to empower the method to generate designs of superior performance on all fronts. These questions, along with many more left unmentioned, represent the next step in the research and development of configurational design as a practical design approach.

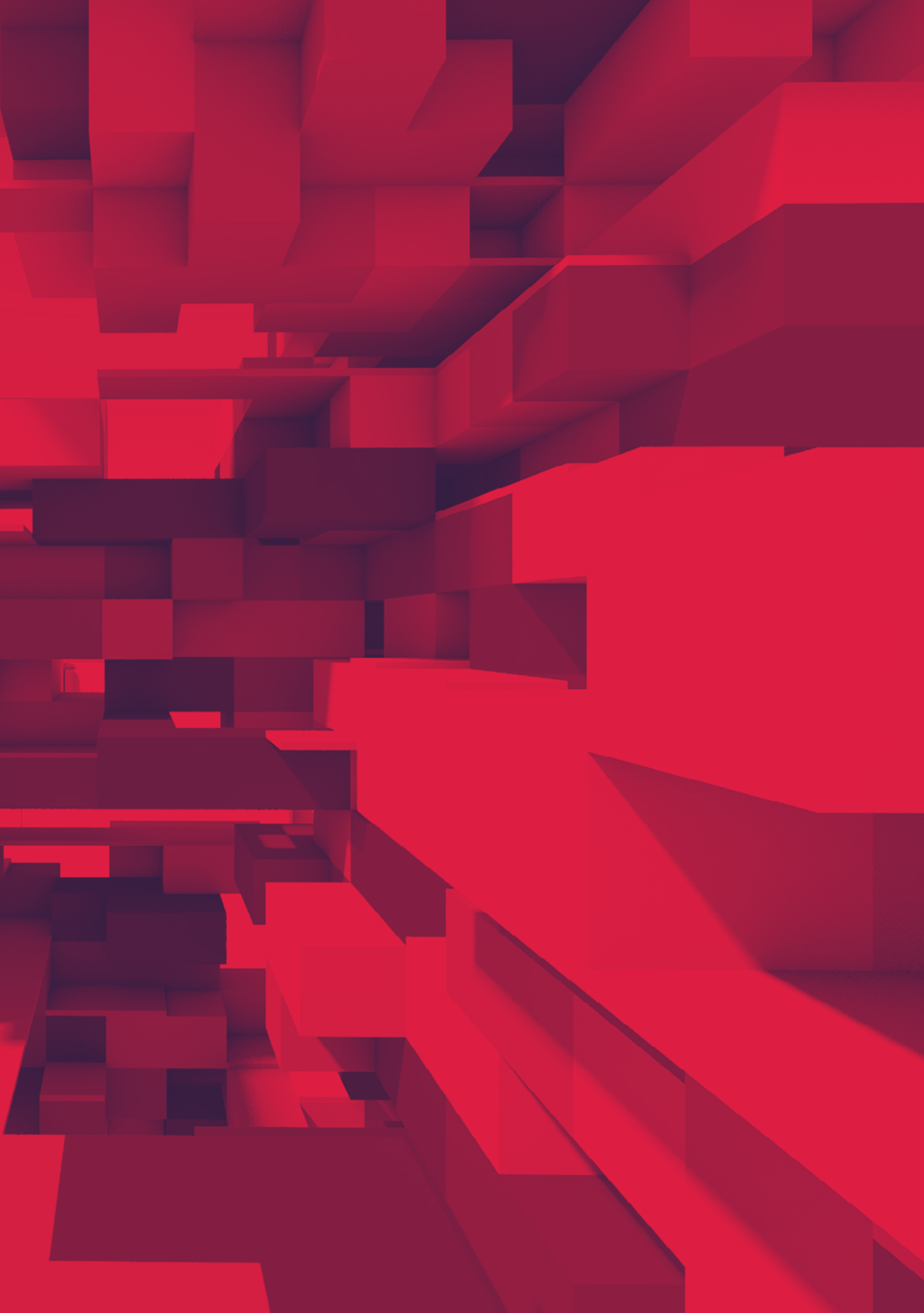
Nevertheless, in spite of the aforementioned drawbacks of the approach and the limitations of this research it is evident configurational design is deeply relevant as a theoretical design framework, a legitimate design approach for architectural practice, as well as a method for creating socially responsive and sustainable urban fabric.

