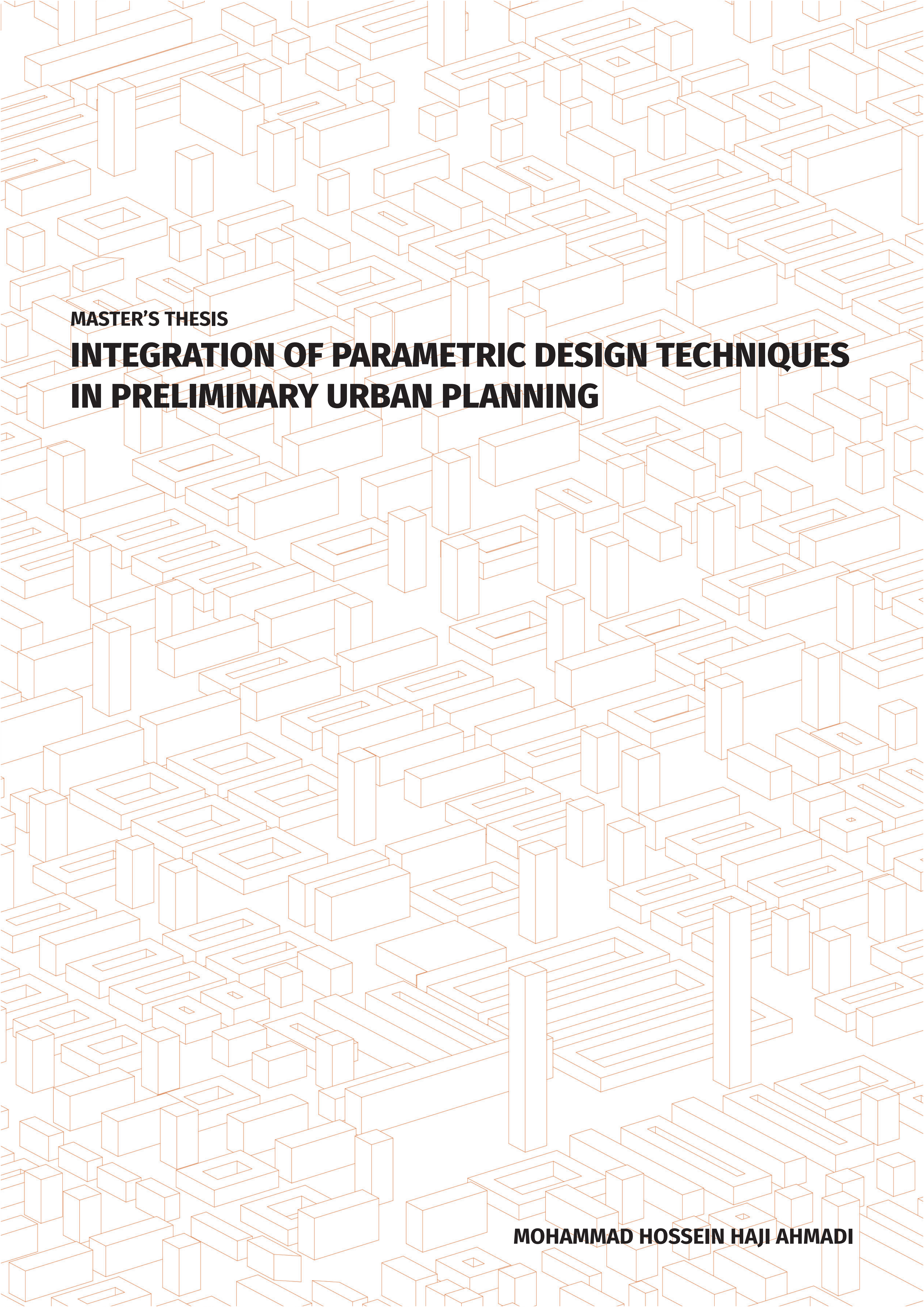

MASTER'S THESIS

INTEGRATION OF PARAMETRIC DESIGN TECHNIQUES IN PRELIMINARY URBAN PLANNING

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Master's Thesis

Integration of Parametric Design Techniques in Preliminary Urban Planning

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I am truly grateful to all of these people, as this thesis, and this entire experience, would not have been possible without their support. I hope I can show my appreciation through continued growth, dedication, and the pursuit of excellence.

CONTENT

ABSTRACT

This thesis explores how parametric design, with its techniques and tools, can support urban planners in the early stages of planning by enabling the generation and evaluation of multiple design scenarios based on municipal regulations and urban principles. Parametric tools use data as input to produce a range of alternatives, allowing planners to test, analyze, and select optimal solutions according to specific criteria and needs. Following a review of the topic, the research focuses on extracting key urban principles such as density, mobility networks, geometry, and space syntax and translating them into parameterized formats suitable for computational design tools.

To evaluate the practical value of this approach, a parametric design process is applied to a real urban site in Turin, Italy. This design process does not aim to deliver a final planning solution for the site, but rather to demonstrate the potential of using parameters and parametric tools during the preliminary phase of urban design. The ultimate goal of the thesis is to assess to what extent parametric techniques can enhance and accelerate early-stage urban planning, and to identify their potential benefits and limitations in professional practice. If the approach proves feasible, it may offer a flexible system that can be adapted to other sites and planning contexts.

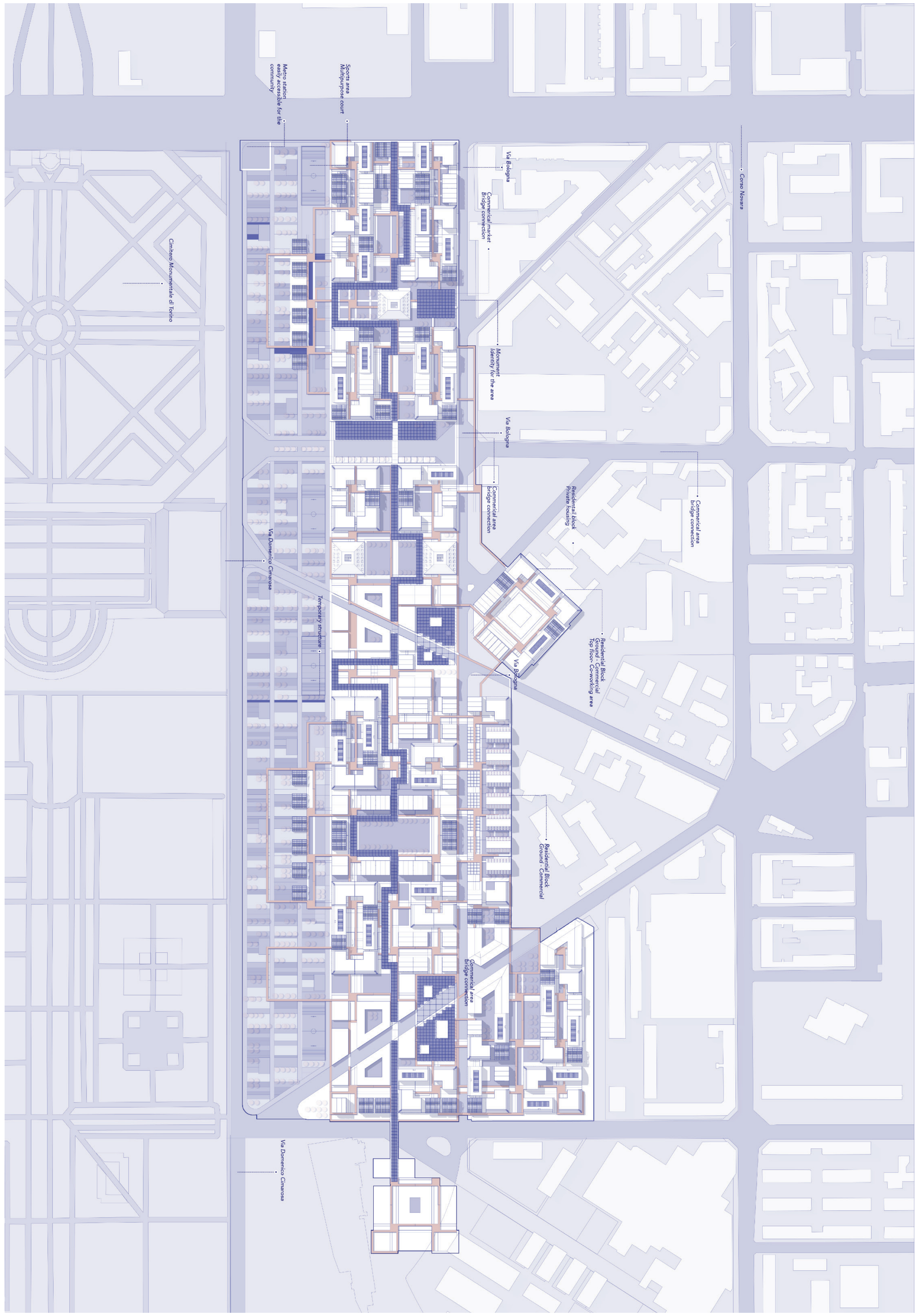


Fig 1. *Computational masterplan in Turin. Source: Author*

INTRODUCTION

This thesis aims to respond to the growing need for adaptive and efficient urban planning solutions by exploring the potential of **parametric techniques** and tools in the **preliminary phases of urban design**. The parametric approach has been selected for its ability to rapidly generate multiple design proposals based on input parameters defined by urban planners. These parameters are typically grounded in municipal regulations or broader **urban principles**, allowing for flexible yet controlled **scenario testing**.

My interest in this topic originated from the course **"Architecture and Computational Design"**, in which we examined an urban site using parametric tools. While that course addressed the topic in a broader and more conceptual way, this thesis narrows its focus to the early planning stages, aiming to establish a **structured and applicable workflow**.

The research includes a theoretical investigation of urban planning principles, the identification and parameterization of **key factors**, and a practical application to test these parameters in a real-world context. The selected site for this application is the **Ex Scalo Vanchiglia** area in Turin, which also served as the case study in the aforementioned course. By revisiting the site with a more focused and structured parametric framework, this thesis seeks to evaluate the practical relevance of such an approach in early-stage planning.

Objectives

The primary aim of this thesis is to explore how parametric tools and techniques can support urban planners during the preliminary phases of urban design. The research sets out to achieve the following specific objectives:

1. Investigate Urban Principles: To study key urban principles such as density, mobility, spatial structure, and form and identify those that can be translated into parameterized formats suitable for computational design tools.

2. Bridge Theory and Practice: To establish a workflow that connects theoretical urban knowledge with practical parametric parameters, and to test this workflow through application on a real-world site.

3. Assess the Role of Parametric Tools: To evaluate the extent to which parametric tools can assist urban designers in generating, analyzing, and selecting design alternatives during the early stages of planning.

4.Develop a Generalizable System: To propose a flexible parametric planning system that, if effective, can be adapted and applied to other urban sites in diverse contexts.

Methodology

To thoroughly explore the thesis topic, a **hybrid methodology** combining both theoretical and practical approaches is adopted.

In the **theoretical phase**, the research investigates the concept of parametric urban design through literature review and analysis of relevant case studies. The goal is to identify key urban principles that are suitable for parameterization such as **density, network structures, geometry, and spatial syntax**. These principles will then be translated into a set of **parameters**, which can be used within selected parametric tools.

In the **practical phase**, the identified principles and parameters are applied to a specific urban site Ex Scalo Vanchiglia in Turin. **Site-specific analysis** is conducted to complement and refine the chosen principles, ensuring their relevance to the context. Using pre-defined parametric tools, **multiple design alternatives** are generated during the preliminary design stage. This design exercise serves to evaluate how effectively the theoretical findings can be implemented in a real-world scenario, and to what extent parametric methods can support and accelerate early-stage urban planning.

Structure

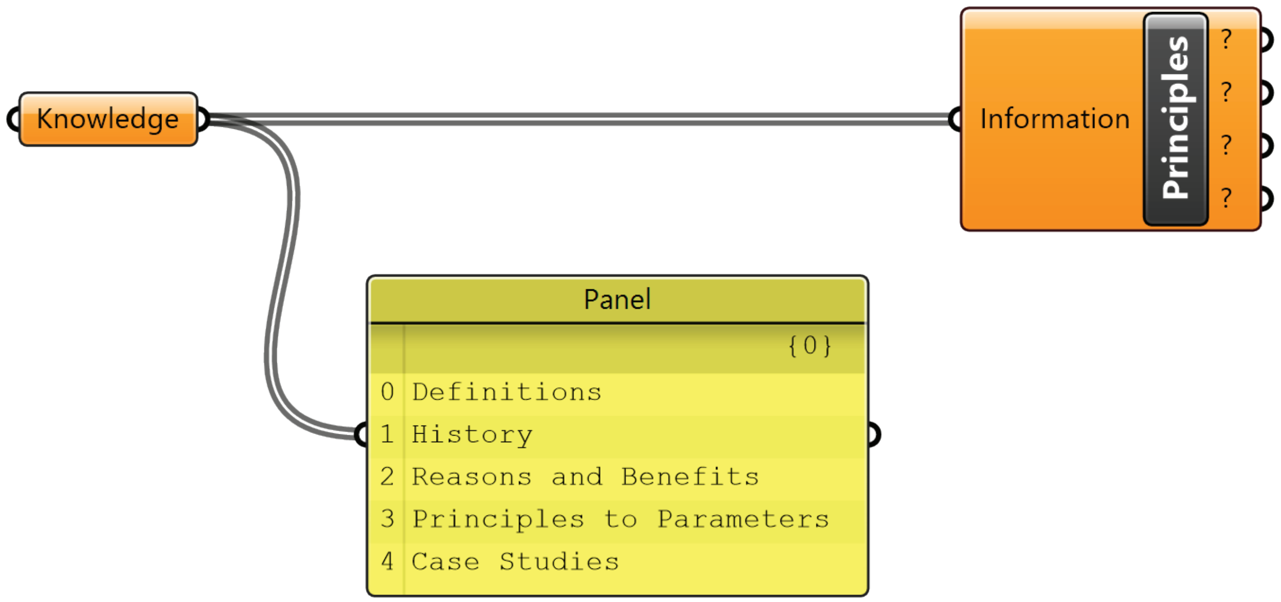
thesis begins with an overview of parametric urban design, including its historical development, benefits, and an analysis of existing case studies that have employed this approach. The second chapter explores the urban planning principles that can be parameterized, focusing on four key aspects: density, network, geometry, and space syntax. These principles are then translated into computational parameters, and the corresponding parametric tools used to implement them are defined.

Following the theoretical groundwork, the thesis moves into its practical phase, where the selected urban site Ex Scalo Vanchiglia in Turin—is analyzed. Site-specific conditions are examined and combined with the predefined parameters. Using parametric tools, the site is developed through iterative processes, generating multiple alternatives for networks, blocks, and building units. Each iteration is assessed according to predefined criteria to identify the most suitable outcome. The resulting preliminary urban plan is then visualized using AI-assisted software. The thesis concludes by reflecting on the effectiveness of the proposed parametric workflow and its potential to be generalized as a flexible system applicable to other urban contexts.

NOTE: To ensure clarity and reduce grammatical and typographical errors, AI-assisted writing tools were utilized throughout the development of this thesis.

PART 1

Background knowledge of parametric urban planning



1-1. WHAT IS PARAMETRIC URBAN PLANNING?

Parametric urban design is an approach to urban planning and design that uses computational algorithms to generate complex forms and patterns. It is based on the idea of setting up a system of rules and parameters that define the relationships between different elements of the urban environment. These rules can be adjusted to create a wide variety of outcomes, allowing for a more **adaptive** and **responsive** design process.

The concept of parametric urban design emerged as a response to the limitations of traditional urban planning methods, which often relied on rigid, top-down approaches. Instead, parametric design embraces the **complexity** and **dynamism** of cities by allowing for incremental changes and emergent patterns to develop over time.

In practice, parametric urban design involves the use of software tools that can manipulate data and parameters to explore different design possibilities. This can include everything from the layout of streets and buildings to the distribution of green spaces and public amenities. By using parametric models, urban designers can quickly test and refine their ideas, leading to more **innovative** and **sustainable** urban solutions. (Caliskan,2017)

1-2. HISTORY OF PARAMETRIC URBAN PLANNING?

Parametric design has long been a part of architectural practice. From the construction of **ancient pyramids** to the realization of modern institutions, architectural forms have historically responded to a range of **dynamic influences** such as climate, technology, functionality, context, and cultural values. The advent of computers did not create parametric thinking, nor did it fundamentally alter architecture as a discipline; however, it introduced a **powerful tool** that now allows architects to craft more innovative designs under both precise qualitative and quantitative parameters. (Philips, 2010)

It is well established that ancient civilizations incorporated **celestial alignments** and astronomical knowledge into the design of sophisticated structures oriented toward the sky. This approach persisted through classical eras when disciplines like mathematics, geometry, astronomy, and geography were deeply interconnected. As a result, the planning of monumental and intricate buildings was often shaped by **geometric principles** rooted in celestial and astrological calculations. For instance, early dome constructions by the Persians and Romans were inspired by astrological beliefs and the symbolic "dome of heaven." The Romans, in particular, associated domes with the celestial sphere. A prime example is the Pantheon in Rome, where architectural form was used to express divine presence and **cosmic harmony**. (Assasi, 2019)

"In the late 19th century Europe, there has been genuine approaches to parametric design among engineers and architects. For example, Antonio Gaudi used analog systems to design complex structural forms that were based on parametric experiments. For example, while designing the church of Colonia Guell, he used an analog **upside-down structural model** made of strings weighted down with birdshot to design interconnected arches and vaulted ceilings. He used the pulling weights in an upside-down tension-based model as a reverse structural model to design a complex system for the efficient distribution of dead loads. He placed a mirror at the bottom of the model to be able to study the architecture form while manipulating the loads." (Assasi, 2019)

Fig 2. *Transition of rectangles in Pantheon dome, Rome, Italy. Source: Archdaily.com*

Fig 3. *Analogue parametric mechanism used by Gaudi to design the Colonia Guell Church, Barcelona, Spain. Source: Assasi, 2019*

Evolution by technology

By the late 20th century, the concept of parametric architecture had entered mainstream architectural discourse. In 1960, Luigi Moretti introduced parametric stadium designs under the title of Parametric Architecture. A few years later, in 1965, he applied advanced computational methods in the design of the Watergate Complex, marking a pioneering use of computers in architecture. Moretti later published detailed reflections on how to define relationships among **spatial dimensions** based on **varying parameters**. (Assasi, 2019)

Moretti' idea about parametricism:
"In this way what I have long solicited and call 'parametric architecture' will be born. Its ineluctable geometric character, its **rigorous concatenation** of forms, the absolute freedom of fantasy that will spring up in places where equations cannot fix their own roots, will give it a crystalline splendour." (Frazer, 2016)

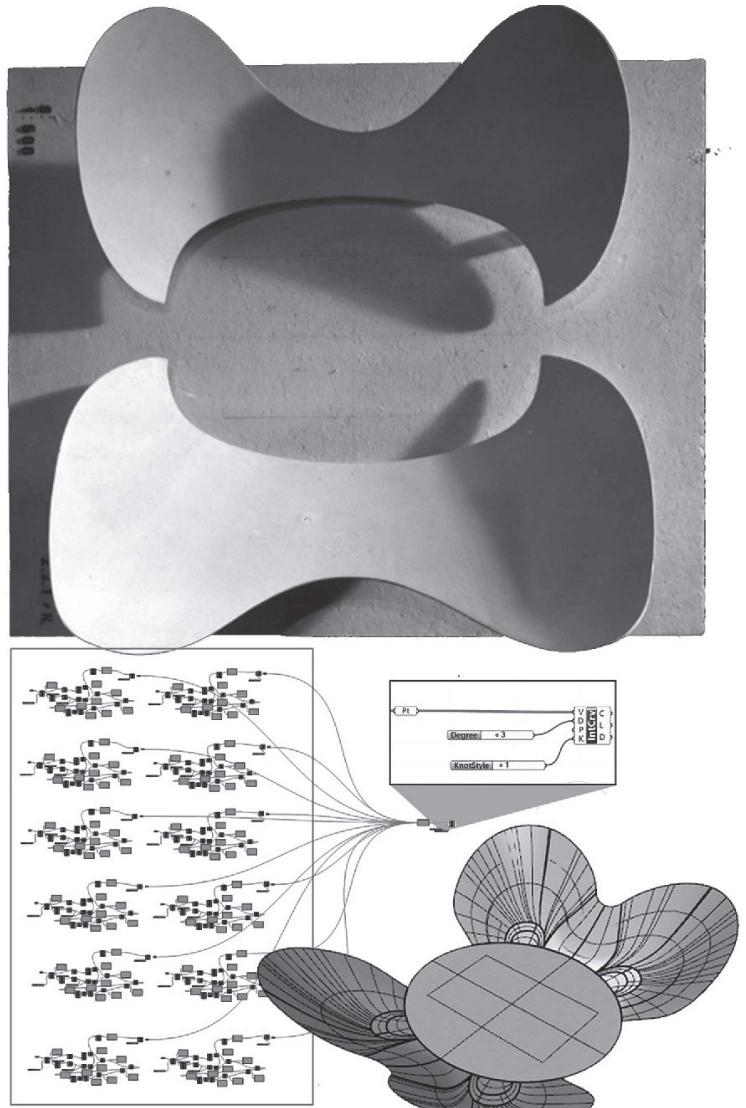


Fig 4. *Luigi Moretti algorithms transcription using Visual Aid for scripting (Grasshopper), Milan, Italy. Source: Representation L. Vitali.*

During the 1960s, Ivan Sutherland leveraged computers to build an interactive digital model that accelerated the processing of parametric equations. He developed Sketchpad, recognized as the first **computer-aided** design (CAD) software. Although he did not use the term "parametric," he referred to the mathematical expressions in the system as "**atomic constraints**."

Initially, CAD technology was too costly to gain traction in architectural practice. It wasn't until 1982—with the launch of AutoCAD and the rise of personal computers—that digital design became more accessible. However, true parametric features were only introduced in AutoCAD's 2010 release. The first widely adopted parametric software in engineering was Pro/ENGINEER, launched in 1988 by Samuel Geisberg. Unlike Sketchpad, it supported three-dimensional modeling and collaborative use. In 1993, Dassault Systèmes incorporated many of Pro/ENGINEER's parametric capabilities into CATIA v4. Gehry Partners used CATIA's functions for projects like the Guggenheim Museum in Bilbao during the early 1990s. These experiences later influenced the creation of Digital Project, a software developed by Gehry Technologies in 2004. (Assasi, 2019)

In early 2000s The use of parametric tools started to extend into urban planning. The ability to model **complex urban systems** and **simulate different scenarios** became invaluable. Urban planners began to see the potential for parametric design to handle large datasets and simulate the impact of various planning decisions. In 2003 he launch of software like Rhinoceros (Rhino) and Explicit history (named later Grasshopper) brought parametric design to a wider audience, including urban planners. Grasshopper, in particular, allowed users to visually script and create parametric models, making the approach more accessible.