As a research project, Configurational Morphology attempts to **question established modes of operation** in architecture by introspectively looking into the fundamental core of design activity, our design process. After critically examining the existing object-based design approach the project points towards **process-based configurational design** as a viable alternative often capable of better adaptation and performance, elaborating it not only through practical examples but a broader theoretical framework based on which other approaches and applications could be developed. Fundamentally, it is a case for a more scientific, objective and rigorous approach to architectural design, one capable of taking advantage of technological advancements. In the process, the project tries to crack open the shell in which architecture as a discipline sometimes encloses itself by attempting to find fertile connections to otherwise unrelated fields and disciplines such as computer science, biology, physics or mathematics. In many cases this **cross-fertilization** leads to new knowledge and techniques applicable within architectural design, showing both the importance of expanding the boundaries of architectural research as well as the value of **speculative design** as a legitimate architectural research activity through which the former can be achieved.[68]

From the perspective of architectural practice, the project tries to show ways configurational design could empower architects to create buildings better adapted to their local conditions resulting in improved economical, social and environmental **sustainability**. Complemented by a proposed paradigm shift to quantitative **performance-based design**, adaptive designs interacting with the environment and its complex influences can be evaluated according to metrics of sustainability, economy and spatial quality allowing for improved performance projections within the development phase before the building is constructed. Applied in practice, such an approach could finally enable us to overcome the serial mass production of urban space leftover from modernism and replace it with diverse **site-specific urban forms** and buildings growing out of local conditions whilst utilising the full potential of available spaces. Today, such invention is more crucial than ever as the worsening climate crisis places increasing pressure on cities to be more sustainable than ever, while architecture has yet to respond effectively with sustainability usually superficially applied in the form of solar panels or greenwashing instead of being the main design driver of urban form. Furthermore, potentials of **computation** are explored as a tool facilitating the automation of the architectural design process. On one hand, this could increase our **efficiency** and **productivity** as well as increase our capacity to deal with complex conditions and design appropriate solutions. On the other hand, the digital algorithms enabling automation present potential **intellectual property** which architects could leverage to their own benefit and increased influence in the construction industry.

Although in itself Configurational Morphology is a profoundly architectural research and design project, it also carries many broader implications for our society and the cities we live in. By virtue of its focus on configurations and consequently the **socio-spatial patterns** underlying our cities, configurational design can empower architects to create buildings in tune with the perpetually evolving patterns of living and interaction in contemporary society. Most importantly, this improved city-making process based on previously explained adaptivity could lead to urban spaces more capable of serving our needs through higher density, improved sustainability, more porosity and social interaction, increased identity, more diversity and higher spatial quality, producing cities of increased livability crucial for our future well-being.

To conclude, Configurational Morphology shows that with further development and refinement **configurational design** has potential to become both a comprehensive theoretical framework and a **practical design methodology** for designing adaptive urban forms **responsive** to the social, economical and environmental pressures of the contemporary city. Moreover, by virtue of its compatibility with digital and computational techniques it encourages the long-overdue inclusion of **automation** in the design process thus increasing **productivity** and **efficiency** on one hand, whilst offering architects the opportunity to create our own tailor-made algorithmic design tools and processes which can be intelectually protected thereby strengthening our role and relevance in the design and construction process. Lastly, the expansion and application of configurational design to other spatial scales could pave the way for a holistic **performance-based design** approach empowering us to create a more livable, equitable, affordable and sustainable built environment fit for the **future** of our society.



IT IS POSSIBLE.

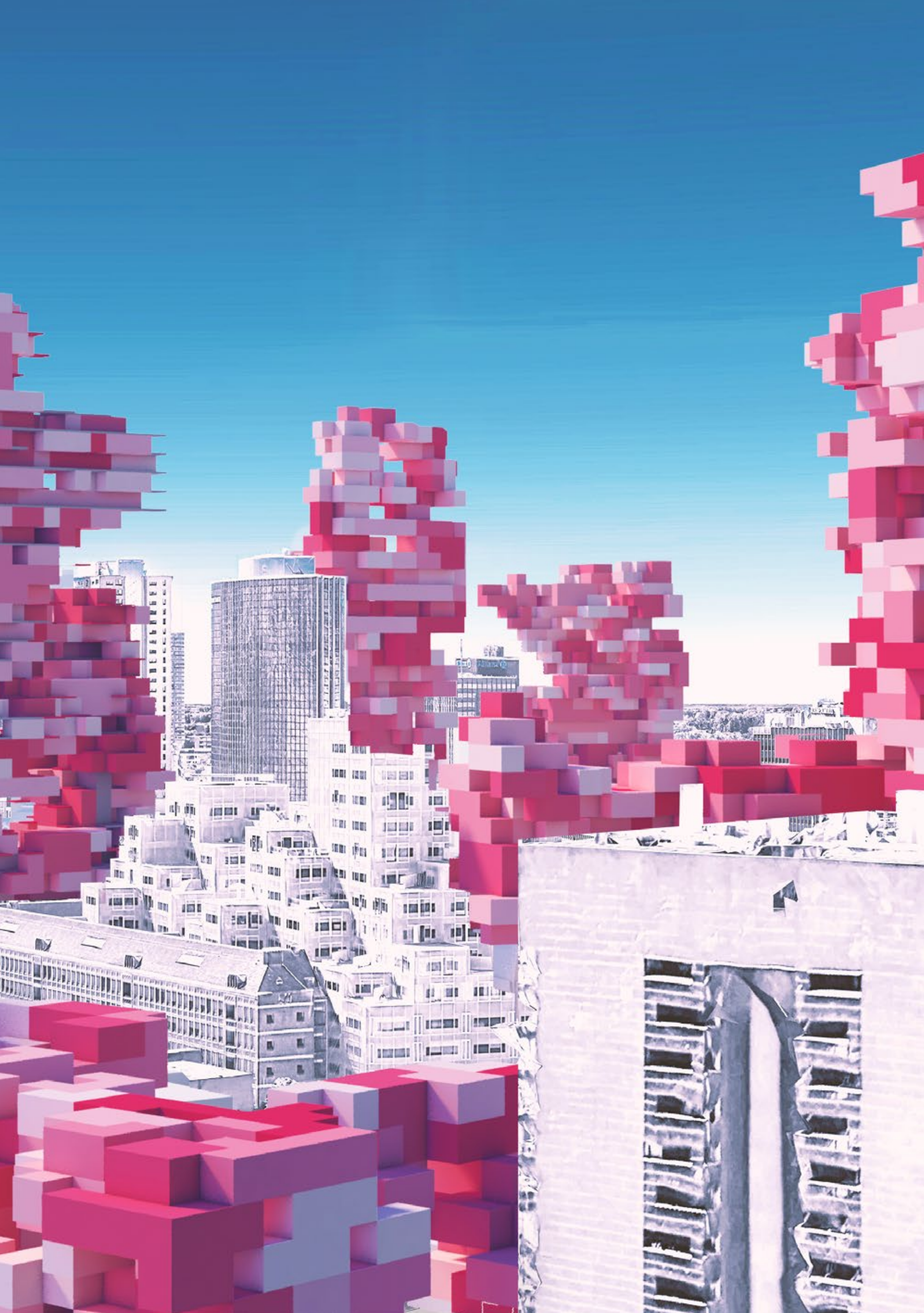
If we squint our eyes, focus and look beyond the diagrams, systems, parameters, algorithms and other technical details, we can see a **vision** emerging in the distance. An optimistic vision of a **future world** where architects empowered with new digital technologies and design approaches play an important role in solving the many challenges facing our society and the cities we call home.

In this world **adaptivity** is the main paradigm and the guiding principle behind all design, having managed to displace the previously entrenched approaches perpetuating the standardized and generic under false promises of efficiency. Appropriately, forms of buildings are not designed in response to changing fashions or the whims and fancies of starchitects but are organically **grown** from their requirements and surroundings in digitally **simulated processes of morphogenesis**. Form is no longer a given, or, for that matter, even the main focus of an architects' work, but a necessary outcome and always a **response** to the specific **conditions** in which it exists. Here the arrays of equally spaced inert boxes that were once generic cities suddenly find themselves in the midst of intense **diversification** as they finally start to respond to their citizens and environment.

Wherever we turn a different city is emerging. Many are **Sustainable**; every form, space and material directly responding to their ecological characteristics to minimise their environmental impact. Some are **Hyperdense**, taking advantage of every possible building space without denying their occupants qualities of sunlight and view. Their relatives, **Porous** cities, balance density with porosity to increase outdoor space by creating vertical urban fabric complete with gardens, public spaces, streets and private sunlit terraces at every imaginable height. Other cities are **Hypercontextual**, extending the traditional city and its patterns into new, sometimes surreal, spatial compositions while maintaining the distinct character and function of its spaces. Still others tightly adapt to their citizens, empowering them to co-create their homes by mediating between individual and collective desires leading to **Participatory** cities where physical communities can again evolve and flourish. Nonetheless, despite all the endless diversity and radical differences, they are all made possible by the same underlying process of **adaptation**; the future design paradigm.