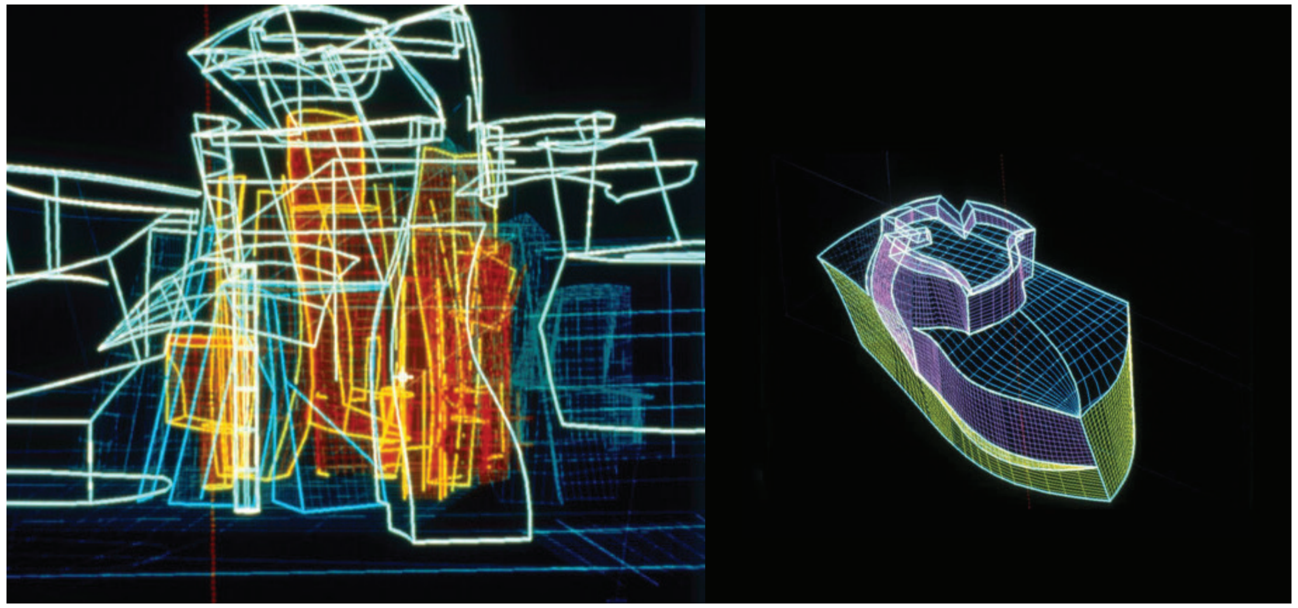


Fig 5. *Guggenheim in CATIA, Bilbao, Spain. Source: D. Davis, 2013*

1-3. WHY USING PARAMETRIC DESIGN IN URBAN PLANNING?

Parametric design has traditionally found its primary application within engineering fields. Nonetheless, the elements that make up urban design share characteristics that can also be expressed parametrically. Features such as **density, usage, mixture, form, spatial organization, and typology** can all be represented through parametric definitions. This approach not only enables a more systematic design workflow but also allows for the **assessment** of advantages and disadvantages across different parameter configurations.

For urban designers, adopting a parametric mindset can inspire innovative design solutions, as thinking in terms of parameters encourages breaking free from conventional and habitual **problem-solving** methods. In essence, parametric design provides an alternative conceptual framework for approaching design challenges. A significant benefit is its potential to **democratize** the creative process, moving it beyond the intellectual control of a single individual assuming effective **collaborative protocols** are established.

Designing through parametrically defined objects and constraints presents clear benefits over traditional design methods, whether digital or manual. Firstly, it preserves the intelligence embedded in **early design iterations**, enabling updates as more detailed data becomes available. Secondly, it facilitates conceptual design by allowing fundamental relationships to be explored through **relational constraints**.

Moreover, as Motta and Zdrahal highlight, parametric design is particularly advantageous when tasks involve **configuration design** where pre-existing elements must be arranged according to specific criteria. This characteristic may explain why parametric design has predominantly been utilized in engineering contexts, with considerably less application in architectural design to date. (Steino & Veirum, 2015)

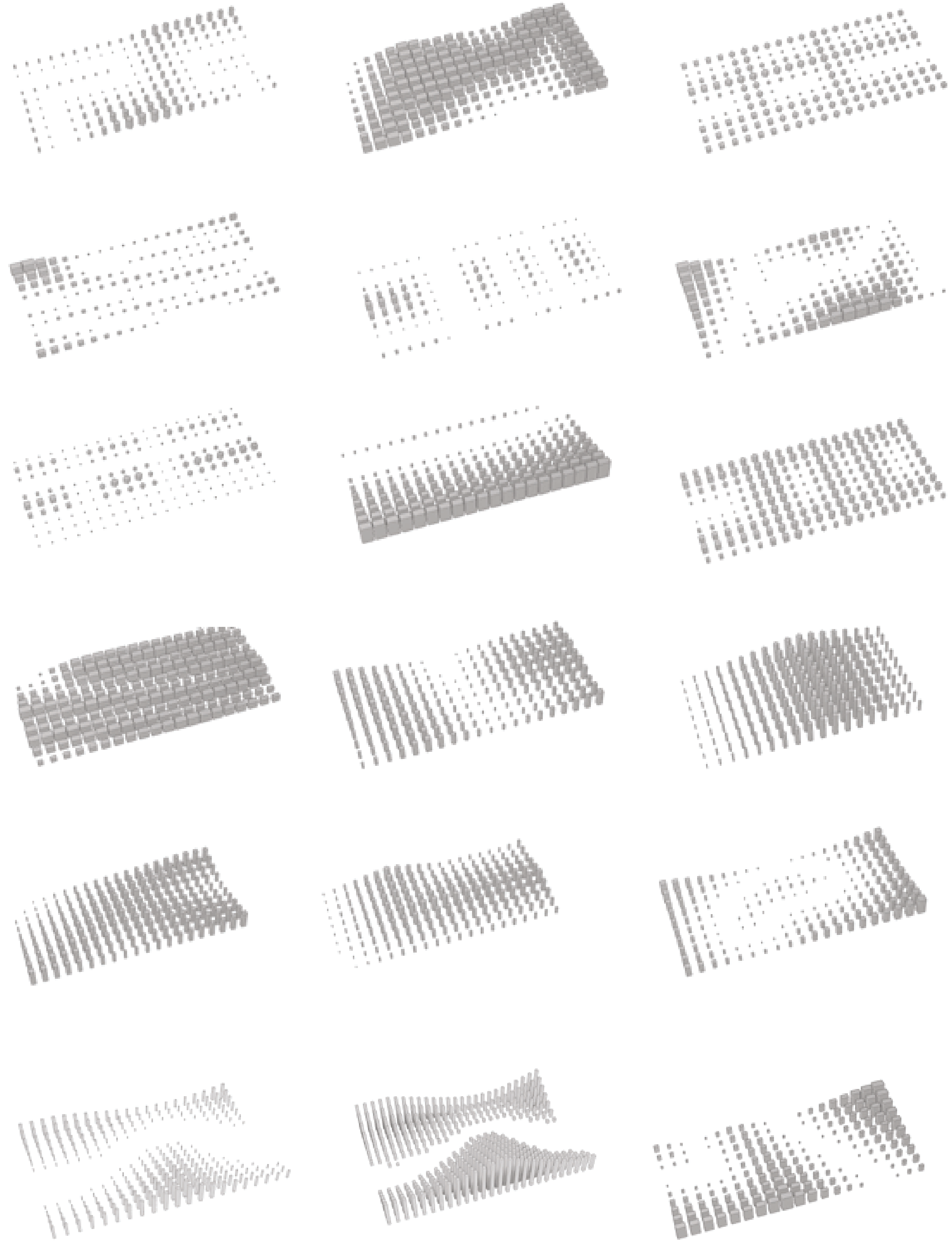


Fig 6 . *Parametric approach allows for the development of a series of urban organizational models, Source: S. Wooff, 2016.*

1-4. FROM PRINCIPLES TO PARAMETERS

As expressed in Jonathan Barnett's famous maxim that urban design is "designing cities without designing buildings," urban design often focuses on conceptual plans that set overall principles for urban development rather than detailed designs. In many practical cases, the intended outcome is expected to be developed using **predefined design elements**. Consequently, the design process consists of assembling and configuring these existing components to meet design requirements and constraints, often aiming to optimize factors such as cost. This category of design is known as configuration design.

Lykke-Olesen (2000) introduced the idea of urban design as a system of **interconnected and continually evolving data** in his thesis. To effectively manage this data in a computational model, he attempted to 'parameterize' them, that is to "... combine their relationships mathematically so that the model can be brought to life when these relationships are impacted." (Steino, 2015)

In the methodology of Parametric Urbanism, traditional geometric forms lose their prominence due to their rigidity and limited adaptability to diverse design challenges. Instead, they are replaced by solutions that are more intuitive, flexible, and responsive.

Parameterization, in this context, introduces its own set of principles, techniques, and characteristics moving away from fixed or inflexible approaches. It treats variables as dynamic, evolving, and responsive elements within the urban system, aligning with the continuous need for adaptability in urban design. In a parametric urban design project, spatial forms are developed in close relationship with other design components. Any change in one element triggers corresponding adaptations throughout the model. This results in an interactive and flexible urban proposal, where all variables are interlinked. As active parameters shift, the system updates itself accordingly, allowing the design to evolve while maintaining coherence and structural consistency with the original model. (Leach, 2009).

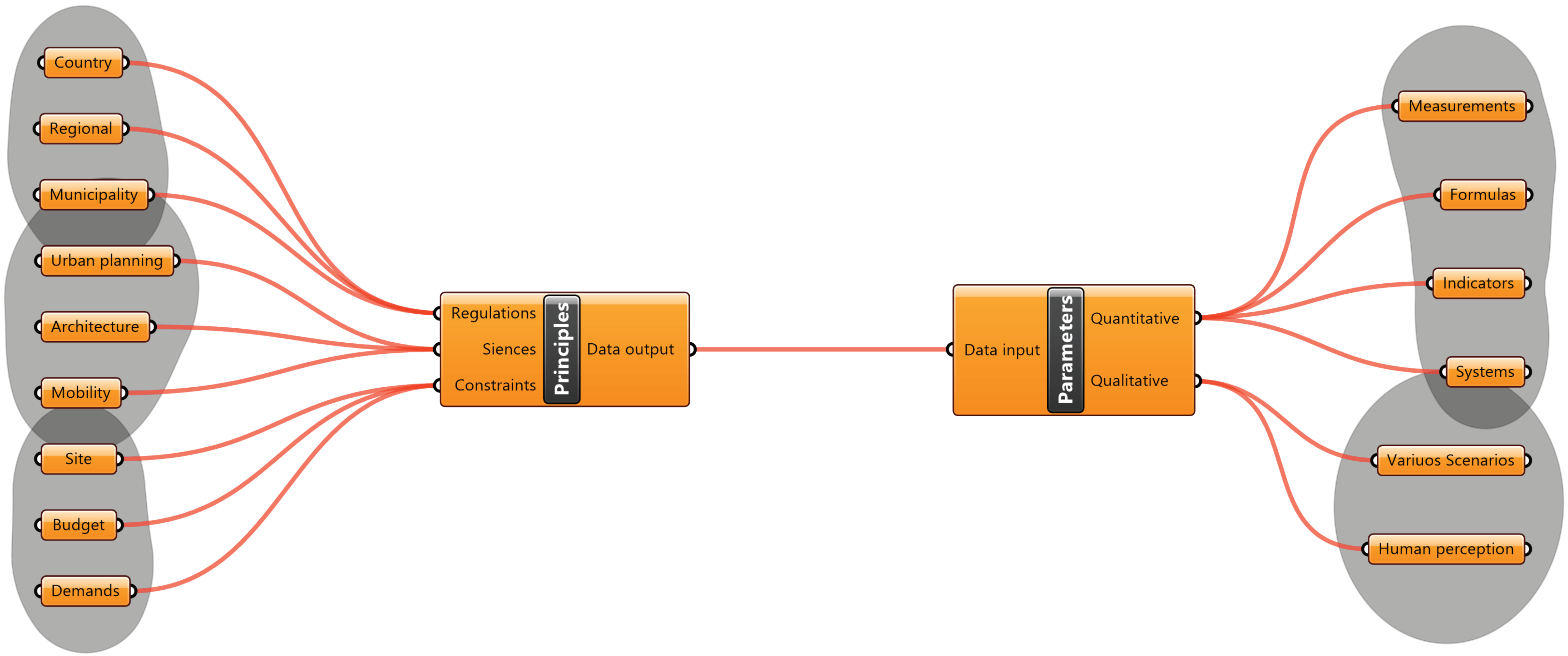


Fig 7. *From principle foundations to parametric results. source: Author*

1-5. CASE STUDIES

By exploring recent urban plans from different parts of the world, we can understand how the evolving use of parametric tools has become increasingly logical. The following case studies are pioneering examples of parametric urban plans, helping us recognize the key aspects of applying these tools in urban planning, as well as the exceptional outcomes they offer, providing a glimpse into the near future of cities.

1-5-1. Kartal-pendik Masterplan, Turkey

An example of a project that applies parametric methods to urban design is the Kartal Pendik Masterplan, developed in 2006. Created five years after the Singapore masterplan, this project demonstrates a more advanced and refined use of parametric approaches in urban planning. It takes its name from the effort to organize and enhance the urban area linking the districts of Kartal and Pendik in Istanbul. The existing street grids of both regions served as the foundation for defining a gently modified urban grid, designed to maintain continuity with the primary existing roadways. Beyond reinforcing these connections, the plan introduces a prominent avenue that intersects the grid, forming an integrated road network that links this part of the city to broader national and international systems, spanning both Asia and Europe. (Fusero, 2013)

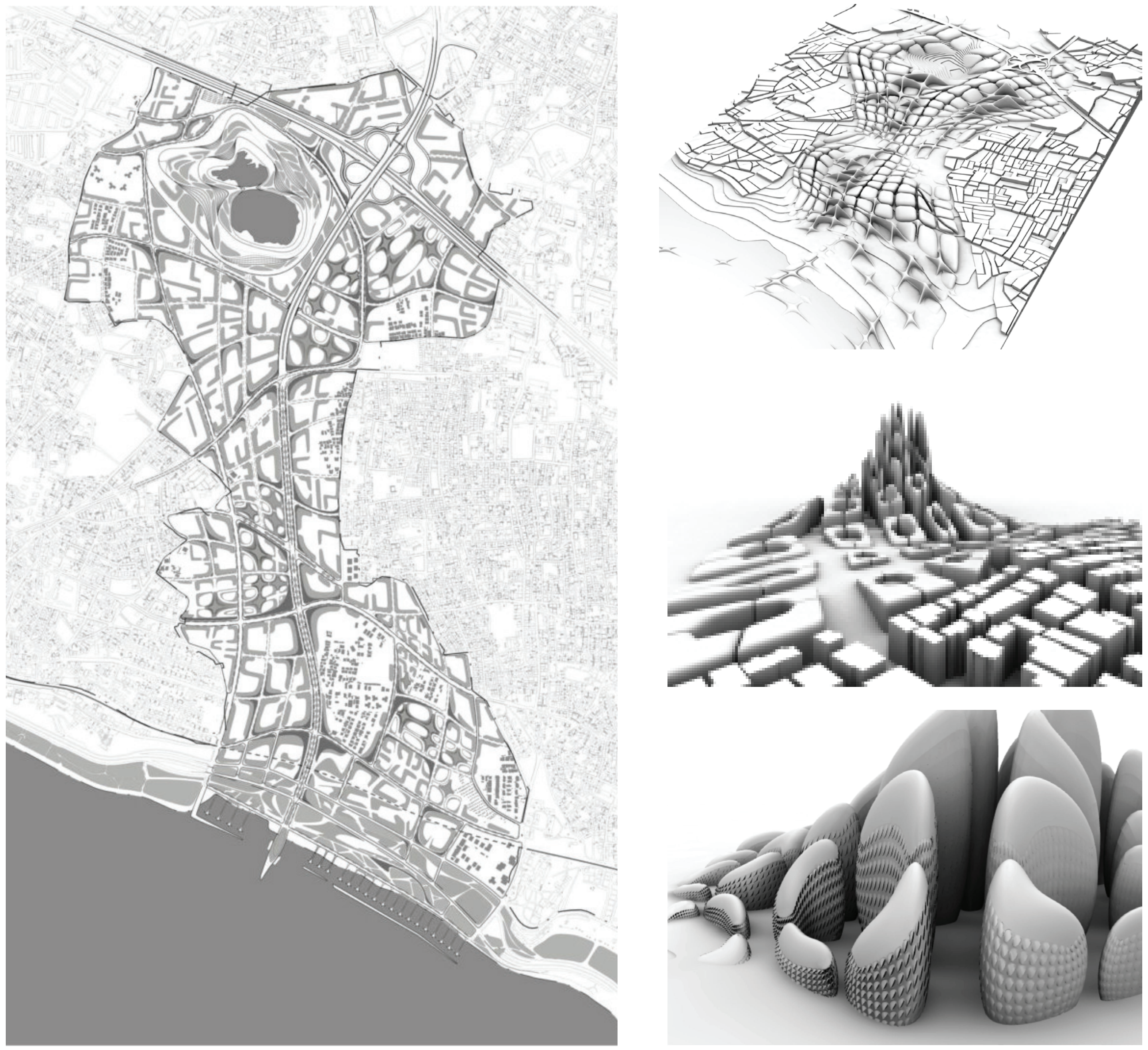


Fig 8. *Kartal-pendik Masterplan and views, Turkey. Source: Zaha Hadid Association*

1-5-2. 123, Dubai

The project titled 123 responds to the rapid and often disjointed urban growth in the Gulf region particularly the fragmented architecture spurred by globalization by investigating the algorithmic and geometric logic found in traditional Arabic patterns. This computational strategy forms the foundation of a new scripted morphology that introduces variation and differentiation throughout urban landscapes, clusters, and architectural configurations. The design seeks to establish dynamic and inclusive metropolitan environments that counter the generic, fragmented characteristics of contemporary urban models in Dubai, instead promoting adaptability within a structured and coherent system.

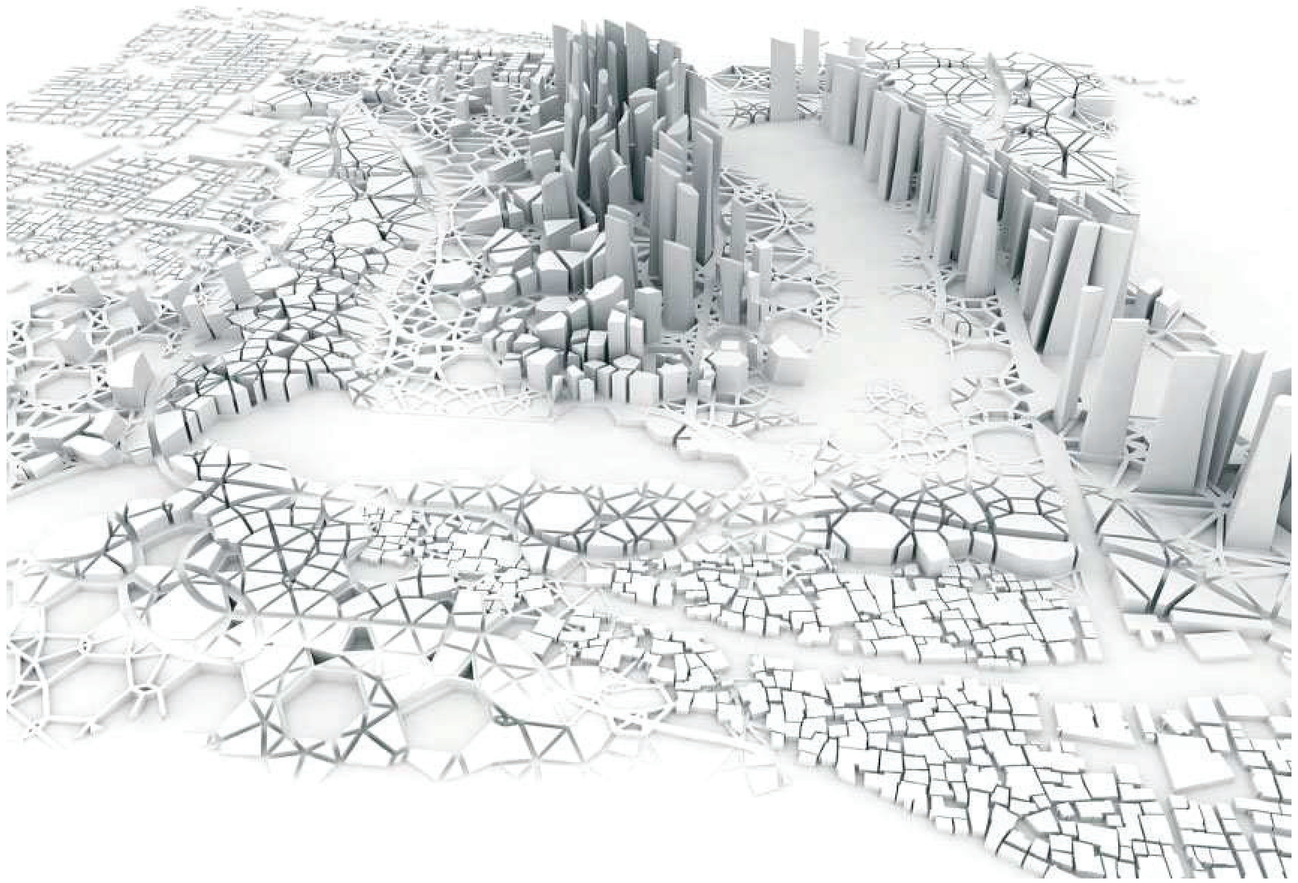


Fig 9. *Scripted morphology of 123 project , Dubai. Source: Design Research Lab, 2009*

1-5-3. One north, Singapore

Located in Singapore, One North is a business park established as a center for research and innovation, encompassing fields such as biomedical sciences, IT, and media. The masterplan was created by Zaha Hadid and her team at Zaha Hadid Architects, featuring multiple districts with specialized purposes. These zones are thoughtfully linked through green corridors and shared public facilities, fostering both connectivity and a cohesive urban environment.