Looking at these remarkable cities, one cannot help but wonder; **what is keeping us from living in such cities today?** In my opinion, only ourselves.

Jaka Korla



A P P E

N D I X

GLOSSARY

Explanation of used terms

ADAPTIVE: *providing, contributing to, or marked by adaptation : arising as a result of adaptation*

ADJACENCY: *describes whether two areas are next to each other. Can refer to two things that touch each other or have the same wall or border.*

AGENT-BASED MODEL: *a class of computational models for simulating the actions and interactions of autonomous agents (both individual or collective entities such as organizations or groups) with a view to assessing their effects on the system as a whole.*

AGGREGATION: *a group, body, or mass composed of many distinct parts or individuals.*

ALGORITHM: *a process or set of rules to be followed in calculations or other problem-solving operations, especially by a computer. In mathematics and computer science, a finite sequence of well-defined, computer-implementable instructions, typically to solve a class of problems or to perform a computation.*

BOTTOM-UP: *a bottom-up approach is the piecing together of systems to give rise to more complex systems, thus making the original systems sub-systems of the emergent system.*

BUBBLE DIAGRAM: *architectural bubble diagrams are sketches used at the preliminary phase of the design process for space planning and organization.*

BUILT FORM: *refers to the function, shape and configuration of buildings as well as their relationship to streets and open spaces.*

CELLULAR AUTOMATA: *a collection of "colored" cells on a grid of specified shape that evolves through a number of discrete time steps according to a set of rules based on the states of neighboring cells. The rules are then applied iteratively for as many time steps as desired.*

COMPUTATION: *any type of calculation that includes both arithmetical and non-arithmetical steps and which follows a well-defined model (e.g. an algorithm). Architecturally, digital computation harnesses computational power to generate outcomes through algorithmic processes; opposite to computerisation which uses the computer as a tool of representation relying on explicit modelling techniques.*

CONFIGURATION: *the relative disposition or arrangement of the parts or elements of a thing. / the particular arrangement or pattern of a group of related things*

CONTEXT: *the interrelated conditions in which something exists or occurs, environment, physical setting.*

COMPLEXITY: *characterises the behaviour of a system or model whose components* *interact in multiple ways and follow local rules, meaning there is no reasonable higher instruction to define the various possible interactions.*

COMPLEX SYSTEM: *a system consisting of many diverse and autonomous but interrelated and interdependent components or parts linked through many (dense) interconnections. Complex systems cannot be described by a single rule and their characteristics are not reducible to one level of description. They exhibit properties that emerge from the interaction of their parts and which cannot be predicted from the properties.*

COMPOSITION: *the act or process of composing / specifically : arrangement into specific proportion or relation and especially into artistic form.*

DATASET: *a collection of related sets of information that is composed of separate elements but can be manipulated as a unit by a computer.*

DIAGRAM: *a simplified drawing showing the appearance, structure, or workings of something; a schematic representation.*

DISCRETIZATION: *in applied mathematics, discretization is the process of transferring continuous functions, models, variables, and equations into discrete counterparts. This process is usually carried out as a first step toward making them suitable for numerical evaluation and implementation on digital computers.*

EDGE: *also called links or lines; An edge is (together with vertices) one of the two basic units out of which graphs are constructed.*

EMERGENCE: *emergent properties are those which occur only when two or more subsystems or components are assembled into a system. An emergent property is a property of the system but not of any of the components; 'the whole is greater than the sum of the parts'.*

ENVIRONMENT FIELD: *a three-dimensional grid array of points spanning a defined volume of space, each point associated with a numerical value representing the measured intensity of either a single or a combination of defined environmental property.*

EVOLUTION: *descent with modification from preexisting species : cumulative inherited change in a population of organisms through time leading to the appearance of new forms : the process by which new species or populations of living things develop from preexisting forms through successive generations. Also, the scientific theory explaining the appearance of new species and varieties through the action of various biological mechanisms (such as natural selection, genetic mutation or drift, and hybridization).*

FORDISM: *the use in manufacturing industry of the methods pioneered by Henry Ford, typified by large-scale mechanized mass production.*

GENOTYPE: *a genotype is an organism's complete set of heritable genes, or genes that can be passed down from parents to offspring. These genes help encode the characteristics that are physically expressed (phenotype) in an organism.*

GRAPH: *a diagram (such as a series of one or more points, lines, line segments, curves, or areas) that represents the variation of a variable in comparison with that of one or more other variables. A graph drawing should not be confused with the graph itself (the abstract, non-visual structure) as there are several ways to structure the graph drawing.*

GENERATIVE: *having the power or function of generating, originating, producing, or reproducing.*

HOLISTIC: *dealing with or treating the whole of something or someone and not just a part.*

INTENSITY: *the measurable amount of a property, such as force, brightness, or a magnetic field.*

METHODOLOGY: *the rationale for the research approach, and the lens through which the analysis occurs. Said another way, a methodology describes the "general research strategy that outlines the way in which research is to be undertaken".*

METHOD: *a particular procedure for accomplishing or approaching something, especially a systematic or established one. A method is simply the tool used to answer your research questions — how, in short, you will go about collecting your data.*

MORPHOGENESIS: *the biological process that causes an organism to develop its shape. It is one of three fundamental aspects of developmental biology along with the control of cell growth and cellular differentiation, unified in evolutionary developmental biology.*

MORPHOLOGY: *the study of the forms of things. / a particular form, shape, or structure*

NETWORK: *a group or system of interconnected people or things.*

NODE: *see: Vertex.*

NOTATION: *the act, process, method, or an instance of representing by a system or set of marks, signs, figures, or characters. / a system of characters, symbols, or abbreviated expressions used in an art or science or in mathematics or logic to express technical facts or quantities.*

OPTIMIZATION: *an act, process, or methodology of making something (such as a design, system, or decision) as fully perfect, functional, or effective as possible. Specifically, the mathematical procedures (such as finding the maximum of a function) involved in this.*

PARAMETER: *a numerical or other measurable factor forming one of a set that defines a system or sets the conditions of its operation.*

PATTERN: *a reliable sample of traits, acts, tendencies, or other observable characteristics of a person, group, or institution / a reliable sample of traits, acts, tendencies, or other observable characteristics of a person, group, or institution*

PHENOTYPE: *the observable properties of an organism that are produced by the interaction of the genotype and the environment*

PHYLOGENY: *the evolutionary development and diversification of a species or group of organisms, or of a particular feature of an organism. It organizes things into categories, but implicitly requires that that organization the reflects an evolutionary relationship of those organisms.*

PROCEDURAL GENERATION: *In computing, procedural generation is a method of creating data algorithmically as opposed to manually, typically through a combination of human-generated assets and algorithms coupled with computer-generated randomness and processing power. Commonly used in the gaming industry to automatically create large amounts of content in a game.*

RELATIONAL: *concerning the way in which two or more people or things are connected.*

SCALAR FIELD: *in mathematics and physics, a scalar field associates a scalar value to every point in a space – possibly physical space. The scalar may either be a mathematical number or a physical quantity.*

SHAPE GRAMMAR: *a set of shape rules that apply in a step-by-step way to generate a set, or language, of designs. Shape grammars are both descriptive and generative. The rules of a shape grammar generate or compute designs, and the rules themselves are descriptions of the forms of the generated designs.*

SOCIO-SPATIAL: *Relating to sociological aspects of (mostly urban) spaces. The socio-spatial perspective in urbanism research addresses how built infrastructure and society interact. It assumes that social space operates as both a product and a producer of changes in the metropolitan environment.*

SPATIAL NETWORK: *a spatial network is a graph in which the vertices or edges are spatial elements associated with geometric objects, i.e. the nodes are located in a space equipped with a certain metric. Usually used where the underlying space is relevant and where the graph's topology alone does not contain all the information.*

SPATIAL RELATIONSHIP: *a spatial relation specifies how some object is located in space in relation to some reference object. Architecturally, this can describe many qalities such as adjacency, connectivity, distance relations, etc.*

STRUCTURE: *the arrangement of and relations between the parts or elements of something complex.*

SYSTEM: *a set of principles or procedures according to which something is done; an organized scheme or method.*

TAXONOMY: *is the practice and science of classification of things or concepts,* *including the principles that underlie such classification.*