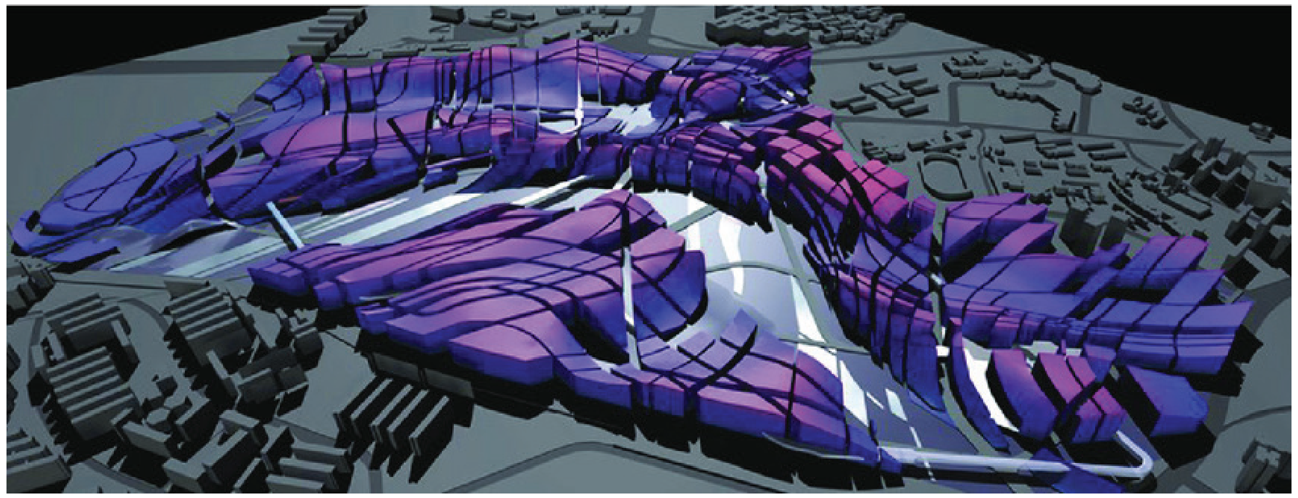


Fig 10. *Conceptual design and sketch of a parametric model . Source: Zaha Hadid Association*

1-5-4. Deep ground, China

The Longgang City Deep Ground project introduces the “thickened ground” concept, which redefines traditional urban planning by merging underground development with dynamic public spaces. This strategy creates a folded surface that integrates underground access, parking, and public programs within the Central Business District, blurring the boundary between architecture and landscape while fostering vibrant urban activities at street level.

Another significant aspect is the restoration of the Longgang River as an ecological corridor. By rejuvenating previously overlooked river spaces, the design incorporates green zones, public amenities, sports fields, and leisure areas. This ecological integration enhances the city’s environmental sustainability while addressing rainwater collection, flood defense, and water quality through strategic infrastructure.

Parametric design plays a pivotal role in uniting these elements by employing algorithmic models to craft a cohesive and adaptive urban fabric. This approach ensures that the multiple ground levels are seamlessly connected, fostering intuitive navigation and connectivity. The result is an innovative and flexible urban system that harmoniously integrates ecological and architectural considerations.

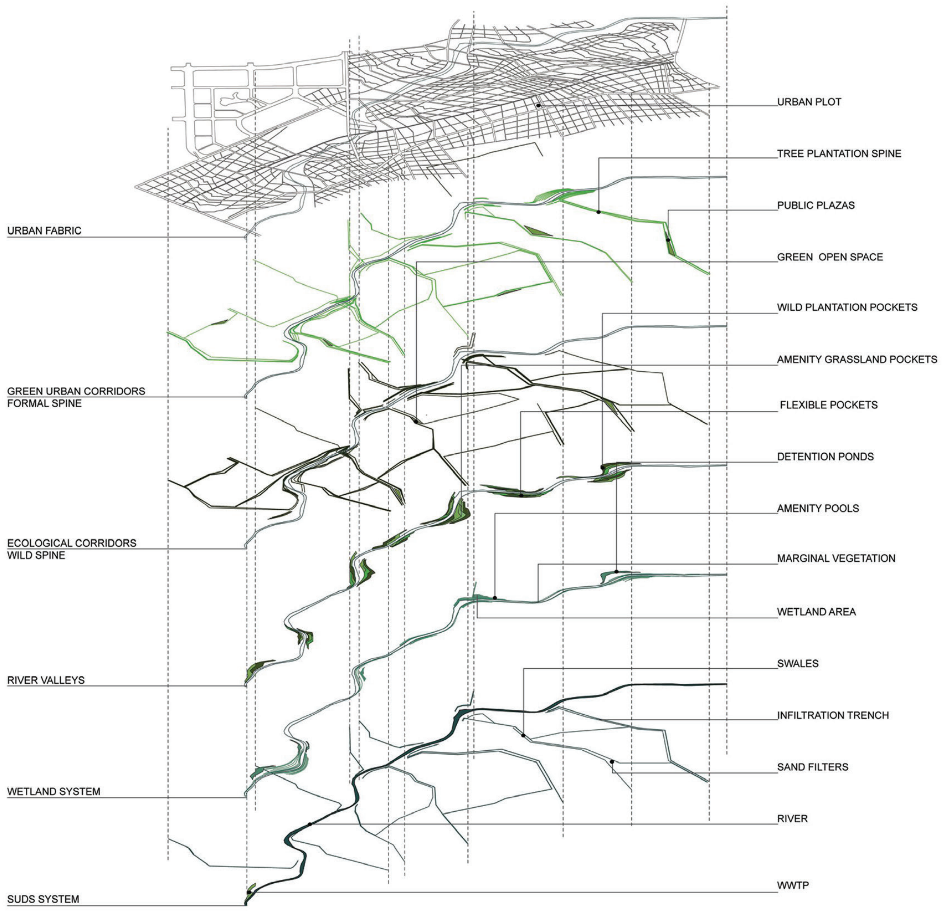
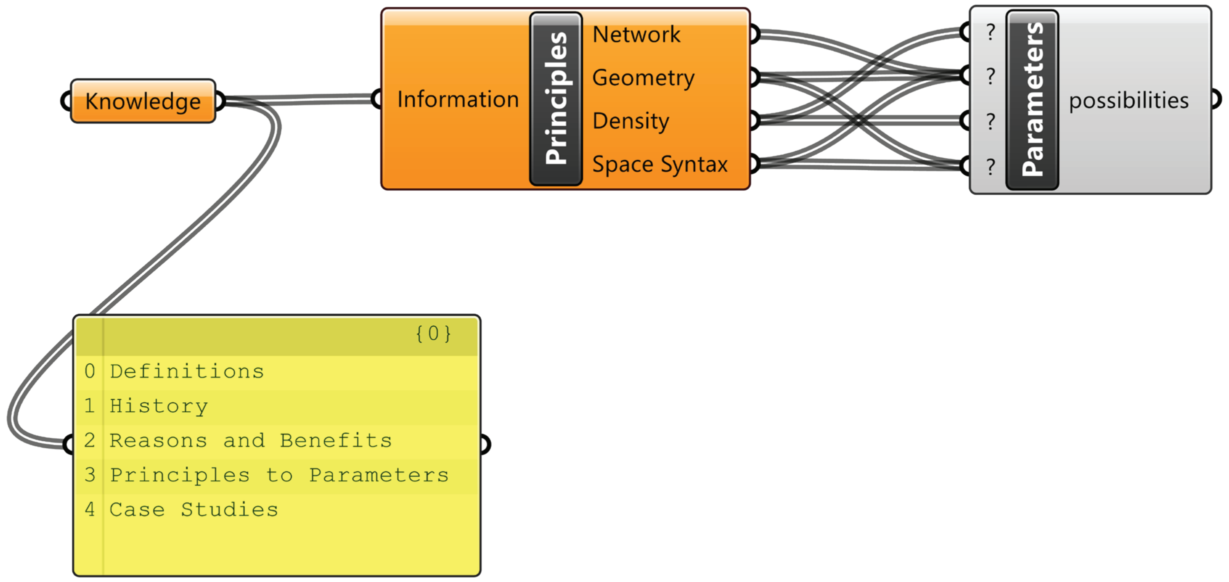


Fig 11. *Landscape network strategy of Longgang City Centre, Shenzhen, China. Source: Plasma Studio, 2008*

Fig 12. *Masterplan for the redevelopment of Longgang City Centre, Shenzhen, China. Source: Groundlab, 2008*

URBAN PRINCIPLES



Urban planning, like many other disciplines, is guided by established principles and rules that must be adhered to by designers and planners. These principles have deep historical roots, evolving alongside the development of cities. Urban planners have traditionally sought to identify and apply these **established principles**, whether set by previous planners or by governing authorities.

In some instances, planners have been able to introduce new rules or modify existing ones in response to economic, geographic, and cultural contexts, thereby creating a specific **framework** for their designs. Although this approach remains valid, the increasing complexity of principles and the diversity of rules have led modern planners to adopt new tools for their implementation.

In this section we learn about these foundation principles and in the next section, we explore how parametric techniques can facilitate design that aligns with various principles and rules in a more comprehensive yet simplified manner. To do so, we will examine urban rules and delve into some of the most important principles in detail.

2-1. GENERAL RULES

Alex Lehnerer, in his work **"Grand Urban Rules"**, identifies 115 different rules that are essential for any urban plan. He asserts that "rules supply design principles that represent alternatives and expansions of the conventional plan. They render design control adjustable ranging from a determinism that resembles automatism to an existential aura of personal responsibility. This **adjustability** is one of the most important preconditions for urban diversity, participation, vitality, and, not least of all, for urban design that is successful in the long term."

The book categorizes the rules into distinct thematic frameworks, such as *general declarations, superordinate land use rules, district-related land use rules, streetscape rules, neighborhood rules, plot/block rules, and building rules*. Each theme encompasses regulations derived from diverse urban contexts, reflecting **regional priorities** or **scholarly theories**. For instance, the 2-hour shadow rule in Zurich, which prohibits high-rises from casting more than two hours of shadow per day on residential areas, prioritizes sunlight access as a communal right. In contrast, New York's street wall length rule (limiting building facades to 185 feet in residential districts) emphasizes streetscape continuity. These examples illustrate how rules codify competing values: environmental equity versus formal order, or private development versus public welfare.

After listing these 115 rules, Alex Lehnerer analyzes their **real-world implications** through case studies, dissecting how abstract principles manifest or fail in practice. One such study examines the plaza bonus rule in Manhattan, where developers traded public space for extra height, yielding iconic spaces like Paley Park but also barren, windswept plazas. Through these cases, Lehnerer reveals a paradox: rules that succeed in one context may falter in another due to cultural or economic disparities. His critique extends to irrational rules, like uniform setback mandates, which ignore local topography or social patterns.

Ultimately, Lehnerer's case studies underscore that urban rules are neither neutral nor static. They are cultural artifacts, shaped by power dynamics (e.g., Paris's Haussmannian boulevard widths enforcing state control) or collective aspirations (e.g., San Gimignano's height thresholds preserving medieval identity). This tension, Lehnerer argues, demands rules that are specific enough to guide but open enough to adapt a lesson vital for contemporary cities grappling with climate crises and inequity. (Lehnerer, 2015)

Given the classifications discussed, **rule-based design** can be achieved by distinguishing between two ruling processes: the first involves codes used as **juridical instruments**, and the second involves codes used as **design tools.** This differentiation is not tied to the code itself but rather to the scope and process of **codification**.

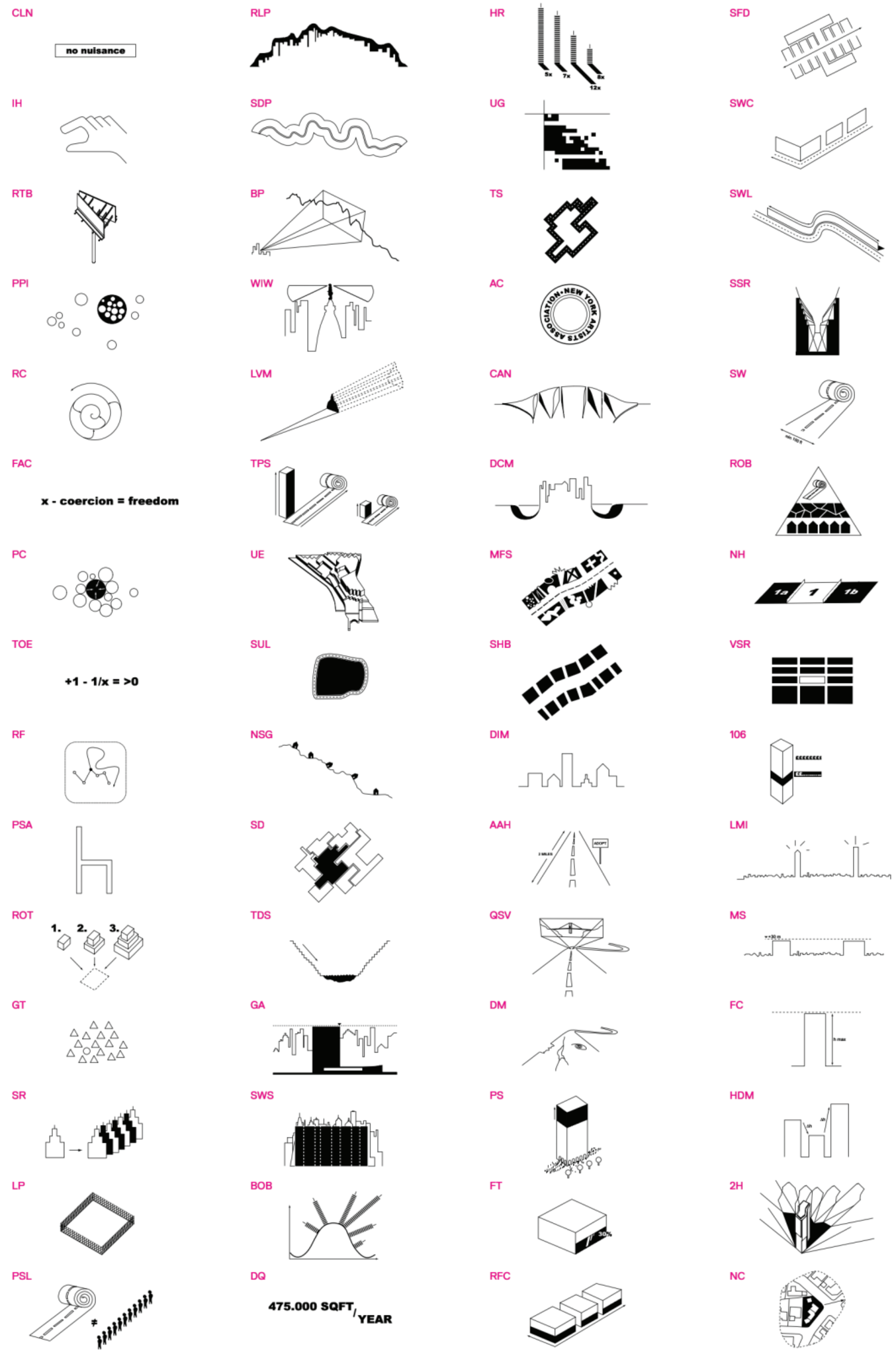


Fig 13. *Diagram index of Grand urban rules. Source: A. Lehnerer, 2015*

In recent decades, the ideology of managing city form and performance through predetermined plans has gradually lost its validity. Some contemporary urban planning theories advocate for the use of smart design techniques to manage urban complexity. Designers are increasingly less trained in dealing with urban rules, often seen as abstract patterns that define the physical relationships underlying urban form. These rules are typically the domain of municipal building authorities, administrators, lawyers, and economists. Although rules have often been perceived as potential constraints on artistic creativity, it is arguable that they have always underpinned the composition and control of urban form.

Several contemporary movements have explored the use and utility of design codes in various ways, proposing practical methods that frame urban composition into a series of small algorithms. For instance, in the foreword to his Notes on the Synthesis of Form, Christopher Alexander proposes an approach based on the idea that the physical complexity of a city can be resolved into a small system of interacting and conflicting independent patterns. Under the term **"generative planning and design"** Alexander and others propose a precise definition of generating systems, "whose parts and rules will (incrementally) create the necessary holistic system properties of their own accord." To establish these systems, it is necessary to identify and categorize the rules that guide urban design, ensuring that each aspect of the city's form and function is systematically addressed. (Pisano & De Luca, 2019).

Predetermined Static Rule-based Outdated

Algorithmic and generative Dynamic Rule and practice-based Updated

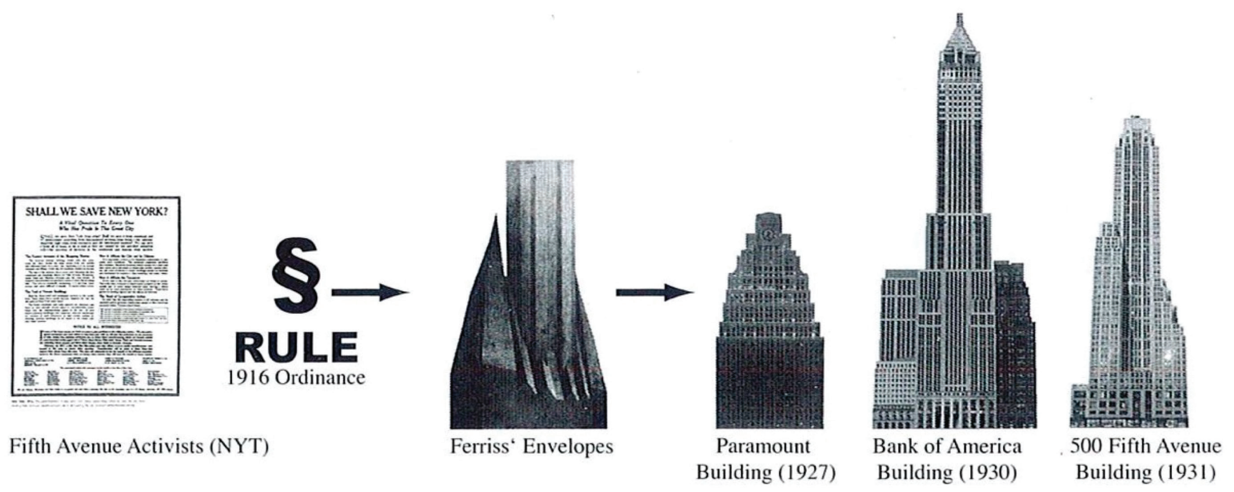


Fig 14. *Codification proccess in 1916 for New York city. Source: J. Punter. 1999.*

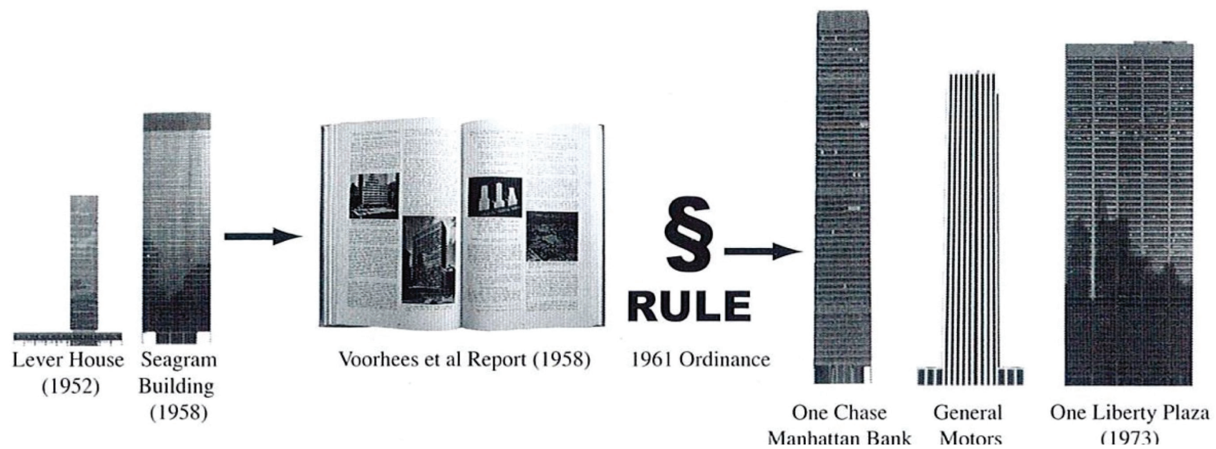


Fig 15. *Codification proccess in 1961 for New York city. Source: J. Punter. 1999.*

MAIN PRINCIPLES?

Among the urban principles there some important ones which are determining the many plan decesions. These main prinicples should answer the fundamental questions of the design. Every urban planners needs to know where, how big, in which shape should place the building volumes. These simple questions requiere a deep and holistic knowledge and analysis.

In this thesis we are going to think deeply about these questions and we need to consider these main principles to be able convert them into a parametric system. Density, Geometry, Network, and space syntax are the important topics that can answer many fundamental questions and also they can be parametrized with the computational tools.

Density deals with the amount of building that can occur within a specific area, influencing the **scale and intensity** of development. This includes considerations like building heights, floor area ratios, and the overall massing of structures, which together shape the character and livability of the urban space.

Block geometry examines the formal arrangement and dimensional properties of urban blocks, defining the **skeletal structure** of cities. This includes variables such as block size, shape regularity (e.g., rectangular vs. organic), and street-frontage proportions, which collectively influence pedestrian accessibility, land-use efficiency, and microclimate conditions.

The network principle addresses the **connective tissue** of urban systems: streets, sidewalks, and transit corridors that facilitate movement and interaction. Key metrics include connectivity indices (e.g., intersection density), street hierarchy (arterial vs. local), and pedestrian permeability, which determine traffic flow, walkability, and economic vitality. By parametrizing network attributes, such as adjusting street widths or node centrality, designers can simulate scenarios balancing vehicular efficiency with pedestrian priority, revealing trade-offs between speed and spatial experience.

Space Syntax deciphers the **implicit social logic** of urban layouts through topological relationships and visibility structures. It quantifies how spatial configurations axial lines (longest visibility paths), isovists (visible fields), and integration values shape human behavior, such as pedestrian movement or commercial clustering. Unlike conventional network analysis, Space Syntax exposes cognitive biases in wayfinding, revealing why certain routes feel “natural” despite geometric inefficiency. Parametrizing these relationships (e.g., correlating integration values with land-use mix) enables data-driven predictions of emergent urban vibrancy.

2-2. DENSITY

Urban density refers to the concentration of people, buildings, or other structures within a specific urban area. It is a critical metric in urban planning and design, influencing infrastructure, services, quality of life, and environmental sustainability. Urban density can be measured in several ways, with two primary dimensions being:

Population Density: This measure indicates the number of people living in a given area, typically expressed as people per square kilometer or square mile. Population density provides an overview of how crowded an area is, impacting the demand for infrastructure, public services, and overall quality of life.

Land Use Density: This dimension focuses on the extent and intensity of land usage for various purposes, such as residential, commercial, or industrial. It considers not only the number of buildings but also their size, height, and the proportion of land they occupy.