TOP-DOWN: *the breaking down of a system to gain insight into its compositional sub-systems in a reverse engineering fashion. In a top-down approach an overview of the system is formulated, specifying, but not detailing, any first-level subsystems. Each subsystem is then refined in yet greater detail, sometimes in many additional subsystem levels, until the entire specification is reduced to base elements.*

TOPOLOGY: *the study of geometrical properties and spatial relations unaffected by the continuous change of shape or size of figures. / the way in which constituent parts are interrelated or arranged.*

TYPE: *a particular kind, class, or group*

TYPOLOGY: *study of or analysis or classification based on types or categories*

URBAN FORM: *urban form is the physical characteristics that make up built-up areas, including the. shape, size, density and configuration of settlements. It can be considered at different. scales: from regional, to urban, neighbourhood, 'block' and street.*

URBAN FABRIC: *the physical aspect of urbanism, emphasizing building types, thoroughfares, open space, frontages, and streetscapes but excluding environmental, functional, economic and sociocultural aspects. / Urban fabric is the physical form of towns and cities.*

URBANIZATION: *increase in the proportion of a population living in urban areas.*

VERNACULAR: *architecture characterised by the use of local materials and knowledge, usually without the supervision of professional architects. Vernacular architecture represents the majority of buildings and settlements created in pre-industrial societies and includes a very wide range of buildings, building traditions, and methods of construction.*

VERTEX: *also called nodes or points; is the fundamental unit of which graphs are formed.*

VISUAL PROGRAMMING: *any programming language that lets users create programs by manipulating program elements graphically rather than by specifying them textually.*

VOXEL: *a unit of graphic information that defines a point in three-dimensional space. In computer-based modelling each of an array of elements of volume that constitute a notional three-dimensional space, especially each of an array of discrete elements into which a representation of a three-dimensional object is divided.*

BIBLIOGRAPHY

References and further reading

1. Global Urbanization. (n.d.). Retrieved July 05, 2020, from https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

2. Živković J. (2019) Urban Form and Function. In: Leal Filho W., Azeiteiro U., Azul A., Brandli L., Özuyar P., Wall T. (eds) Climate Action. Encyclopedia of the UN Sustainable Development Goals. Springer, Cham

3. Population. (n.d.). Retrieved October 13, 2020, from https://ourworldindata.org/grapher/projected-population-by-country?tab=chart

4. Mumford, L. (1961). The city in history : its origins, its transformations, and its prospects. Harcourt, Brace & World.

5. Koolhaas, R., Mau, B., Sigler, J., Werlemann, H., & Office for Metropolitan Architecture. (1998). Small, medium, large, extra-large : office for metropolitan architecture, rem koolhaas, and bruce mau (2d ed.). Monacelli Press.

6. Verebes, T. (2015). Cities and their specificities: standards, customs and the making of 21st-century urbanity. Architectural Design, 85(6), 8–17. https://doi.org/10.1002/ad.1971

7. Gelernter, M. (1995). Sources of architectural form : a critical history of western design theory. Manchester University Press.

8. Shane, D. G. (2011). Transcending type: designing for urban complexity. Architectural Design, 81(1), 128–134. https://doi.org/10.1002/ad.1197

9. Habraken, J. (1998). Type as a social agreement.

10. Lambert, L. (2016, January 14). Why do Architects dream of a World without them? Retrieved October 13, 2020, from https://thefunambulist.net/architecture/architecture-without-architects-why-do-architects-dream-of-a-world-without-them

11. Alexander, C., Ishikawa, S., & Silverstein, M. (1977). A pattern language : towns, buildings, construction. Oxford University Press.

12. De Landa, M. (2011). Philosophy and simulation: The emergence of synthetic reason. London: Continuum.

13. Hillier, B. (1996). Space is the machine : a configurational theory of architecture. Cambridge University Press.

14. Space Syntax. (n.d.). Retrieved October 13, 2020, from https://www.spacesyntax.online/overview-2/

15. Hillier, B., & Hanson, J. (1984). The social logic of space. Cambridge University Press.

16. Alexander, C. (1964). Notes on the synthesis of form. Harvard University Press.

17. Van Eyck, A. (1962). Steps Towards a Configurative Discipline.

18. Carlson, S. (2010, July 30). Königsberg bridge problem. Retrieved October 13, 2020, from https://www.britannica.com/science/Konigsberg-bridge-problem

19. March, L., & Steadman, P. (1971). The geometry of environment: an introduction to spatial organization in design. RIBA Publications.

20. Spatial network. (n.d.). In Wikipedia. Retrieved July 05, 2020, from https://en.wikipedia.org/wiki/Spatial_network

21. Gorny, R. A. (2019). Lecture; On Types and Typology: A critique of typological thinking

22. Hays, K. M. (1998). Oppositions reader : selected readings from a journal for ideas and criticism in architecture, 1973-1984. Princeton Architectural Press.

23. Argan, G. C. (1963). On the Typology of Architecture.

24. Lee, C. C. (2011). The City as a Project: Type. Retrieved July 05, 2020, from http://thecityasaproject.org/2011/08/type/

25. Colquhoun, A. (1969). Typology and design method. Perspecta, 12, 71–74.

26. Jonghoon Im & Jiae Han (2015) Typological Design Strategy of FOA's Architecture, Journal of Asian Architecture and Building Engineering, 14:2, 443-449, DOI: 10.3130/jaabe.14.443

27. Jacoby, S. (2015). Type versus typology introduction. The Journal of Architecture, 20(6), 931–937. https://doi.org/10.1080/13602365.2015.1115600Toyo ito el croquis 1996

28. Itō, T. (1994). El croquis 71: 1986-1995. Madrid, España: ARCE.

29. Allen, S. (1998). Diagrams matter. Any: Architecture New York, 23(23), 16–19.

30. Visual programming language. (n.d.). Retrieved October 13, 2020, from https://en.wikipedia.org/wiki/Visual_programming_language

31. Appacitive. (2020, July 24). Appacitive software Data Explorer. Retrieved October 13, 2020, from https://vimeo.com/84661858

32. Hosick, E. (n.d.). Interface Vision. Retrieved October 13, 2020, from http://blog.interfacevision.com/design/design-visual-progarmming-languages-snapshots/

33. Collapsible Force Layout. (n.d.). Retrieved October 13, 2020, from https://bl.ocks.org/mbostock/1062288

34. Genotype vs. Phenotype. (2020). Retrieved July 05, 2020, from https://evolution.berkeley.edu/evolibrary/article/genovspheno_01

35. De Landa, M. (1998). Deleuze, diagrams, and the genesis of form. Any: Architecture New York, 23(23), 30–34.

36. Somol, R. E. (1998). The diagrams of matter. Any: Architecture New York, 23(23), 23–26.

37. Eisenman, P. (2001). Diagram diaries. Thames and Hudson.

38. Hosick, E. (2014). Interface Vision. Retrieved July 05, 2020, from http://blog.interfacevision.com/design/design-visual-progarmming-languages-snapshots/

39. Scalar field. (n.d.). In Wikipedia. Retrieved July 05, 2020, from https://en.wikipedia.org/wiki/Scalar_field

40. Veloso, P., Rhee, J., & Krishnamurti, R. (2019). Multi-agent Space Planning A literature review (2008-2017).

41. Pirouz, N. (2016). Configraphics: graph theoretical methods for design and analysis of spatial configurations, 14(14), 1–348. https://doi.org/10.7480/abe.2016.14

42. Mereology. https://lab-eds.org/About-lab-eds

43. About Wallacei. (n.d.). Retrieved October 13, 2020, from https://www.wallacei.com/about

44. Meyboom, Annalisa & Reeves, Dave. (2013). Stigmergic Space.

45. Discretization. (n.d.). In Wikipedia. Retrieved July 05, 2020, from https://en.wikipedia.org/wiki/Discretization

46. Derix, C., & Izaki Åsmund (Eds.). (2014). Empathic space : the computation of human-centric architecture (Ser. Architectural design, volume 84, issue 5). John Wiley & Sons.

47. Allen, S. (2015). Field Conditions (1997). In The Digital Turn in Architecture 1992–2012, M. Carpo (Ed.). doi:10.1002/9781118795811.ch5

48. Carpo, M. (2019). Particlised: computational discretism, or the rise of the digital discrete. Architectural Design, 89(2), 86–93. https://doi.org/10.1002/ad.2416

49. Peters, B. (2013), Computation Works: The Building of Algorithmic Thought. Archit Design, 83: 8-15. doi:10.1002/ad.1545

50. Derix, C., & Izaki Åsmund. (2014). New curricula: syntonic systems. Architectural Design, 84(5), 122–129. https://doi.org/10.1002/ad.1818