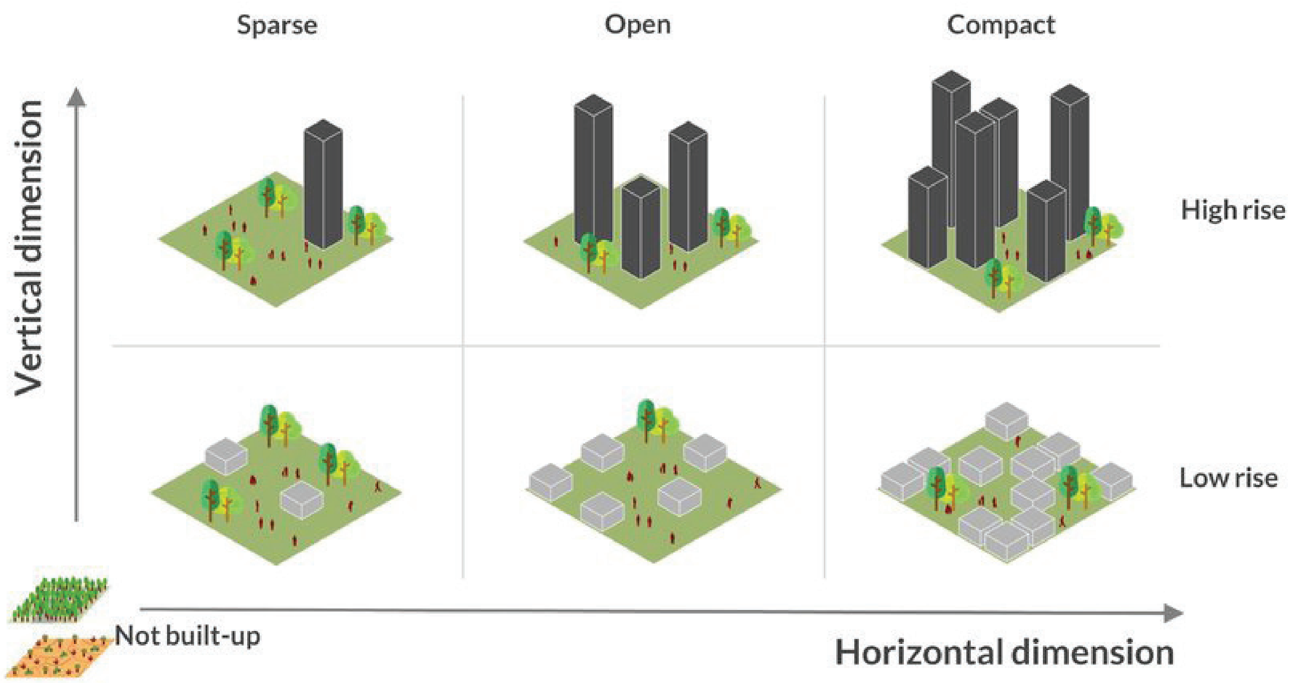


Fig 16. *Classication scheme for urban density in horizontal and vertical dimensions. Source: Bechtel et al. 2105.*

2-2-1. Land Coverage in Urban Areas

Land coverage refers to the proportion of land occupied by impervious surfaces, such as buildings, roads, and other infrastructure. It is a crucial factor in urban planning, influencing water runoff, urban heat islands, and the availability of green spaces. Land coverage can be measured using the following metrics:

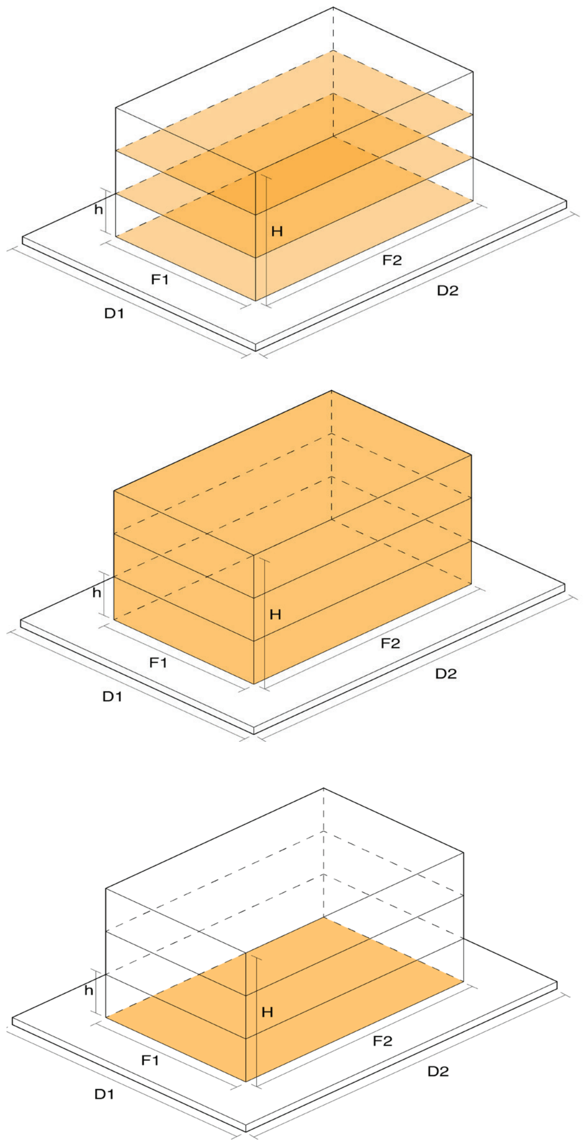
Floor Area Ratio (FAR): This ratio compares a building's total floor area to the size of the land upon which it is built. FAR is a key indicator of the intensity of development in an area. It can be calculated in two ways: by indicating the Gross Floor Area (GFA) in square meters, which helps assess the building's volume, or by specifying the volume in cubic meters. Maximum and minimum permitted heights are also considered to understand the development's scale.

Building Coverage Ratio (BCR): BCR measures the portion of a land plot covered by buildings. This metric is essential in determining the amount of open space remaining on a plot, which affects urban aesthetics, environmental quality, and the livability of an area.

Cities with limited land, high demand for space, or a focus on vertical growth (e.g., New York, Tokyo) often have higher FARs. This approach maximizes the use of scarce land resources. Conversely, cities with more land availability or a preference for lower-density development (e.g., many American or Australian cities) may have lower FAR and BCR values.

Local governments, through urban planning departments, set these ratios within the framework of zoning ordinances and building codes. These regulations guide long-term urban development, considering factors such as infrastructure capacity, population growth, environmental impact, and economic goals. In some regions, specialized urban planning authorities or commissions oversee the determination of FAR and BCR values.

These regulations, which vary depending on the city and region, establish the permissible dimensions of the built environment for planners. While there are other limits and rules, such as parking requirements, minimum permeable surfaces, and building setbacks, this thesis focuses on density in terms of land coverage and GFA, as they are more critical and applicable.



FAR:
Total Built surfaces ÷ Total land (m^2)

F1×F2× Number of floors (3) ÷ D1×D2

FAR:
Total Built Volume ÷ Total land (m^3)

F1×F2×H ÷ D1×D2

BCR:
Total covered surfaces ÷ Total land (m^2)

F1×F2 ÷ D1×D2

Fig 17. *Diagrams and formulas to measure land use density in different ways. Source: Author*

Beyond Regulations: The Role of Design Judgment

While regulations provide a framework, the final decision on the volume and distribution of buildings within a plot is often left to the planner or designer. Although rules determine the minimum and maximum allowable densities, planners must decide whether to distribute buildings across the surface with higher land coverage or opt for multi-story buildings with more open spaces.

In some cases, planners and stakeholders might choose to use less than the maximum allowable density for various reasons. To arrive at the final decision on density and building distribution, several key factors must be considered.

2-2-2. Light Access

Urban density and the distance between buildings significantly impact access to natural light in urban areas. In densely populated areas with closely spaced buildings, the likelihood of one building casting a shadow over another increases, reducing the amount of natural light that reaches lower floors and adjacent structures.

Adequate spacing between buildings is essential to allow sunlight to penetrate deeper into the urban fabric, ensuring that indoor spaces receive sufficient daylight. This not only enhances the quality of life for residents by improving comfort and reducing the need for artificial lighting but also contributes to energy efficiency. Conversely, insufficient spacing can lead to poorly lit interiors, affecting both the livability and sustainability of urban environments.

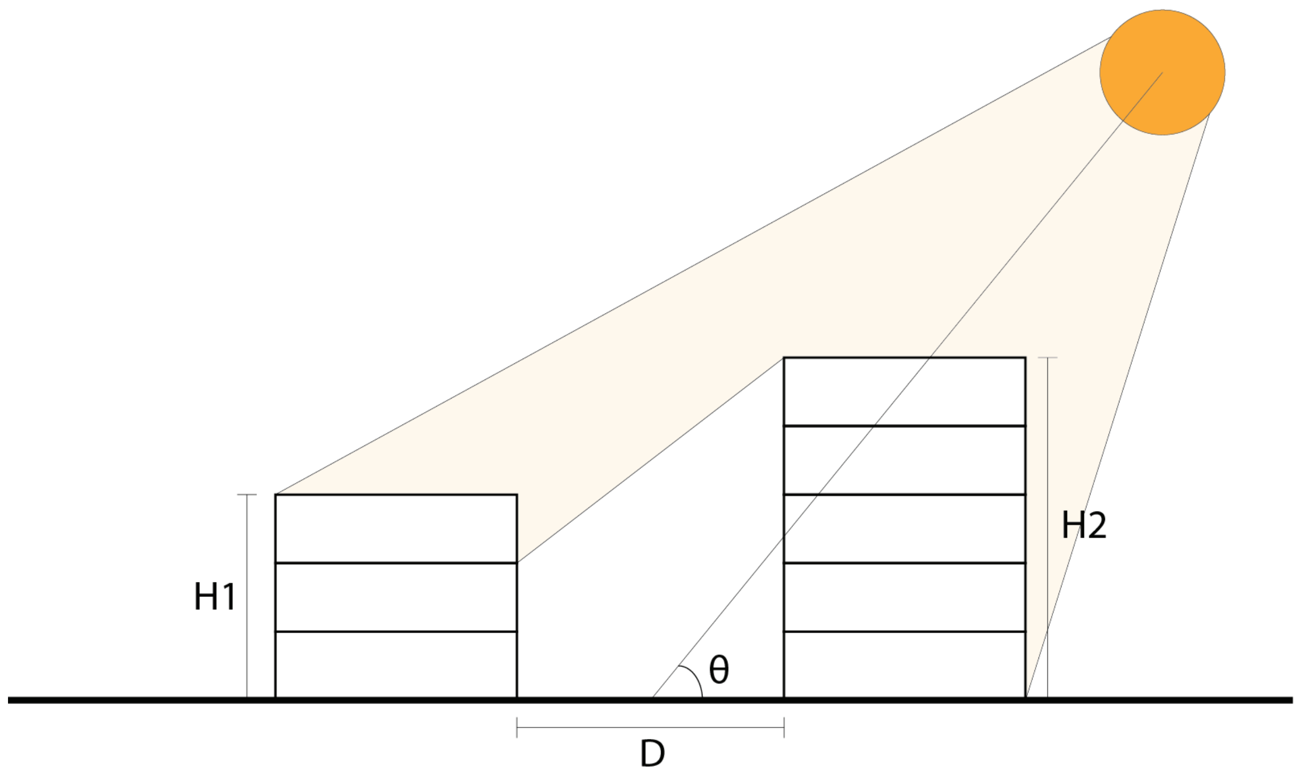


Fig 18. *Light access diagram showing the different indicators. Source: Author*

To ensure that the shadow from Building 2 does not cover Building 1, the minimum distance(D) between the buildings can be calculated as:

$$D \geq \max(H1, H2) \times \tan(\theta)$$

2-2-3. Air Circulation

Proper building spacing facilitates air circulation, reducing heat buildup and improving air quality. In densely packed areas, careful design is needed to avoid creating wind tunnels or areas of poor ventilation.

Buildings that are too close together can create high-velocity wind tunnels, which may be uncomfortable or even dangerous at ground level. Conversely, buildings that are too far apart may lead to poor air circulation and stagnant zones, reducing air quality and increasing the risk of urban heat islands. Optimal spacing can be determined by simulating wind flow using **computational fluid dynamics (CFD)** models, which provide detailed wind patterns around buildings.

CFD models break down the physical space into a grid of small cells, creating a mesh that represents the area of interest. This system has some numerical method that can be applicable in the parametric formulas but due to complexity, we do not consider them in this thesis.

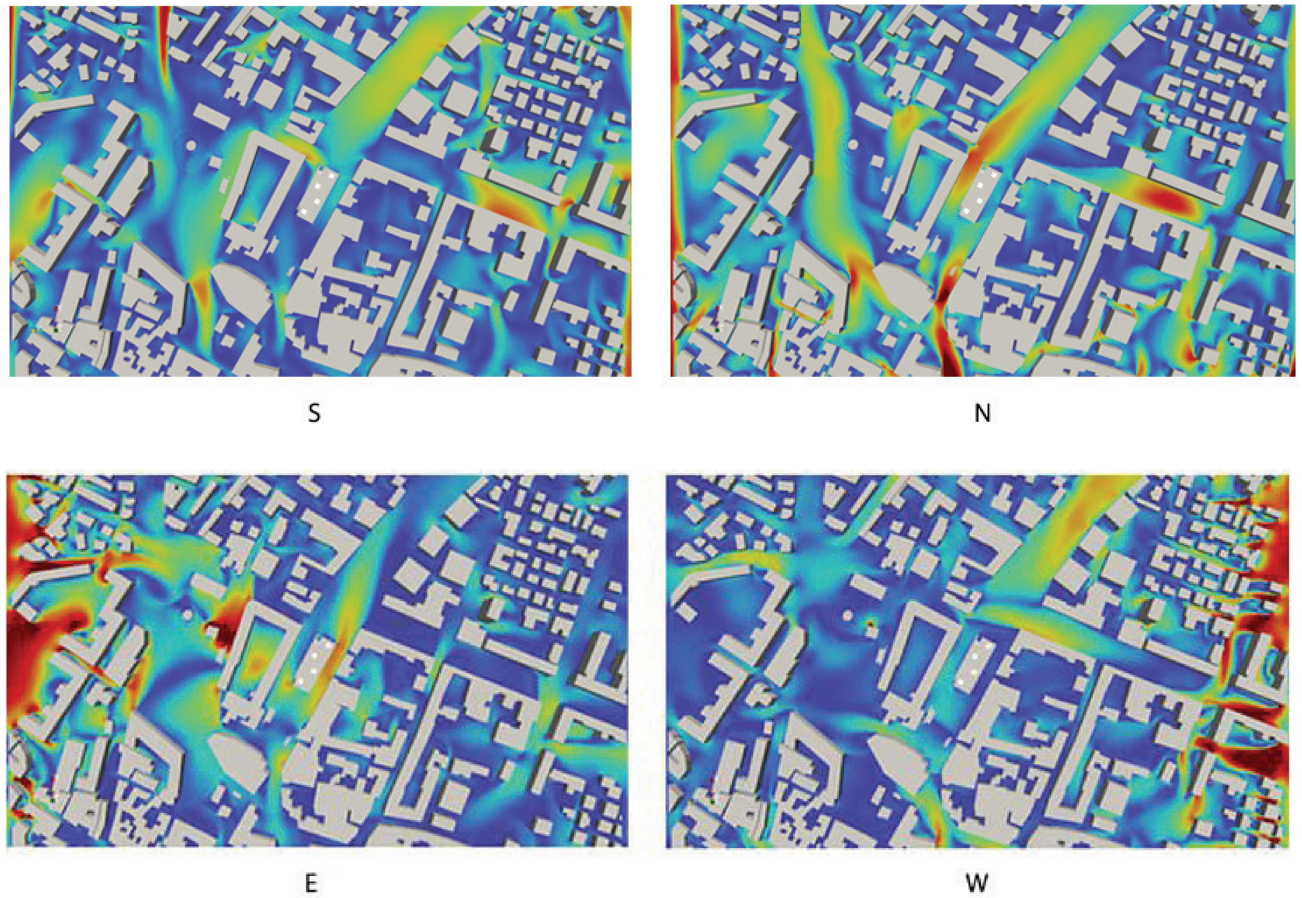


Fig 19. Effect of the wind direction on the flow pattern in an urban area. Source: Simscale, 2023

2-2-4. Climate

Local climate conditions, including temperature, precipitation, and wind patterns, dictate appropriate building densities and designs.

Urban areas in **hot climates** typically feature lower building density. Buildings are spaced farther apart to enhance air circulation and reduce heat buildup, helping to mitigate the urban heat island effect. Open spaces, green areas, and reflective surfaces are common to cool the environment and provide shade.

In **cold climates**, higher building density is preferred to conserve heat and reduce energy demands. Buildings are closely packed together, minimizing heat loss and exposure to cold winds. The proximity of structures helps retain collective warmth and can optimize solar gain during winter.

Temperate climates often feature a mix of building densities. Urban areas may include both densely packed zones and more open spaces, striking a balance that offers comfort throughout the year. Building distances are moderate, ensuring adequate sunlight, ventilation, and a diverse mix of land uses.

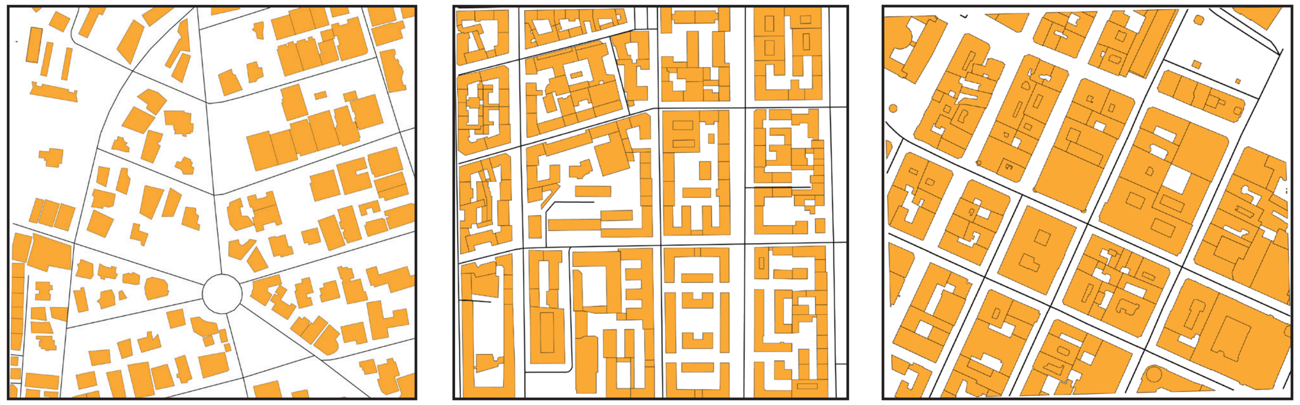


Fig 20. *Hot climate and lower density in Cairto (left), Moderate climate and balanced density in Milan (middle), Cold climate and higher density in Oslo (right). Source: Author*

2-2-5. Context

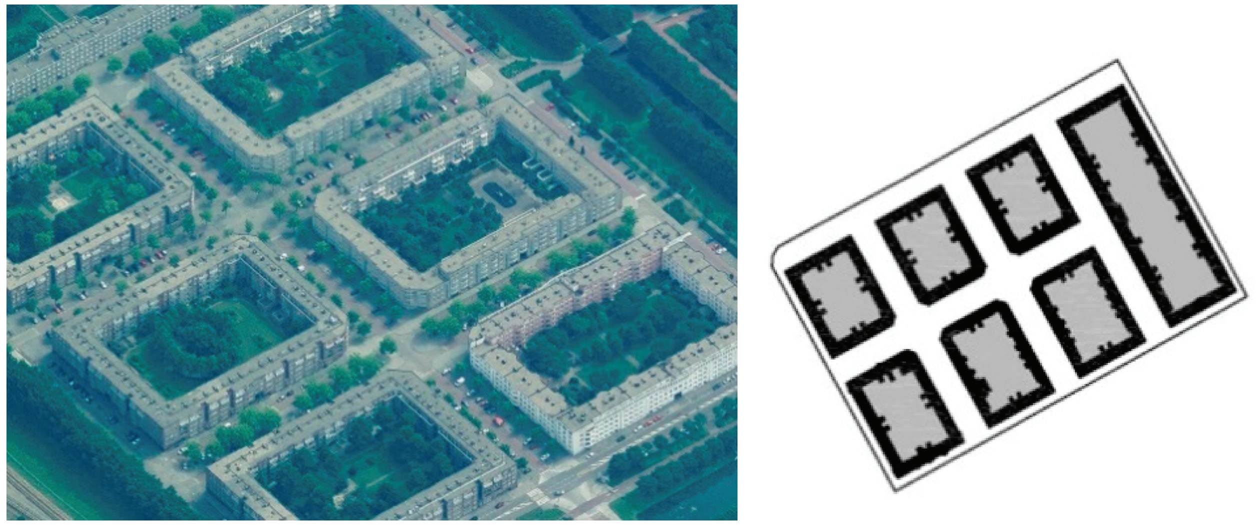
Architectural context and urban fabric significantly influence the built density of an area. Historical and cultural factors often dictate building heights, styles, and spacing, leading to either higher or lower density depending on the need to preserve architectural heritage or adapt to modern needs.

Additionally, the urban fabric, including the layout of streets, block sizes, and the availability of infrastructure and services, determines how densely an area can be developed. Well-connected areas with efficient public transit and small block sizes typically support higher density, while regions with more spread-out or irregular layouts tend to have lower density.

2-2-6. Open/Permeable Spaces

Open and permeable spaces within urban blocks are vital for ensuring environmental sustainability, enhancing the quality of life, and promoting public health in urban areas. These spaces allow for natural water infiltration, reducing the risk of flooding, and help mitigate the urban heat island effect by providing green areas that cool the environment. They also offer essential recreational and social spaces for residents, contributing to the livability of urban neighborhoods.

To determine the necessary amount of open and permeable space, planners use metrics like the **Green Space Ratio (GSR)**, which indicates the proportion of green space relative to the total area of a block, and **permeable surface requirements**, often set by local regulations to ensure sufficient ground area for water absorption. Calculating the **Building Coverage Ratio** (BCR) also helps in determining the balance between built-up and open areas, ensuring that enough land is left unbuilt to meet ecological and social needs. These measures help guide the design of urban blocks to maintain a healthy and balanced urban environment.



A

B

C

Fig 21. *Different density and permeable spaces in different contexts in the Netherlands. A. Venserpolder B. Watergraafsmeer C. Colijnspaat. Source: F. Abarca-Alvarez et al., 2019.*

2-3. GEOMETRY

Identifying the density of an urban area provides valuable insights into the block sizes and land coverage, offering a foundational understanding of the spatial organization within a city. However, density alone does not fully capture the complexities of urban form. Various other parameters, such as function, sustainability, and context, significantly influence the **shape** and overall **configuration** of buildings within a block. These factors play a crucial role in determining how volumes are distributed, how light and air permeate the spaces, and how the built environment interacts with public and private realms.

In this section, we will delve deeper into these parameters, exploring how they collectively contribute to the morphological characteristics of urban blocks. By examining aspects such as the relationship between building mass and open spaces, the impact of zoning laws, and the integration of architectural forms with urban infrastructure, we aim to define the principles that govern the design and development of urban blocks. Understanding these principles is essential for creating coherent, functional, and aesthetically pleasing urban environments that respond to both human needs and environmental constraints. Through a parametric approach, we can systematically analyze and manipulate these parameters to achieve **optimal urban forms** that balance density with livability and sustainability.

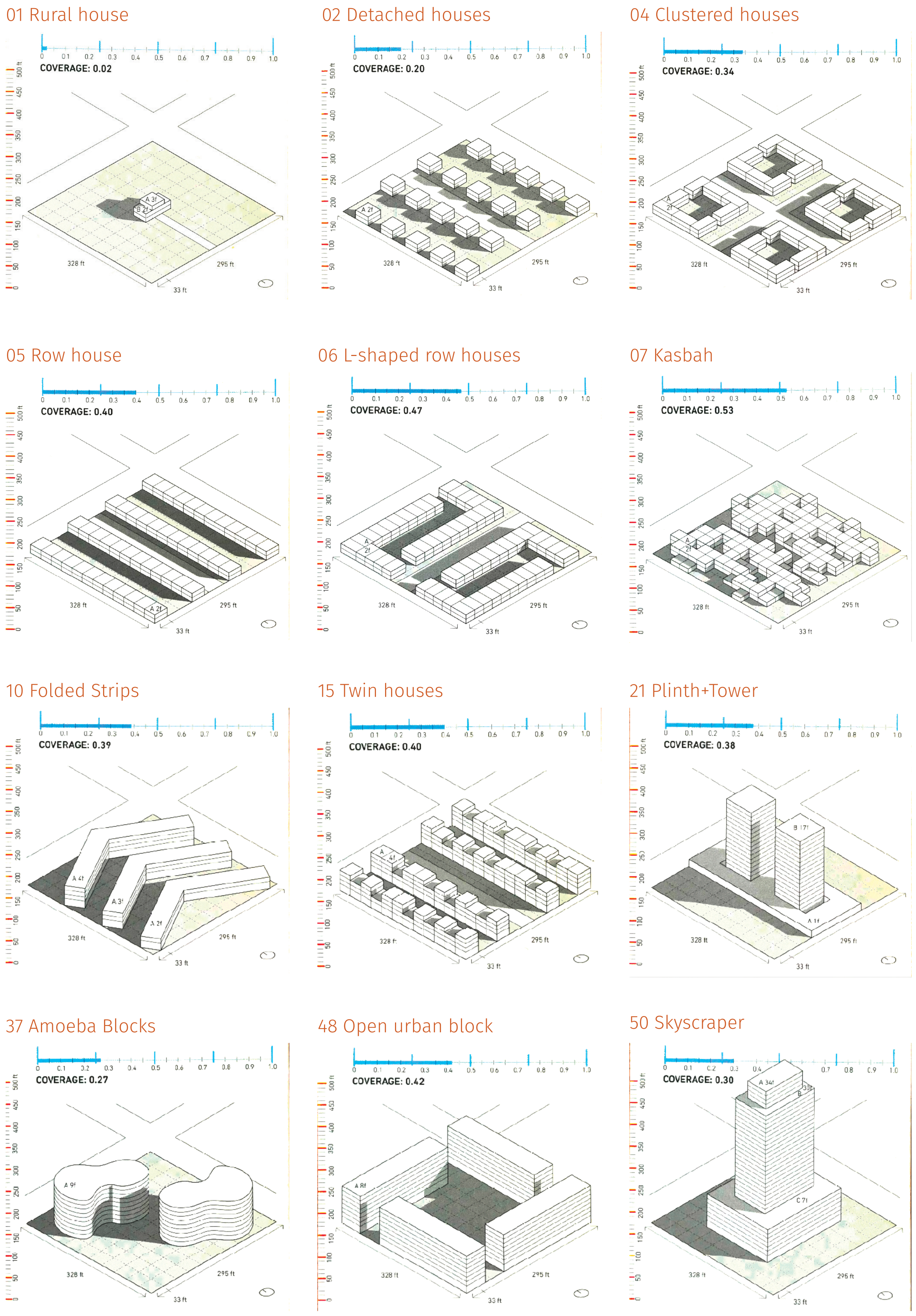


Fig 22. *Some examples of urban block Geometry. Source: 50 Urban Blocks, 2017.*

2-3-1. Function

Considering the function of buildings in urban areas is crucial when studying urban geometries because different functions lead to distinct shapes and layouts within urban blocks. Residential, commercial, industrial, and mixed-use areas each have unique spatial requirements, resulting in varying building shapes and arrangements. Understanding these differences helps urban planners, architects, and researchers design and analyze urban spaces more effectively, taking into account the specific needs and characteristics of each function. By considering the function, we can create more tailored and efficient urban environments that cater to the diverse activities and interactions that occur within them. Here's a detailed description of the typical shapes or geometries associated with different functions within urban blocks:

Residential Blocks

Geometry: Residential blocks often exhibit a more uniform and repetitive geometry, with a focus on maximizing living space. This can result in rectangular or square-shaped blocks with a higher density of buildings and a more closed-off structure to ensure privacy for residents.

Characteristics: The presence of courtyards, balconies, and a higher number of smaller living units contribute to the overall geometry of residential blocks.

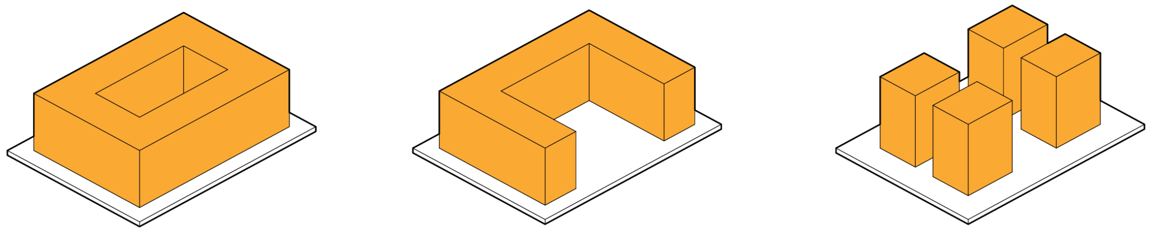


Fig 23. *Typical residential blocks. Closed couryard(left), open courtyard (Middle), Cluster (right) Source: Author.*

Industrial Blocks

Geometry: Industrial blocks are characterized by large, open spaces with expansive, often rectangular, buildings. The geometry is optimized for efficient movement of goods and materials, leading to a more functional and utilitarian layout.

Characteristics: Large warehouses, loading docks, and minimal emphasis on aesthetic design contribute to the geometry of industrial blocks.

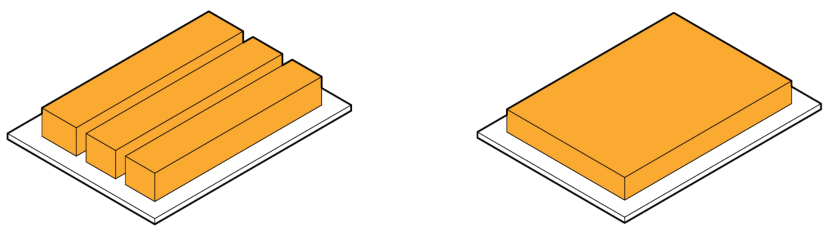


Fig 24. *Typical Industrial blocks. Multiple Linear units (left), Single flat factory. (right) Source: Author.*

Commercial Blocks

Geometry: Commercial blocks tend to have a more irregular and diverse geometry, often reflecting the variety of businesses and services they accommodate. This can lead to a mix of building shapes, including rectangular, L-shaped, or irregular configurations.

Characteristics: The presence of larger storefronts, varied building heights, and a more open layout to attract customers contribute to the unique geometry of commercial blocks.

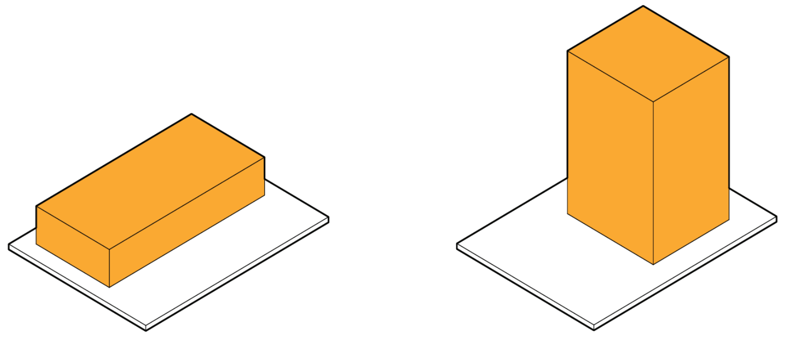


Fig 25. *Typical commercial blocks. Single story markets (left), high-rise Shopping malls (right). Source: Author.*

Mixed-use Blocks

Geometry: Mixed-use blocks combine residential, commercial, and sometimes industrial functions, resulting in a blend of geometries. This can lead to a mix of building shapes and sizes within the same block, creating a diverse and dynamic urban environment.

Characteristics: The coexistence of different functions within the same block can result in a varied streetscape and building layout, reflecting the combination of residential and commercial needs.

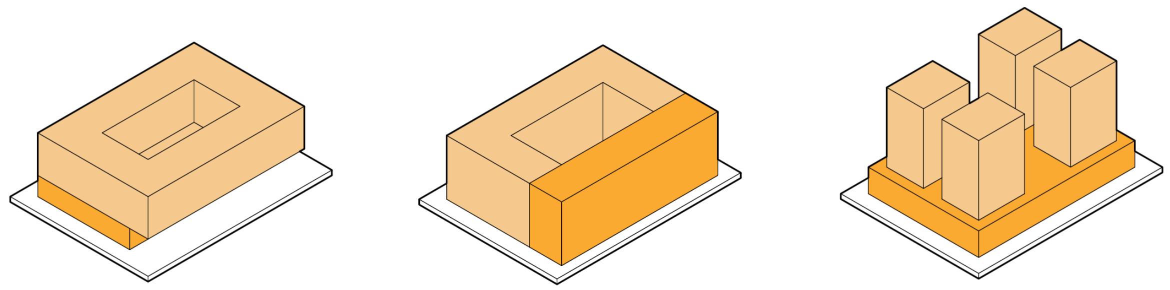


Fig 26. *Typical mixed-use blocks. Ground floor commercial(left), Detached Stores and Offices (Middle), Ground floor commercial and cluster of residentials(right) Source: Author.*

2-3-2. Context

Contextual elements in the context of urban design and architecture refer to the various factors and influences that shape the physical, social, and cultural environment of a specific area. These elements play a crucial role in determining the form, function, and overall character of urban spaces and buildings. Here's a detailed description of some key contextual elements

Historical Elements: Historical context encompasses the legacy of past developments, architectural styles, and cultural heritage. It includes the preservation of historical buildings, landmarks, and the evolution of urban form over time.

Cultural Influences: Cultural elements encompass the social practices, traditions, and rituals of the community. They influence the spatial organization, architectural styles, and the design of public spaces to reflect the cultural identity of the area.

Urban Fabrics and City Forms: refer to the physical layout, street patterns, building heights, and architectural styles that define the urban environment. They contribute to the visual and spatial character of the area.

Typologies: Urban block typologies, such as courtyard blocks, grid blocks, or mixed-use blocks, are specific spatial configurations that are influenced by the surrounding context and urban history.

Monumental and Natural Elements: Monumental elements include landmarks, significant buildings, and public spaces that shape the identity of the area. Natural elements, such as rivers, hills, and parks, contribute to the overall urban form and influence the design of urban spaces.

Urban Development Forces: Urban development forces encompass factors such as urban renewal projects, infrastructure development, and technological advancements that impact the physical and social fabric of the urban environment.

Site-Specific Context: Site-specific context refers to the unique characteristics of a particular location, including its topography, existing land use, and cultural significance, which influence the design and development of urban spaces. (Panerai, 2004)

An Interview

Contextual elements in the context of urban design and architecture refer to the various factors and influences that shape the physical, social, and cultural environment of a sDuring a personal visit to an exhibition in Amsterdam, I explored how contextual influences shaped the block and building geometries in the city's Eastern Docklands. The exhibition focused on the transformation of this former industrial zone into a residential district—a shift driven by Amsterdam's housing shortage and the broader urban goal of relocating industrial activities outside the city center.

The Eastern Docklands possess several distinctive features: a riverside location, a network of canals that penetrate the area's "islands," and proximity to Amsterdam's historic center. Over time, the municipality redeveloped each island in phases, ensuring that every project adhered to specific urban design principles and contextual foundations.

One striking example was a high-density area where architects were tasked with designing 40 individual houses side by side, with only one constraint: uniform building height. This decision paid homage to the site's industrial past, as the varied facades within a consistent roofline echoed the iconic streetscapes of Amsterdam's historic center. Thus, the interplay of historic context, urban fabric, monumental influences, and development pressures collectively defined the area's unique character.

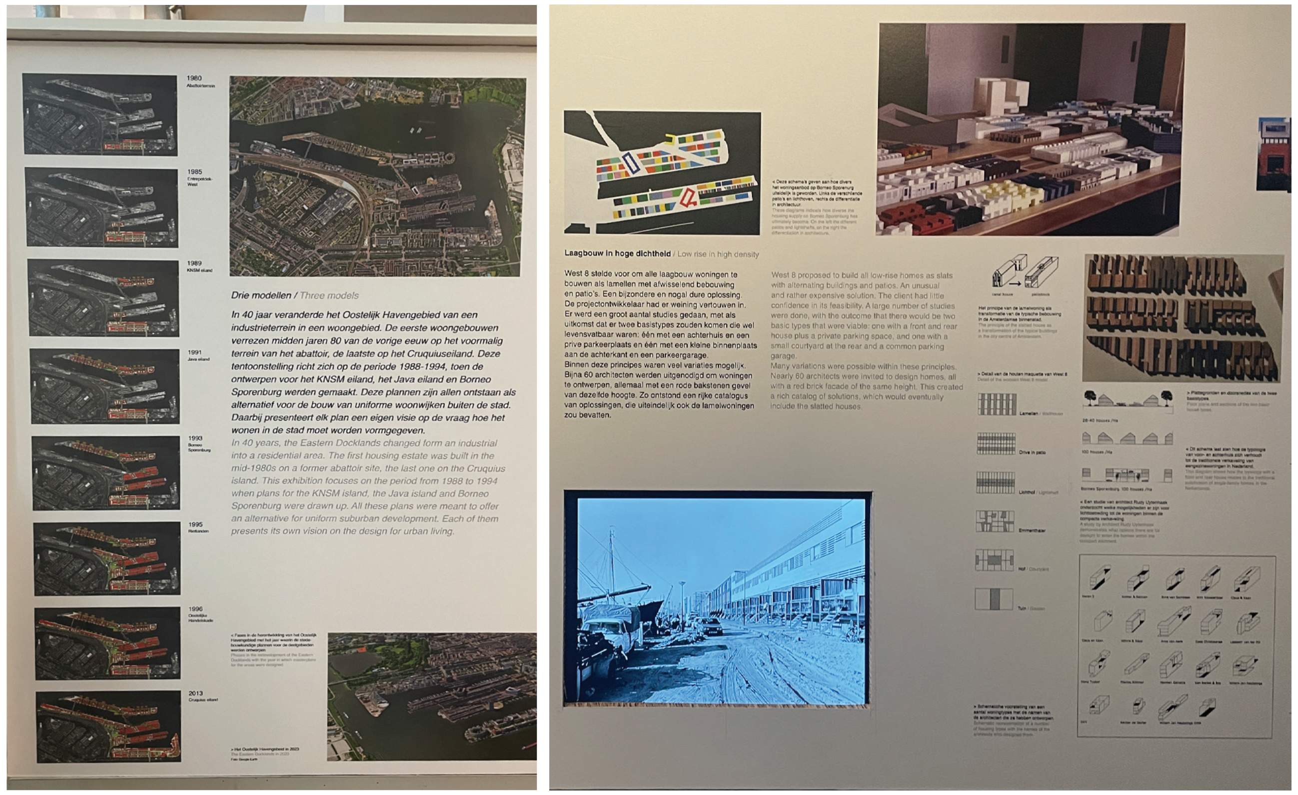


Fig 27. *Typical mixed-use blocks. Ground floor commercial(left), Detached Stores and Offices (Middle), Ground floor commercial and cluster of residentials(right) Source: Author.*

2-3-3. Sustainability

The impact of block geometry and form on sustainable and healthy environment is a multifaceted topic. There are different parameters that the block shape has significant role such as; energy efficiency, air quality, wind channeling, temperature, and etc.The shape and geometry of urban blocks play a crucial role in determining the energy efficiency of buildings within those blocks. Several factors contribute to this impact:

Solar Energy Penetration: The orientation and shape of the blocks affect the amount of sunlight received by the buildings. Blocks with long east-west edges, for example, may improve the contributions from photovoltaic panels on the façades. The positioning of the blocks can also influence the shading effects, which in turn affects the solar energy penetration.

Building Envelope Surface Area: The ratio of building envelope surface area to building volume, known as the shape factor, influences the exposure to sunlight and solar radiation. Different block shapes and geometries can result in varying surface areas, affecting the potential for solar energy generation.

Intra-and-Inter-Block Shading Effects: The arrangement of buildings within a block can lead to shading effects. The proximity and orientation of buildings impact the amount of sunlight reaching the surfaces, affecting the energy efficiency of the buildings.

Building Patterns: The specific arrangement of buildings within a block, such as podiums with towers versus towers only, can impact the distribution of solar energy penetration. Different building patterns can result in varying contributions to solar energy generation.

Surrounding Contexts: The surrounding urban context, including the road network, orientation, and surrounding buildings, can influence the energy efficiency of the blocks. For example, the preferred orientation in a specific location can impact the energy efficiency of the blocks.

An Example

This research is an useful example that proposes a novel parametric method using vernacular block typologies for investigating the interactions between solar energy use and urban design. The block typologies feature various combinations of block dimensions, building patterns, floor area ratio, and site coverage. These design parameters highlight the connections to the vernacular common practices of design.

To illustrate the approach, a case study focusing on high-density zones in Singapore is presented. Eighteen distinct block typologies representative of Singapore's urban fabric were developed and implemented into a digital tool called the Urban Block Generator, built on the Grasshopper/Rhinoceros platform. This tool assists in producing building geometries for early-stage planning in greenfield developments. The generated forms are subsequently evaluated using the City Energy Analyst to analyze solar energy access and capital expenditure. These tools offer planning authorities the ability to set benchmarks for on-site solar energy use in greenfield projects, while also enabling architects and urban designers to explore alternative spatial configurations that improve solar energy efficiency. (Shi & Fonsca &Schlueter, 2021)

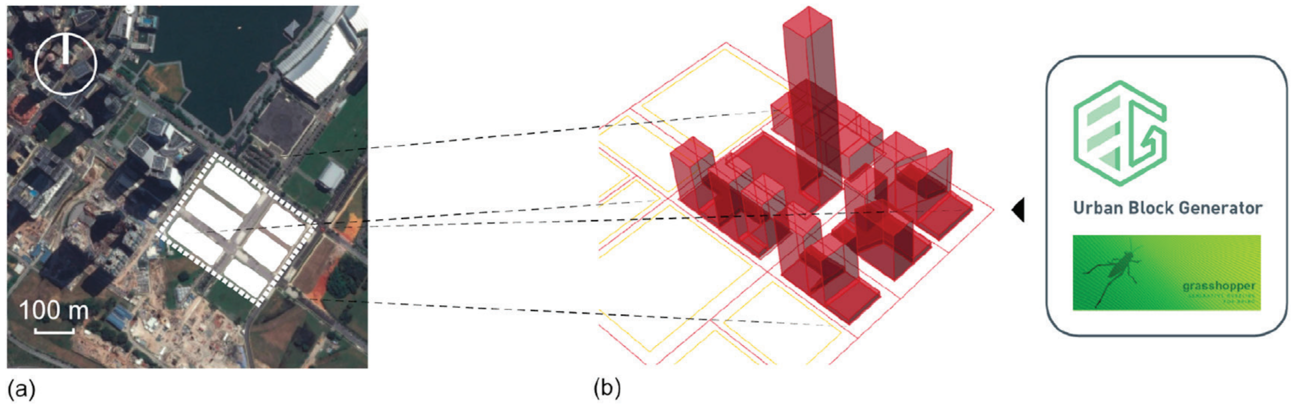


Fig 28. *(a) The location of the six blocks in the north-eastern corner of downtown Singapore; (b) the design generated by the Urban Block Generator. Shi, Fonsca, Schlueter, 2021.*

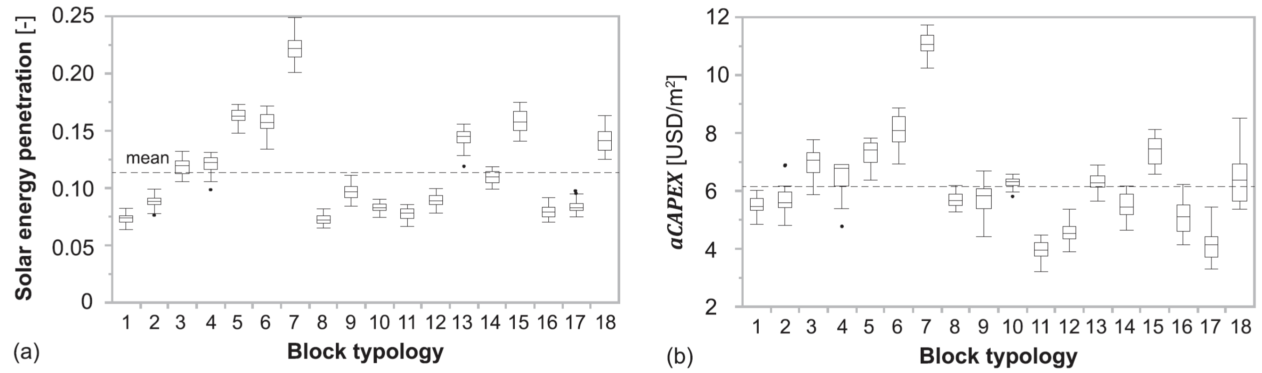


Fig 29. *The results of the assessment of the block typologies for (a) solar energy penetration [], and (b) the cost indicator denoted as aCAPEX [USD/m2]. Source: Shi, Fonsca, Schlueter, 2021.*

2-4. NETWORK

The design of urban transportation networks is guided by a set of fundamental principles that ensure the **system's efficiency**, accessibility, safety, and sustainability. These principles are not one-size-fits-all; they vary depending on the mode of transportation, such as road networks, cycling infrastructure, pedestrian pathways, and public transit systems. Urban planners and designers must consider these distinct principles to create a cohesive transportation network that meets the diverse needs of the population.