51. Complex system. (n.d.). In Wikipedia. Retrieved July 05, 2020, from https://en.wikipedia.org/wiki/Complex_system

52. Janssen, P. H. T., Frazer, J. H., & Tang, M.-X. (2005). A framework for generating and evolving building designs. International Journal of Architectural Computing, 3(4), 449–470. https://doi.org/10.1260/147807705777781112

53. Veloso, P., Rhee, J., & Krishnamurti, R. (2019). Multi-agent Space Planning A literature review (2008-2017).

54. F. (2019, July 31). The Construction Labor Shortage: Will Developers Deploy Robotics? Retrieved July 05, 2020, from https://www.forbes.com/sites/columbiabusinessschool/2019/07/31/the-construction-labor-shortage-will-developers-deploy-robotics/

55. Shelden, D. (2020). Entrepreneurial practice: new possibilities for a reconfiguring profession. Architectural Design, 90(2), 6–13. https://doi.org/10.1002/ad.2541

56. Retsin, G. (2019). Discrete architecture in the age of automation. Architectural Design, 89(2), 6–13. https://doi.org/10.1002/ad.2406Algorithms in use

57. Lynn, G. (2020), Architects = Innovators (sometimes) Innovators ≠ Entrepreneurs (most of the time). Archit. Design, 90: 120-127. doi:10.1002/ad.2555

58. Smithson, A. (1974). How to recognise and read Mat-building. Architectural Design.

59. Koolhaas, R., & Biraghi, M. (2013). Delirious New York. Milano: Electa.

60. Hulsman, B. (2019, June 13). The Noble Beauty of the Terraced House. Retrieved October 13, 2020, from https://the-low-countries.com/article/the-noble-beauty-of-the-terraced-house

61. Gemeente Rotterdam. (n.d.). Rotterdam kiest voor goede en slimme groei. Retrieved October 13, 2020, from https://www.rotterdam.nl/wonen-leven/goede-en-slimme-groei/

62. Minervahuis Meent, Rotterdam. (n.d.). Retrieved October 13, 2020, from http://www.minervahuis.nl/

63. Gemeente Rotterdam. (n.d.). Regels voor hoogbouw. Retrieved October 13, 2020, from https://www.rotterdam.nl/wonen-leven/hoogbouwvisie/

64. Fabrizi, M. (2018, February 09). The Free University of Berlin. Retrieved October 13, 2020, from http://socks-studio.com/2015/10/29/the-free-university-of-berlin-candilis-josic-woods-and-schiedhelm-1963/

65. https://ec.europa.eu/eurostat?

66. Chaillou, S. (2019, July 09). AI & Architecture. Retrieved October 13, 2020, from https://towardsdatascience.com/ai-architecture-f9d78c6958e0

67. Whitney, V. (2018, September 03). Computation in Space Planning. Retrieved October 13, 2020, from https://medium.com/data-mining-the-city/computation-in-space-planning-and-sequencing-f8e279fa9755

68. Dunne, A., & Raby, F. (2013). Speculative everything : design, fiction, and social dreaming. MIT Press.

FIN.

CONFIGURATIONAL MORPHOLOGY is a research and design project exploring the potentials of configurational design as a systematic approach to generating site-specific urban form responsive to its environmental, social end economic context. By looking into both the theoretical potentials of configurational thinking as well as its practical application in the form of design experiments, the project manages to paint a comprehensive picture of how a configurational design process could be structured and what benefits it could bring. From its historical precedents and roots in vernacular architecture, through its analytical capacity to abstract and visualise the socio-spatial patterns of existing cities, its applicability as a digital design interface mediating between humans and machines, its compatibility with advanced computational techniques to finally its ability to generate bottom-up adaptive urban form, the experiments reinforce the idea that such a design approach could indeed be possible as well as feasible.

Throughout, an underlying theme guides the project; a vision of the future city in which generic cookie-cutter urban fabric is replaced by customised adaptive urban forms of tremendous diversity. With it returns local identity, the richness of spatial experiences, increased performance and sustainability, higher density, increased equality and much more. Simultaneously, traditional socio-spatial structures are deconstructed and can be translated to other previously unimaginable forms such as a high-rise row house or a slab functioning as a courtyard block offering completely new possibilities for urban living. The result is a city of infinite opportunities; a city in which our social patterns, buildings, the environment and the urban fabric again become an indistinguishable whole adapted to contemporary urban life and fit for the future of our society.