Each type of transportation network has specific **requirements** and **characteristics**. For instance, road networks need to address vehicular flow and connectivity, while cycling networks prioritize safety and dedicated infrastructure. Pedestrian pathways emphasize walkability and accessibility, and public transit systems focus on coverage, frequency, and integration with other modes of transportation. By applying these tailored principles to the design of each network, planners can ensure that urban transportation systems are effective, inclusive, and sustainable. In the following sections, we will explore the main principles for each type of transportation network, highlighting the key considerations that urban planners must take into account when designing these systems.

2-4-1. Road Network

The design of road networks is foundational to urban transportation, as it accommodates a wide range of vehicles, including cars, buses, and trucks. The main principles include:

Hierarchy of Roads: Establishing a clear hierarchy, from highways to local streets, to manage traffic flow and accessibility.

Highways: 3–4 lanes/direction, max slope ≤4%, design speed 100–120 km/h.
Arterials: 2–3 lanes/direction, 400–800 m spacing, design speed 60–80 km/h.
Collectors: 1–2 lanes/direction, 200–400 m spacing, design speed 40–50 km/h.
Local Streets: 1 lane, 20–30 km/h speed limit, ≤150 m block length.

Connectivity: Ensuring that roads are well-connected to minimize travel distances and reduce congestion.

Capacity and Flow: Designing roads to handle expected traffic volumes efficiently, with appropriate lane configurations and intersection designs.

Lane width: 3.0–3.5 m (general), 3.75 m (bus/truck lanes).
Max daily traffic: 20,000–60,000 vehicles (arterials), <5,000 (local).

Safety: Incorporating safety measures, such as proper signage, pedestrian crossings, and traffic calming in residential areas.

Crosswalks every 80–100 m in urban areas.
Visibility zones: 2.5 m clear zone for pedestrians, 10 m sight distance at intersections.

Sustainability: Promoting the use of sustainable materials and integrating green spaces to reduce the environmental impact of road networks.

Permeable pavements for 50% of local roads; min. 15% tree canopy coverage.

2-4-2. Cycling Networks

Cycling networks are crucial for promoting sustainable and healthy urban transportation. The key principles for cycling infrastructure include:

Dedicated Infrastructure: Providing dedicated bike lanes and paths that are separated from motor vehicle traffic to ensure cyclist safety.

> **Bike lane width:** 1.5 m (1-way), 2.5 m (2-way), 0.5 m buffer from traffic.
> **Protected cycle tracks:** 2.0 m min. width, bollard spacing ≤5 m.

Connectivity: Designing a well-connected network that links residential areas with key destinations such as schools, workplaces, and parks.

> Max 300 m spacing between bike lanes; 500 m to key destinations (transit/schools).

Safety: Ensuring safety through clear signage, proper lane markings, and protective measures at intersections.

> **Intersection treatments:** 3 m advance stop lines, 2.5 m corner radii.

Integration with Public Transit: Facilitating multimodal journeys by integrating cycling networks with public transit systems, including bike-sharing programs and secure parking.

> **Bike parking:** 1 space/10 transit users; 5–10 spaces/100 m² (commercial).

Encouragement and Culture: Promoting cycling through public initiatives and infrastructure that supports and normalizes biking as a mode of transportation.

> **Bike-share density:** 10–15 stations/km², 1 bike/200 residents.

2-4-3. Pedestrian Networks

Pedestrian networks are the backbone of a walkable city. The main principles for designing these networks include:

Walkability: Creating pedestrian-friendly streetscapes with wide sidewalks, clear signage, and amenities that enhance the walking experience.

> **Sidewalk width:** 2.0 m (residential), 4.0 m (commercial), 1.8 m absolute min.
> **Pedestrian flow:** 23 peds/min/m (max comfortable density).

Connectivity and Accessibility: Ensuring that pedestrian pathways are continuous, direct, and accessible to all users, including those with disabilities.

> Max 100 m between crossings; 400 m detour penalty (per NACTO).

Safety: : Prioritizing pedestrian safety with features like well-lit paths, marked crosswalks, and traffic calming measures.

> **Lighting:** 5–10 lux (pathways), 15–20 lux (crossings).
> **Curb height:** 0.15 m standard.

Public Spaces and Amenities: Integrating public spaces and amenities along pedestrian routes to encourage walking and create vibrant urban areas.

> **Bench spacing:** ≤100 m; shade trees every 5–8 m.

Sustainability: Incorporating green infrastructure, such as permeable pavements and street trees, to enhance the environmental benefits of walking.

2-4-4. Public Transport Networks

Public transit networks are essential for providing efficient and equitable urban mobility. The key principles include:

Coverage and Accessibility: Ensuring that transit services are widely accessible, with stops and stations located within easy reach of residents.

Bus stops: 400 m max spacing (urban), 800 m (suburban). Min. 90% of residents within 500 m of transit (per ITE).

Frequency and Reliability: Providing frequent and reliable services to reduce waiting times and encourage the use of public transit.

High-demand routes: ≤10 min peak, ≤15 min off-peak. **Low-demand:** ≤30 min all-day.

Intermodal Connectivity: Designing transit hubs that facilitate easy transfers between different modes of transportation, including buses, trains, and cycling networks.

Transit hubs: Min. 20 bike parking spaces, 5% area for kiss-and-ride.

Flexibility and Scalability: Planning for future growth and adapting services to meet changing demand patterns.

Bus lane width: 3.5–4.0 m; platform height: 0.3 m (low-floor buses).

Environmental Impact: Prioritizing low-emission vehicles and integrating green infrastructure to reduce the environmental footprint of public transit systems.

Electric buses: 250+ km range; 1 charging point/10 vehicles.

2-5. SPACE SYNTAX

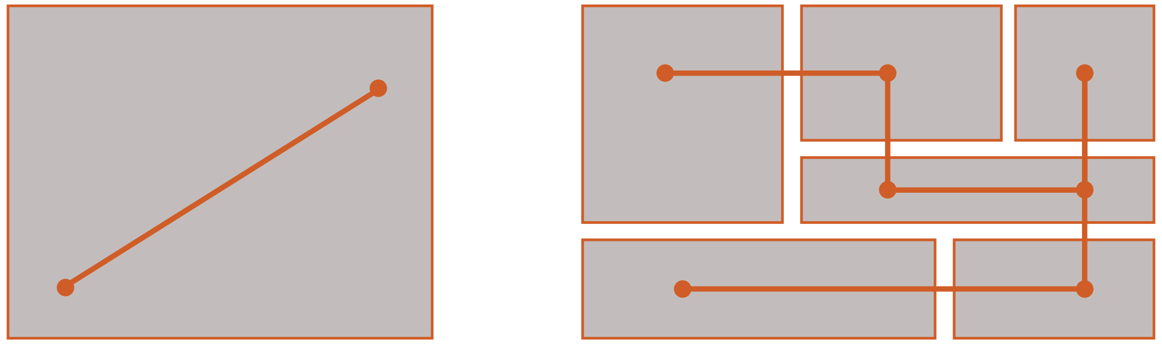
Space Syntax analyzes how spatial layouts shape human behavior and movement. By modeling streets, buildings, and cities as networks of connections, it predicts pedestrian flows, economic activity, and social interaction. Key metrics like integration (accessibility) and choice (through-movement) help planners optimize urban designs for walkability, safety, and vitality, bridging geometry and human experience.

This subject is emerged in the 1970s at the Bartlett School of Architecture, University College London (UCL), through the pioneering work of Bill Hillier and his colleagues. Initially developed to analyze architectural layouts, it expanded into urban studies by revealing how street networks influence movement and social patterns. Hillier's 1984 book "The Social Logic of Space" formalized its theory, introducing key concepts like axial maps and integration. By the 1990s, computational tools (e.g., DepthMap) enabled large-scale urban analyses, transforming it into a global framework for evidence-based planning. Today, it bridges architecture, urban design, and social science, with applications from historic city preservation to smart-city development. (Hillier ,1984)

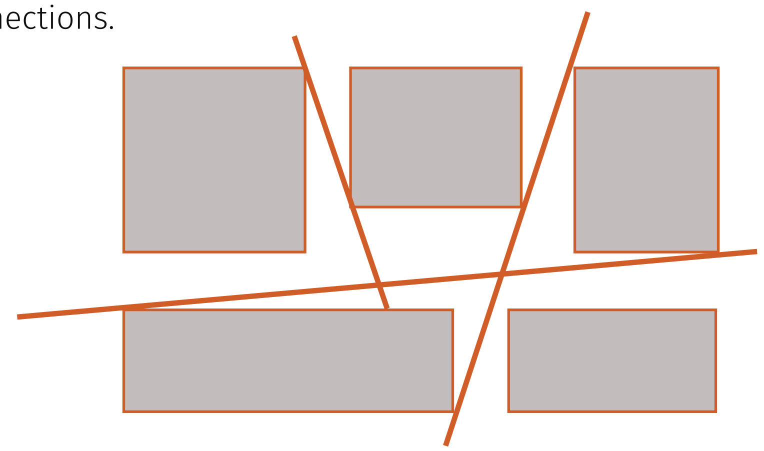
In this part we explore how space syntax define principles based on human activites, social networks, and economic activites.

2-5-1. Basic Conceptions:

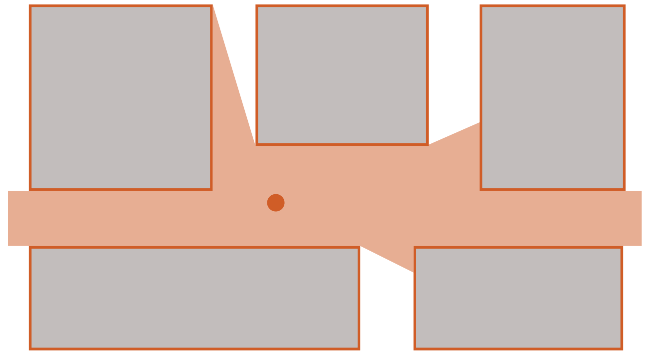
Convex space is a space where no line between any two of its points crosses the perimeter. A concave space has to be divided into the least possible number of convex spaces. **Convex map** depicts the least number of convex spaces that fully cover a layout and the connections between them. The interface map is a special kind of convex map showing the permeable relations between the outdoor convex spaces to the adjacent building entrances.



Axial space or an axial line is a straight line ("sight line"), possible to follow on foot. **Axial map** depicts the least number of axial lines covering all convex spaces of a layout and their connections.



Isovist space is the total area that can be viewed from a point. **Isovist map** depicts the areas that are visible from convex spaces or axial lines. (Klarqvist, 1993)



2-5-2. Graphs

All three types of maps can be transformed into graphs for purpose of analysis:
Graph is a figure representing the relationships of permeability between all the convex spaces or axial spaces of a layout. The spaces are represented by circles or dots (called nodes) and the links with lines. It is possible to also use links in order to represent relationships of visibility between spaces. (Klarqvist, 1993)

Syntactic step is defined as the direct connection or permeable relation between a space and its immediate neighbours or between overlapping isovists. In an axial map a syntactic step may be understood as the change of direction from one line to another. (Klarqvist, 1993)

Depth between two spaces is defined as the least number of syntactic steps in a graph that are needed to reach one from the other. (Klarqvist, 1993)

Justified graph is a spatial graph reorganized so that a particular space, known as the "root space," is positioned at the base. Spaces that are one syntactic step from the root are placed on the first level above, those two steps away on the second level, and so on. This structure provides a clear visual representation of the spatial depth of a layout from a given point. In a tree-like justified graph, most nodes are located several levels above the root, resulting in a high average depth, which is referred to as a "deep" system. Conversely, in a bush-like justified graph, most nodes are situated closer to the root, indicating a "shallow" system with lower mean depth. (Hillier ,1984)

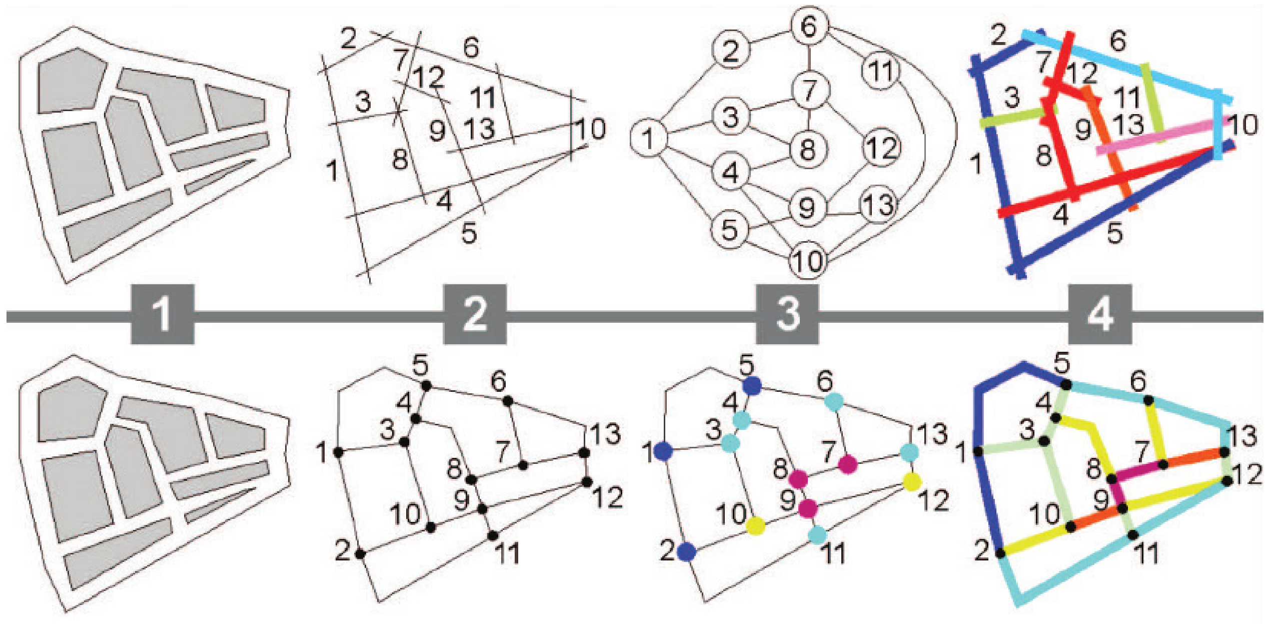


Fig 30. *1. Urban Map, 2. Axial map and syntetic steps, 3. Justified graph, 4. colored graph based on point's conectivity. source: Crucitti, 2006.*

2-5-3. Syntactic measures

There are four syntactic measures that can be calculated. They are used in quantitative representations of building and urban layouts:

Connectivity measures the number of immediate neighbours that are directly connected to a space. This is a static local measure. (Klarqvist, 1993)

Fig 31. *The space syntax graph of connectivity degree.*

Integration is a static global measure. It describes the average depth of a space to all other spaces in the system. The spaces of a system can be ranked from the most integrated to the most segregated. (Klarqvist, 1993)

Fig 32. *The space syntax graph of integration degree.*

Control value is a dynamic local measure. It measures the degree to which a space controls access to its immediate neighbours taking into account the number of alternative connections that each of these neighbours has. (Klarqvist, 1993)

Fig 33. *The space syntax graph of control degree.*

Global choice is a dynamic global measure of the "flow" through a space. A space has a strong choice value when many of the shortest paths, connecting all spaces to all spaces of a system, passes through it. (Hillier et al, 1976)

Fig 34. *The space syntax graph of total depth degree.*

2-5-4. Principles

Building upon our earlier discussion of the foundational concepts and methodologies of space syntax, we can now delineate the core principles that this scientific approach seeks to achieve through specific criteria. Space syntax emphasizes the intrinsic role of spatial configuration in shaping human behavior, movement patterns, and social interactions within urban environments.

By analyzing spatial layouts through quantitative measures such as integration, connectivity, and depth, space syntax provides a framework for understanding how the arrangement of spaces influences accessibility, visibility, and the potential for social engagement. These principles aim to inform urban design practices that foster walkability, safety, and vibrant public spaces by leveraging the relational properties of spatial networks. In the following sections, we will examine these principles individually, exploring their theoretical foundations and practical implications for urban design.

Prioritize High Integration Spaces for Key Functions

One of the foundational principles of space syntax is the concept of integration, which quantifies how accessible a space is within a spatial network. Spaces with high global integration values are more centrally located and accessible, making them prime candidates for hosting key urban functions such as commercial centers, public institutions, and transportation hubs.

Hillier and Hanson (1984) introduced the idea that the spatial configuration of an environment significantly influences movement patterns and social interactions. They posited that spaces with higher integration values tend to attract more movement, leading to increased opportunities for social and economic activities. This concept is further elaborated in Hillier's Space is the Machine (1996), where he emphasizes that the spatial layout of urban environments plays a crucial role in shaping human behavior and the distribution of land uses.

Empirical studies have supported these theoretical assertions. For instance, research has demonstrated that commercial and public functions often thrive in areas with higher integration values due to increased foot traffic and visibility. This correlation between spatial integration and land use distribution underscores the importance of considering integration values in urban planning and design.

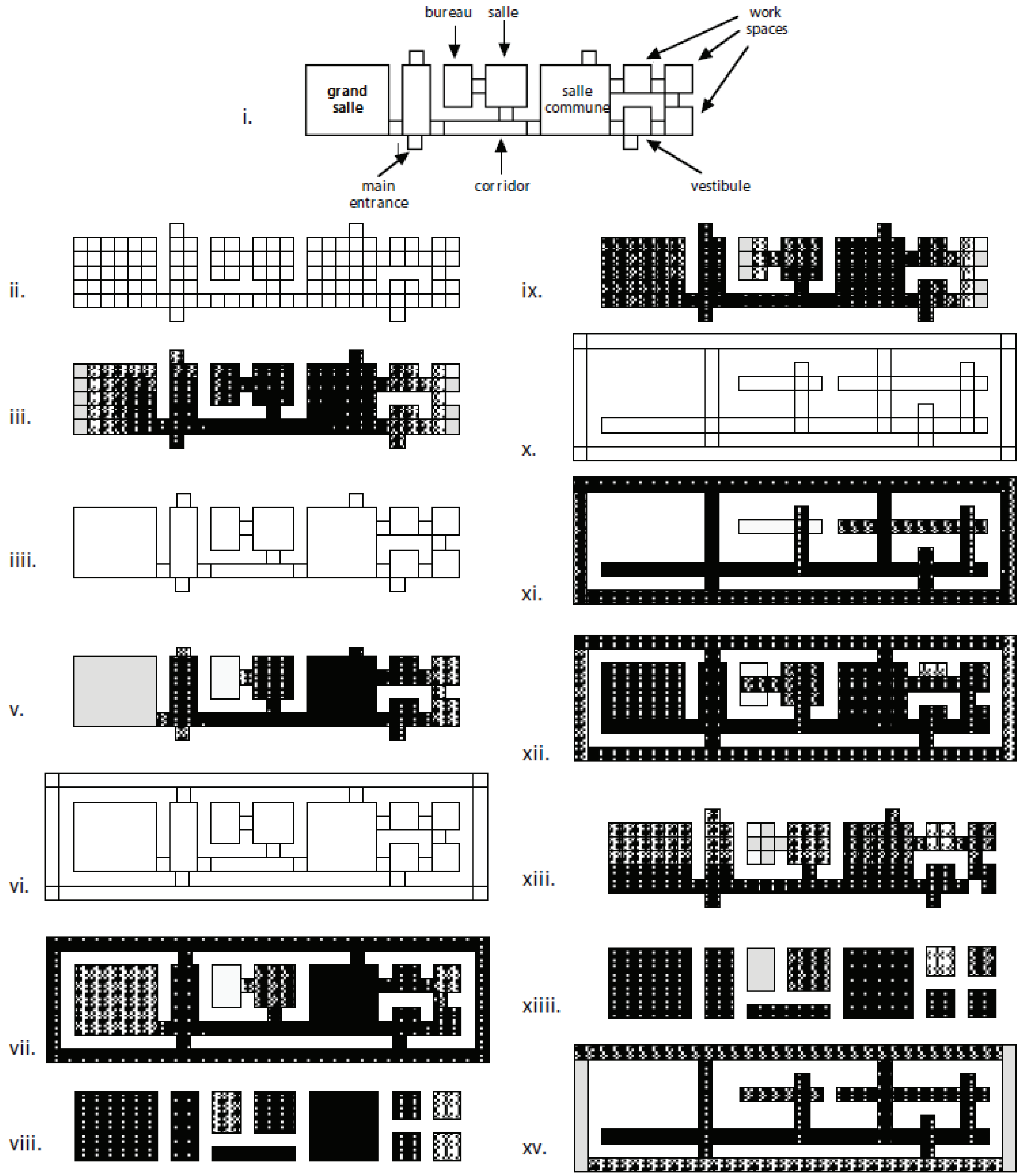


Fig 35. *various diagrams of the integeration degree of convax spaces. Source: B. Hillier, 1996.*

Enhance Spatial Continuity Through Connectivity

A core principle in space syntax is connectivity, defined as the number of immediate connections a space has to others. High connectivity indicates a well-linked space that allows smooth transitions and continuous movement across the urban fabric. In urban design, ensuring good connectivity prevents the formation of spatially isolated or underused areas, thereby enhancing the legibility and flow of the city.

The spaces with higher connectivity support increased movement and interaction, serving as vital components of a city's spatial core. This principle is particularly important in street networks, where direct connections between paths influence pedestrian and vehicular accessibility. By maintaining spatial continuity, urban designers can create environments that are easy to navigate and more inclusive. (Peponis et al., 1989)

Tools such as axial map analysis in DepthmapX can measure the connectivity of each space within a network, helping designers avoid dead-ends or poorly integrated areas. Enhancing connectivity strengthens the spatial structure, promotes active use, and improves overall urban resilience.

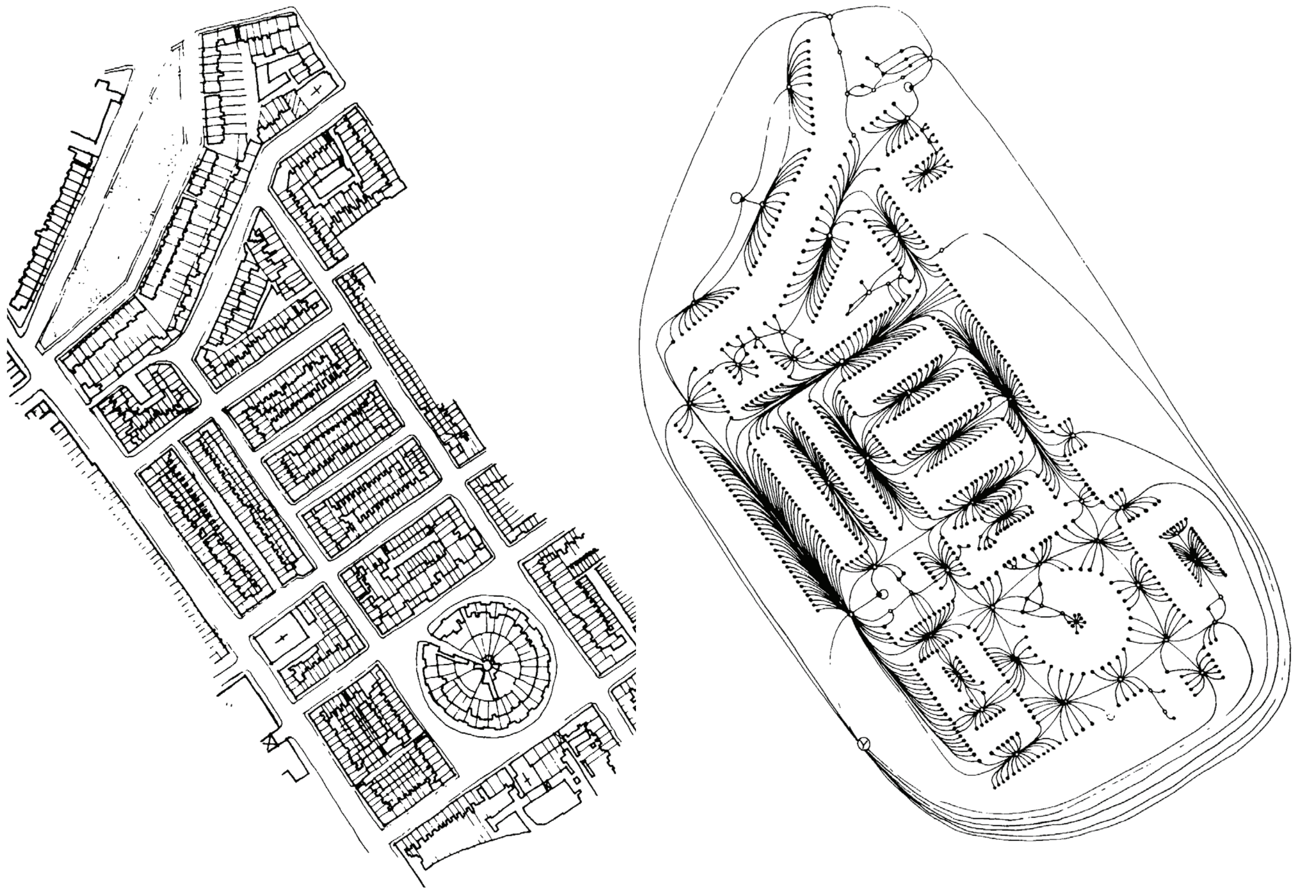


Fig 36. *Somerstown, London, in 19th century (left), Interface map of the connectiviy of this district (right). Source: B. Hillier, 1984.*

Mitigate Spatial Segregation in Public Networks

In space syntax theory, local integration—often measured within a limited radius (e.g., radius-3) assesses how accessible a space is within its immediate surroundings. Spaces with low local integration values are considered more segregated, potentially leading to reduced pedestrian movement and diminished social interaction.

Urban environments often exhibit a gradient of integration and segregation, where certain areas become isolated due to their spatial configuration. Such segregation can result in decreased foot traffic, limited social interactions, and increased vulnerability to crime.

By analyzing local integration values, urban designers can identify these segregated areas within the public network. Addressing these areas—through interventions such as creating new connections or enhancing existing pathways—can improve accessibility, promote social interaction, and enhance overall urban vitality. (Hillier, 1996)

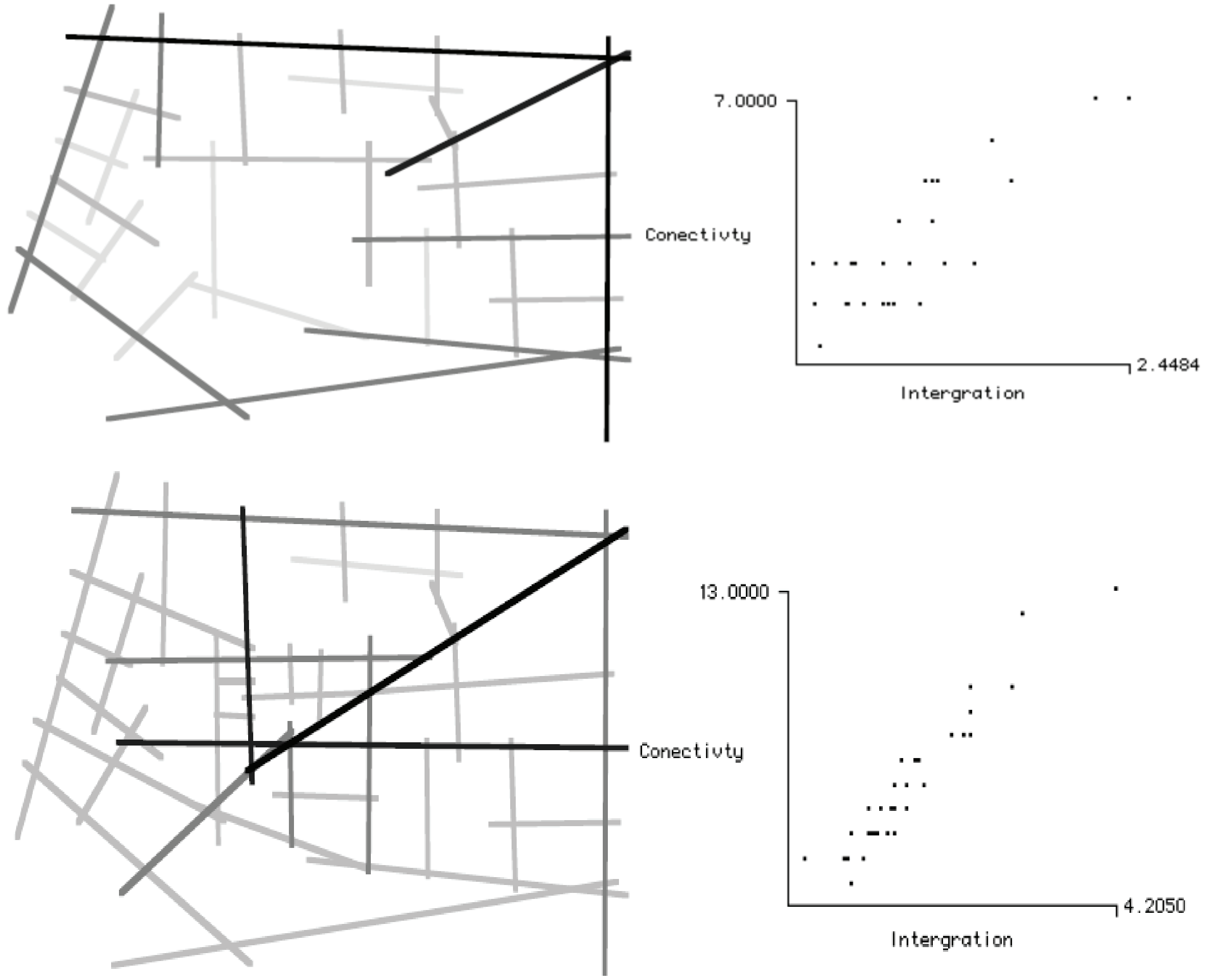


Fig 37 *Emhaned local integration and connectivity by limiting radius. Source: B. Hillier, 1984.*

Optimize Visibility and Visual Fields

Visibility plays a crucial role in shaping human experience and behavior within urban environments. The concept of an isovist—the volume of space visible from a specific vantage point serves as a foundational tool in space syntax for analyzing visual accessibility and spatial perception. By examining isovist fields, designers can assess how the configuration of spaces influences what individuals can see and, consequently, how they navigate and interact within those spaces.

In the context of urban design, ensuring strong visibility in critical locations—such as public squares, intersections, and communal gathering points—plays a key role in improving safety, orientation, and social engagement. Areas with broad lines of sight support both formal and informal monitoring, which in turn fosters a heightened sense of security. Additionally, clearly defined visual pathways support intuitive wayfinding, helping people to understand their surroundings and move smoothly through the cityscape. By thoughtfully improving visual connections, urban designers can develop spaces that are not only easier to navigate but also more welcoming and socially vibrant. (Benedikt, 1979)

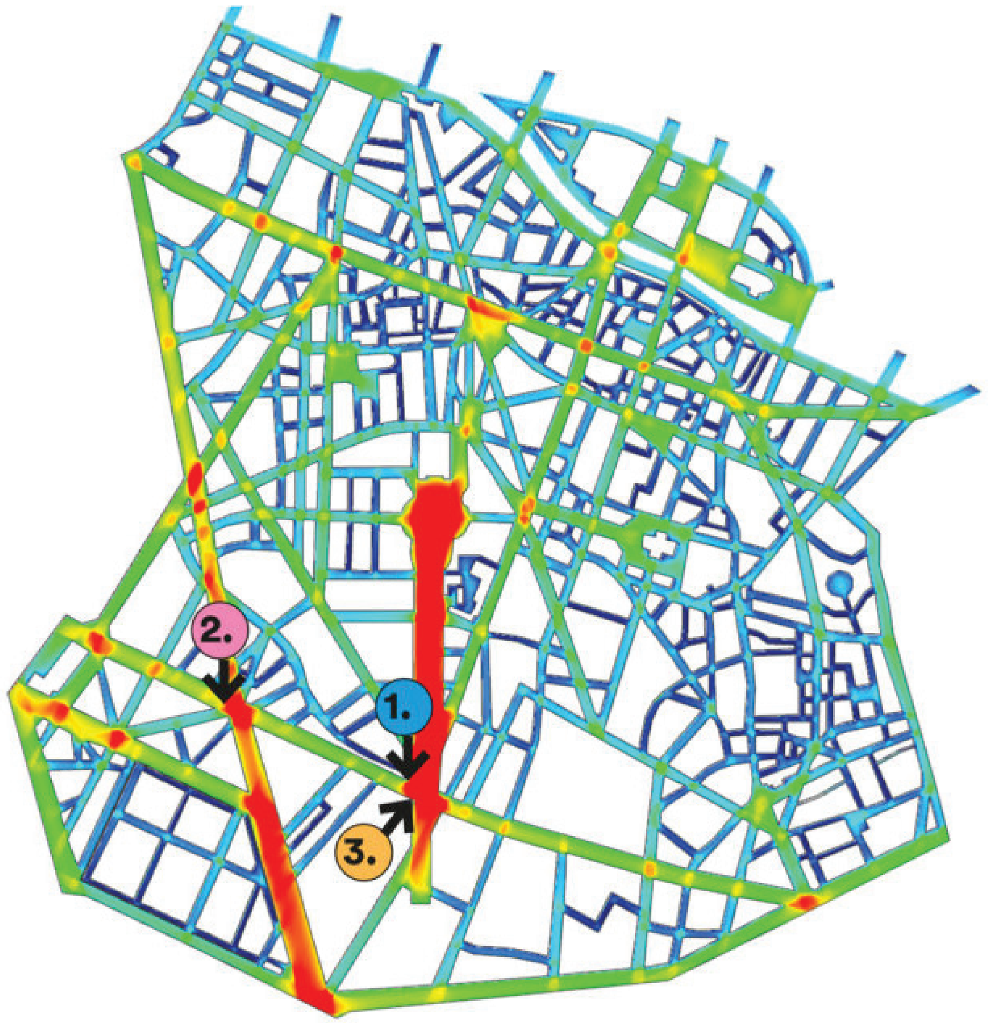
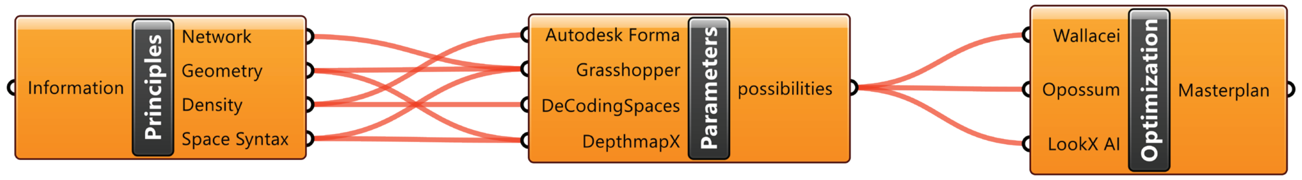


Fig 38. *Isovist map showing "average radial" for the Paris south of the river. Source: Isovists.org*

PARAMETRIC FOUNDATION



In this section we are going to experiment and explore how urban principles can be applied in an urban design and master plan with the help of parametric techniques.

To do so, each of the urban principles and rules should be parametrize one by one with different tools and then they can be combined and make a complex system that it helps us to design various masterplans with different **inputs** and data.

The aim is creating a **comprehensive system** that we need to provide the data regarding the desired area and this system can produce different scenarios. These scenarios make the designer able to select the one that is a better answer to the design question. This answer might not be complete or has slight problems, but to reach the exact design, the planners should take the last steps with or without using parametric tools.

To undrestand how the **parametric tools** work and which are the proper tools for the specific function, we should explore and get familiar with the tool's possibilities and options.

3-1. COMPUTATIONAL TOOLS

The developments in parametric software and artificial intelligence in recent years have revolutionized multiple disciplines, particularly in the field of urban planning. As cities continue to expand and the demand for housing intensifies, urban planners have risen to the challenge by creating innovative tools and software that enable the design of parametric, sustainable, analysis-based, and adaptive master plans.

These sophisticated tools primarily utilize measurable and parametric data, which necessitate thorough analysis of both on-site and off-site conditions, as well as regulatory frameworks and standards, collectively referred to as urban principles in the previous section. By leveraging these urban principles, planners can ensure that their designs are not only functional but also responsive to the unique characteristics and needs of each urban environment.

The parametric data generated by these tools can be adjusted according to various factors, including geographical location, climate conditions, municipal regulations, architectural and urban styles, as well as the historical context of the area. This adaptability is crucial in an increasingly diverse urban landscape, where one-size-fits-all solutions are often inadequate. Therefore, it is essential to develop a comprehensive system that can be tailored to different locations and a variety of objectives, ensuring that urban design is both context-sensitive and forward-thinking.

In this section, we will explore the capabilities and options offered by a range of parametric design tools. By understanding the functionalities of these tools, we can better identify how to effectively apply various urban principles and create innovative solutions that address the complex challenges facing modern urban environments. This exploration will not only highlight the strengths of each tool but also provide insights into best practices for integrating technology into the urban planning process. (Reitberger et al, 2024)

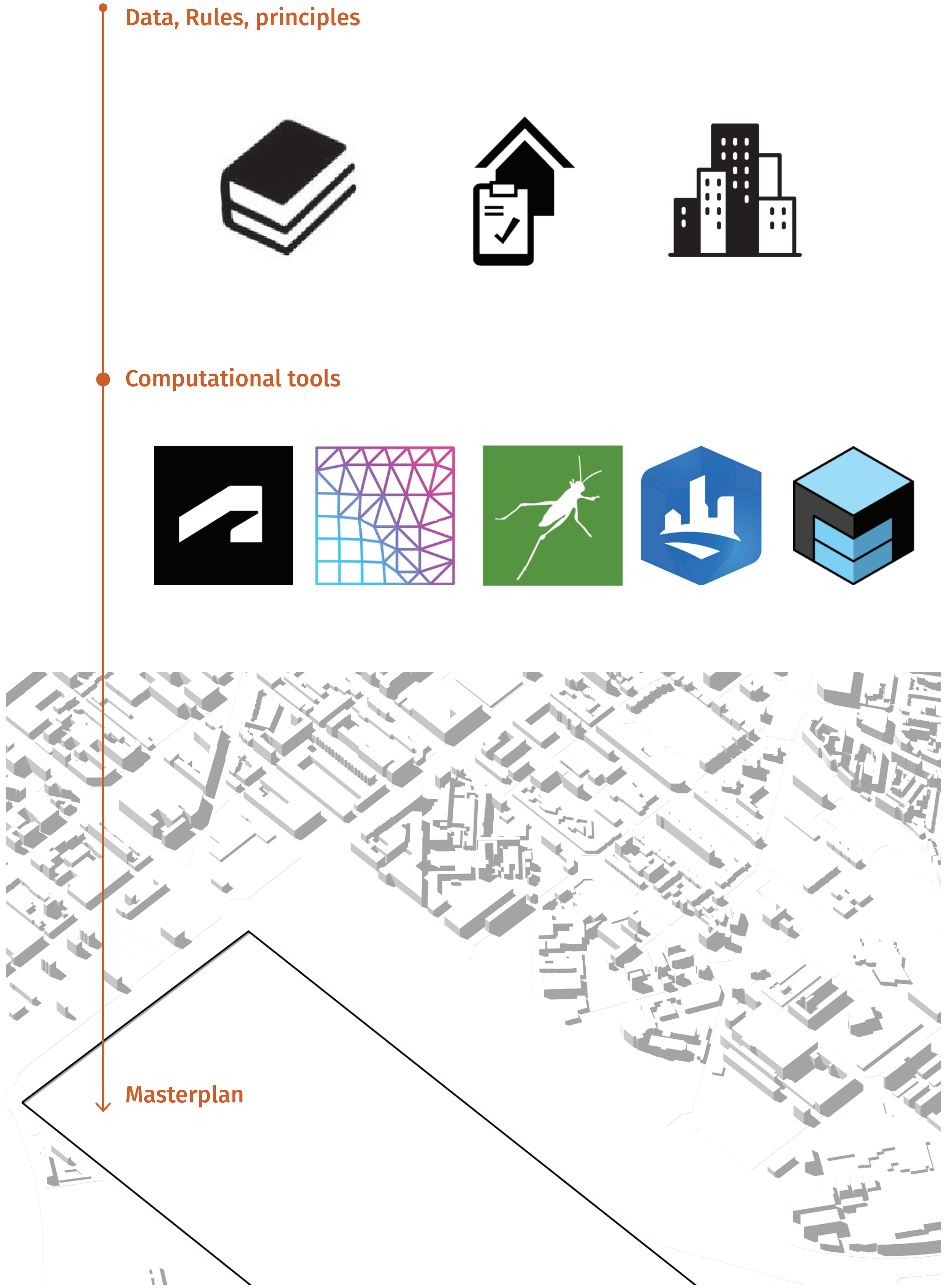


Fig 39 . *Tools as generators for urban designers. Source: Author*

3-1-1. CityEngine

CityEngine is a rule-based urban modeling software package. It offers a flexible pipeline to transform 2D data into 3D urban models. Typical applications include processing 2D urban cartographic geographic information system (GIS) data to create a detailed 3D city model, creating a detailed visualization of a proposed development, or exploring the design space of a potential project. The rule-based core of Esri's CityEngine has some unique advantages: Huge cities can be created as easily as small ones, while the quality of the models is consistent throughout. Additionally, this rule-based approach means that large design spaces can be explored quickly, interactively, and analytically compared. Such advantages must be carefully balanced against the increased time to create and parameterize the rules and the sometimes stylistic or approximate models created; coming from more traditional workflows, CityEngine's pipeline can be initially overwhelming. We introduce the principal workflows and the flexibility they afford, sketch the procedural programming language used, and discuss the export pathways available. (Kelly, 2021)

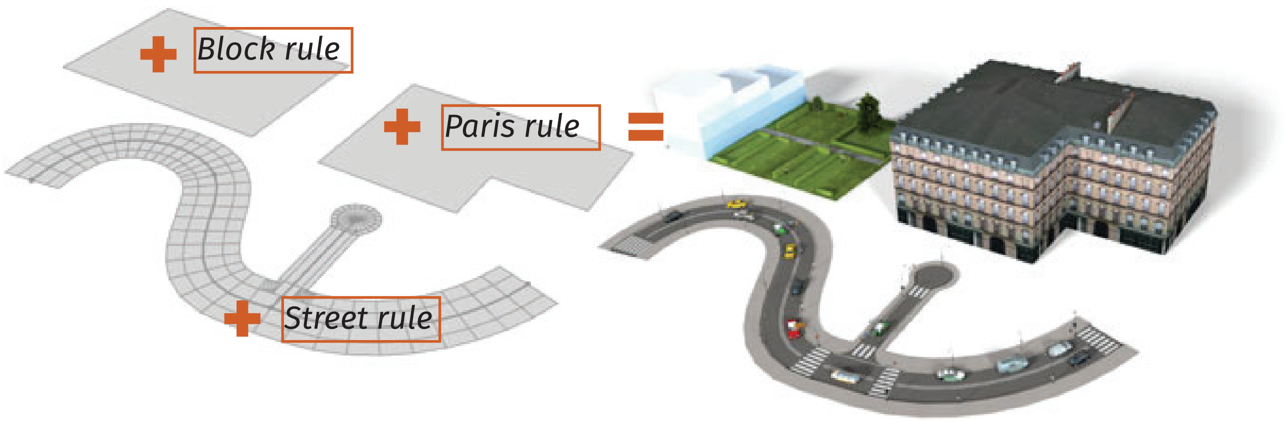


Fig 40. *The central paradigm of CityEngine is to apply rules to shapes (gray, left) to create 3D models (right). This approach is able to create a large variety of rule-driven models. Source: T. Kelly, 2021.*

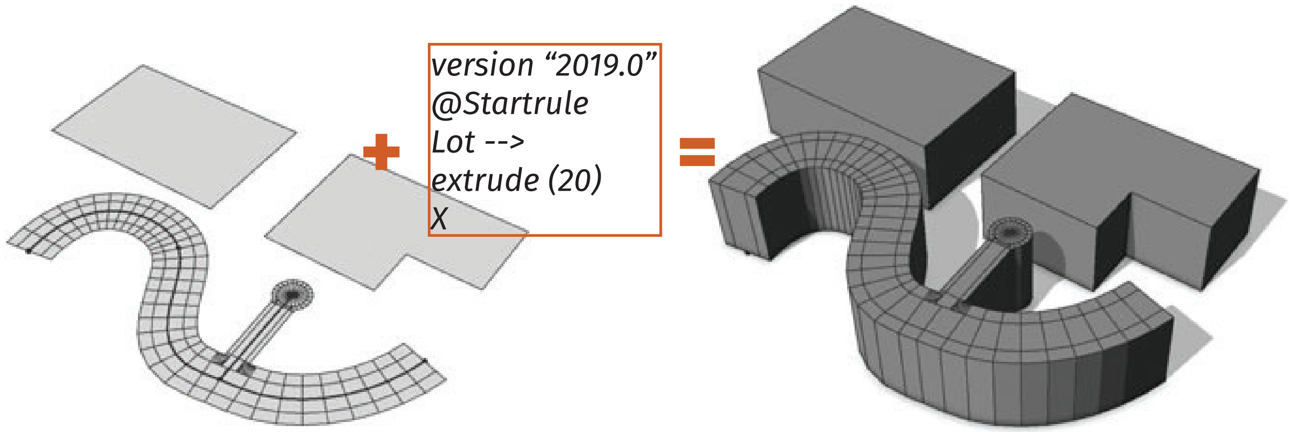


Fig 41. *A simple CGA rule file (center) is applied to several different shapes (left) to create the associated 3D models (right). This rule creates a prism of height 20 m over the shape. Source: T. Kelly, 2021.*

2D Shapes + Rules = 3D Models

The limitations of traditional 2D representations in capturing the complexities of urban environments. While 2D plans and maps have been foundational in urban planning, they often fall short in conveying the spatial depth and intricacies of real-world settings. The advent of 3D technologies has revolutionized this domain, offering more accurate, accessible, and immersive representations. Tools like virtual and augmented reality (VR and AR) have further enhanced the ability to visualize and interact with urban designs, facilitating better understanding and communication among stakeholders.

Rule-based scripting

At the core of CityEngine's functionality is its rule-based modeling paradigm. Unlike manual 3D modeling tools that require meticulous placement and adjustment of individual elements, CityEngine utilizes a procedural approach. Users define a set of rules using the Computer Generated Architecture (CGA) scripting language, which dictates how 2D shapes are extruded and detailed into 3D models. This method allows for the rapid generation of complex urban environments, ensuring consistency and scalability. For instance, a single rule can automate the placement of architectural features, such as windows or doors, across multiple buildings, significantly reducing manual effort.

Applications and Advantages in Urban Design

CityEngine's capabilities extend beyond mere visualization. Its integration with GIS data enables urban planners to simulate various scenarios, assess design alternatives, and make informed decisions. The software's ability to handle large datasets and generate expansive city models makes it invaluable for tasks ranging from detailed visualizations of proposed developments to comprehensive urban simulations. Moreover, the procedural nature of CityEngine allows for real-time modifications, enabling users to explore different design iterations swiftly.

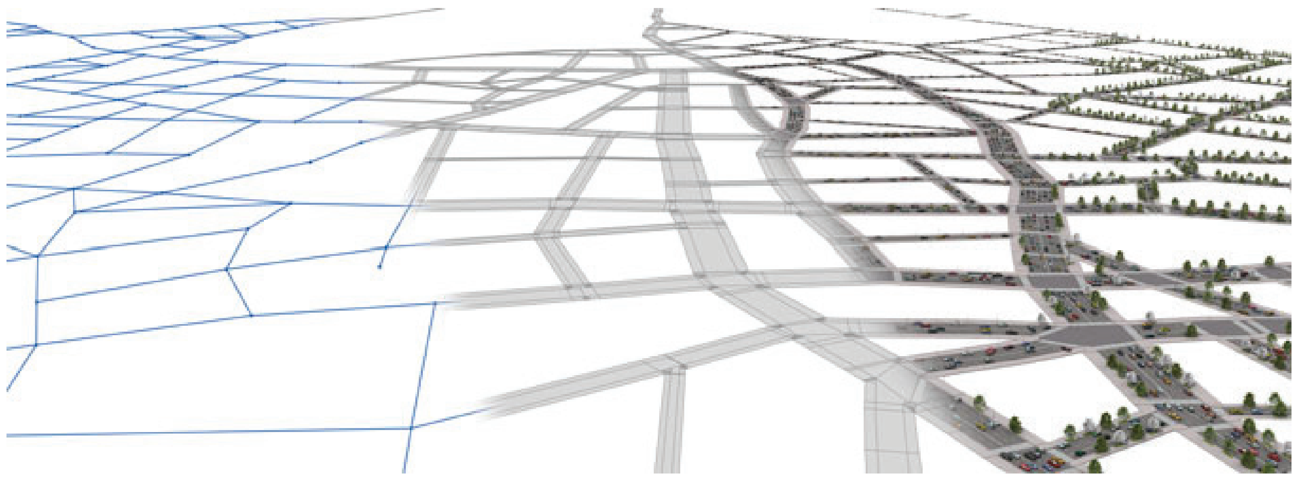


Fig 42. *Left: a blue street centerline graph; middle: the generated street shapes; right: 3D models generated by applying rules to the shapes. Source: T. Kelly, 2021.*

3-1-2. Autodesk Forma

Autodesk Forma is a cloud-based platform primarily designed for early-stage planning and design, especially for architecture, engineering, and urban design projects. It enables users to create, analyze, and iterate on large-scale projects efficiently by combining AI-driven suggestions, real-world data, and parametric modeling capabilities. Forma integrates environmental analysis, regulations, massing studies, and simulations into one environment, making it especially valuable for urban planning and concept design. Because it's part of Autodesk's ecosystem, it also easily connects with tools like Revit and other BIM software.

Autodesk Forma works by integrating real-world data with intelligent modeling and simulation tools to support early-stage design decisions. Users begin by importing or defining site information, after which the platform automatically brings in data such as topography, climate, noise levels, and zoning constraints. Within this context, designers can create massing models and adjust parameters like height, setback, or density, while Forma instantly evaluates these changes through simulations. It offers real-time feedback on environmental factors like sunlight, wind, energy performance, and regulatory compliance. Because it's cloud-based, multiple users can work together on a single project, making it ideal for team collaboration and rapid iteration. The result is a responsive, data-driven workflow where design and performance evolve hand in hand.

Fig 43. *Sun Analysis (left), Daylight Analysis (middle), Wind Analysis (right) of an urban area. Source: Autodesk.com*

Parametric urban design is about setting rules and relationships rather than drawing fixed forms. Forma supports this approach by:

Defining Parameters for Urban Blocks: Set constraints like maximum building heights, FAR (Floor Area Ratio), open space ratios, building typologies, etc., and Forma adapts building forms accordingly.

Testing Urban Density and Infrastructure: You can manipulate building massing and see immediate effects on daylight, walkability, views, noise, and energy performance — all vital urban factors.

Climate-Responsive Urban Design: Forma allows you to simulate wind flow, solar access, and thermal comfort early, helping to design sustainable neighborhoods.

Regulation Compliance: It automatically checks designs against local zoning rules and codes, ensuring proposals are viable.

Speed and Iteration: Since changes are parametric and feedback is instant, urban designers can test hundreds of versions quickly, leading to better, data-driven decisions.

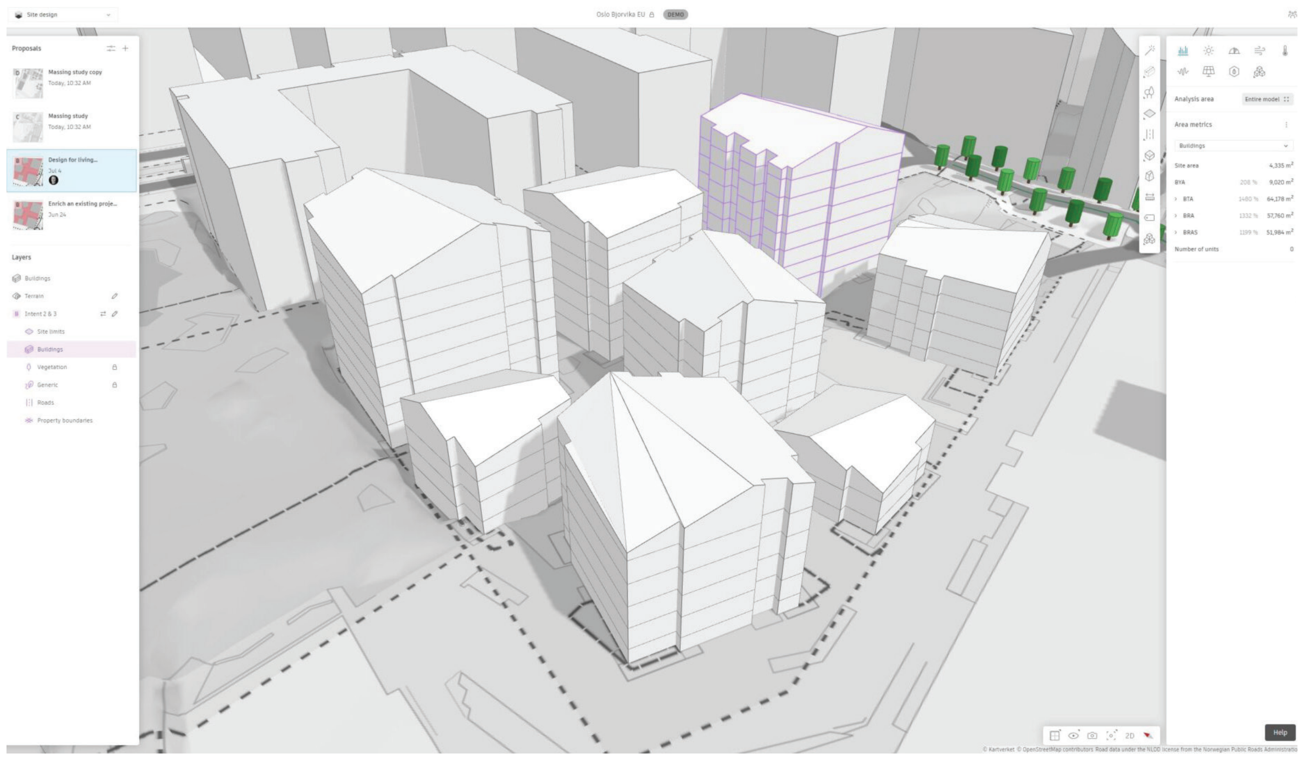


Fig 44. *Autodesk Forma viewport showing Area and density analysis in diffrent proposals. Source: Autodesk.com*

3-1-3. Grasshopper

Grasshopper was created by David Rutten at Robert McNeel & Associates in the mid-2000s as a response to the growing need for visual scripting in Rhino. It began as a tool named "Explicit History," which allowed users to create complex parametric models without writing traditional code. Over time, it evolved into Grasshopper, a node-based editor that gave designers intuitive control over geometry through algorithms and logic. By 2007–2009, it started gaining traction among architects and researchers due to its open and flexible architecture, which allowed integration with plugins like Kangaroo (physics engine), Ladybug Tools (environmental analysis), and Elk (GIS and mapping data). These plugins made Grasshopper especially attractive for urbanists and environmental designers.

Grasshopper is widely used in urban design for its ability to create parametric and data-driven models that respond dynamically to changing inputs. Designers can define rules and relationships—such as building heights, setbacks, density, or road networks—and instantly visualize how changes affect the urban form. This makes it easier to explore multiple design scenarios and test their performance based on environmental, spatial, or regulatory constraints. With plugins like Elk, Ladybug, and Decoding Spaces, Grasshopper becomes a powerful platform for integrating GIS data, simulating sunlight and wind flow, and analyzing accessibility or mobility patterns.

The benefits of using Grasshopper in urban design include improved precision, faster iteration, and more informed decision-making. Its visual programming environment lowers the barrier for designers to use computational tools without needing deep coding knowledge. It also enables a more collaborative and transparent planning process, where stakeholders can see real-time impacts of design changes. Ultimately, Grasshopper helps create more efficient, sustainable, and adaptable urban environments by linking design intent with measurable performance.

One often overlooked aspect of Grasshopper is its extensibility and strong community-driven ecosystem. Beyond the standard toolset, hundreds of custom plugins—such as Wallacei for evolutionary optimization or Heteroptera for advanced data manipulation—expand its capabilities far beyond geometry creation. Grasshopper also supports scripting through Python and C#, allowing for more complex logic and integration with external tools like Excel, GIS platforms, and simulation engines. This makes it not just a modeling tool, but a flexible framework for developing customized workflows in urban design, capable of addressing unique challenges through automation, analysis, and real-time feedback.

A case study

In this case study, Grasshopper was used to enhance urban design by enabling the creation of custom tools for generating street networks and subdividing blocks—tasks previously hard to manage parametrically. Researchers integrated advanced methods from CityEngine into Grasshopper, making these tools accessible within a platform commonly used by architects. This allowed more realistic and context-aware urban models.

The approach was applied in a Master's project in Moscow and a teaching exercise in India. In both cases, Grasshopper enabled designs that responded to local context, such as proximity to infrastructure and landscape features. While early versions had limitations, especially in street layout realism, further development through custom scripts and plugins improved the process, showing Grasshopper's flexibility and potential in real-world urban planning. (Schmitt, Koltsova 2011)

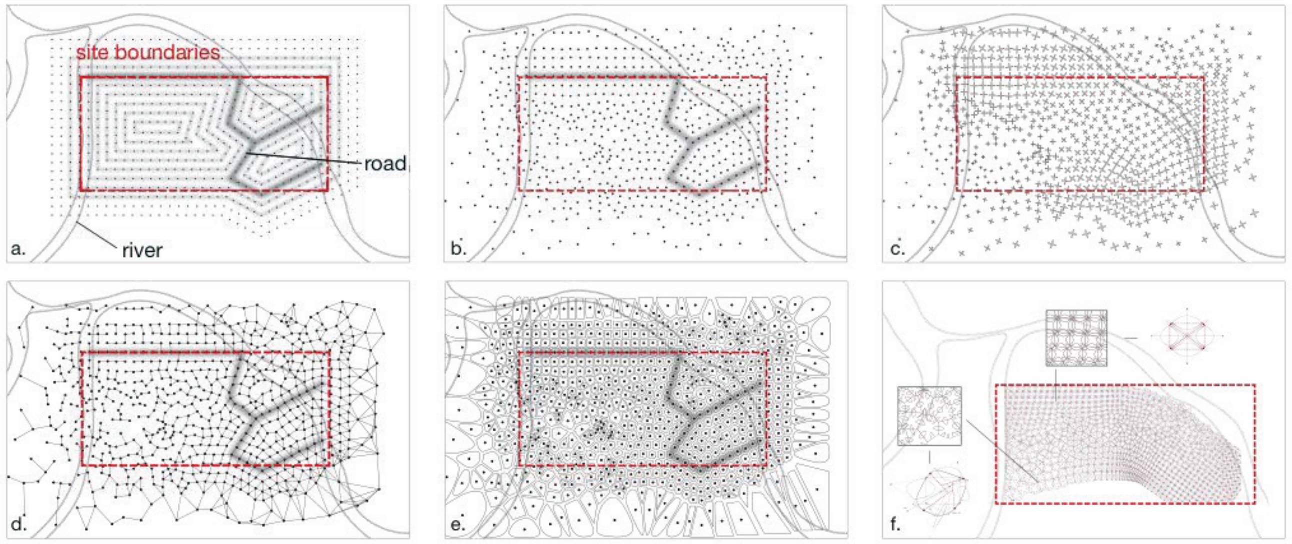


Fig 45. *a. Initial point grid setup b. Point shift c. Orientationd. Connectivity e. Voronoi subdivision f. Geometry in Voronoi cell*

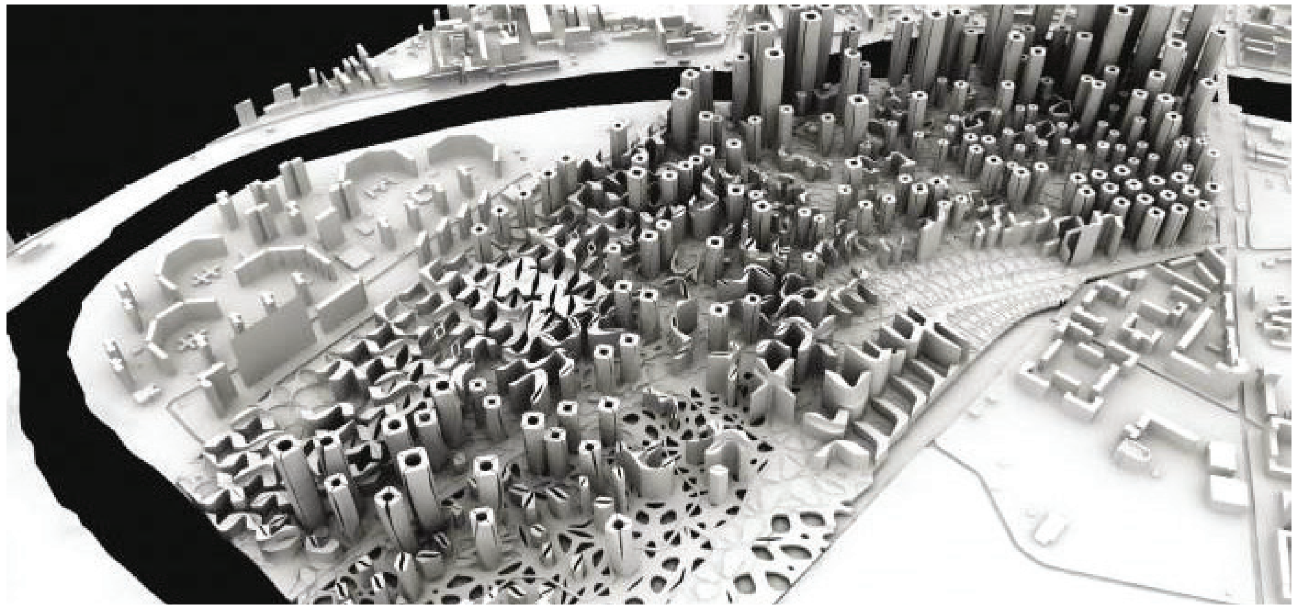


Fig 46. *Final urban design proposal of the master's project in Moscow. Source: Schmitt, Koltsova 2011.*

3-1-4. DeCodingSpaces (Grasshopper plug-in)

The DeCodingSpaces Toolbox is a comprehensive suite of generative and analytical components designed for urban and architectural planning within the Grasshopper environment. Developed by the Computational Planning Group (CPlan) in collaboration with global academic and professional partners, this open-source tool enables users to algorithmically generate and analyze street networks, plots, and building layouts. Its generative capabilities include the creation of street networks based on parameters like segment length and angular deviation, plot divisions with specified minimum widths, and building massing. Analytically, it offers tools for evaluating street network centrality, shortest paths, and visual accessibility through isovist analysis, facilitating data-driven urban design decisions.

In urban parametric design, the DeCodingSpaces Toolbox enhances the design process by providing rapid prototyping and iterative testing of urban configurations. Its integration with the Speckle plug-in allows for real-time sharing and stakeholder engagement, enabling collaborative exploration of design alternatives. By facilitating the generation of multiple urban planning variants, the toolbox aids in identifying optimal trade-offs between economic, social, and ecological factors. This approach supports more informed, participatory, and adaptable urban planning processes, ultimately leading to more efficient and higher-quality urban environments.

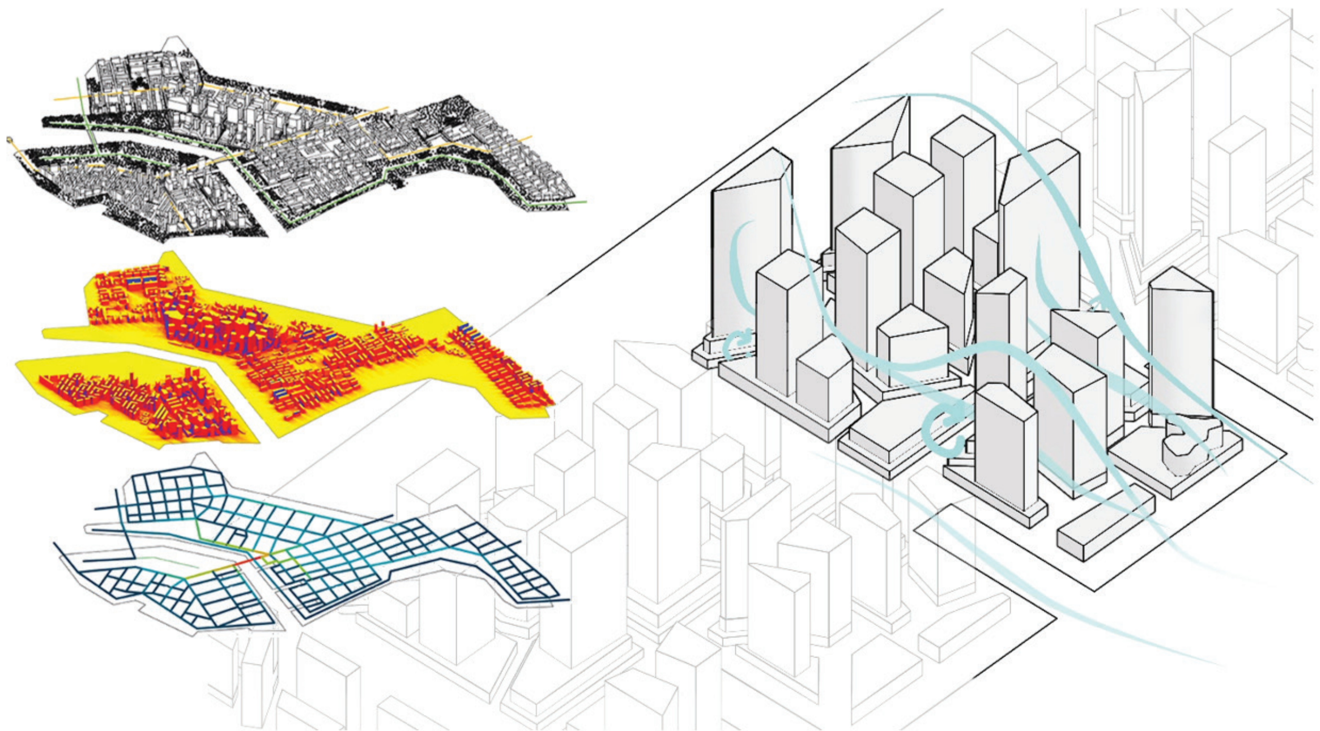


Fig 47. *Different layers of parametric outputs from DeCodingSpaces tool. Source: decodingspaces.net, 2018.*

3-1-5. DepthmapX

DepthmapX is an advanced, open-source spatial analysis software developed by Dr. Tasos Varoudis, building upon the original Depthmap by Alasdair Turner. It operates across various scales—from individual buildings to entire cities—and employs graph-based methodologies to analyze spatial configurations. At its core, DepthmapX utilizes Space Syntax theory to assess the connectivity and integration of spaces, providing insights into how spatial layouts influence movement patterns and social interactions. The software offers tools like axial and segment analysis, visibility graph analysis (VGA), and agent-based modeling to quantify spatial relationships and predict human behavior within built environments.

In urban parametric design, DepthmapX serves as a crucial analytical tool, enabling designers to evaluate the spatial performance of different layouts. By integrating DepthmapX with parametric design workflows, planners can iteratively test and optimize urban configurations, enhancing accessibility, safety, and social interaction. The software's ability to visualize and quantify spatial relationships aids in making informed decisions that align with human behavior and social dynamics. Additionally, DepthmapX's compatibility with GIS platforms, such as the Space Syntax Toolkit for QGIS, facilitates seamless integration into broader urban planning processes, promoting evidence-based design practices.

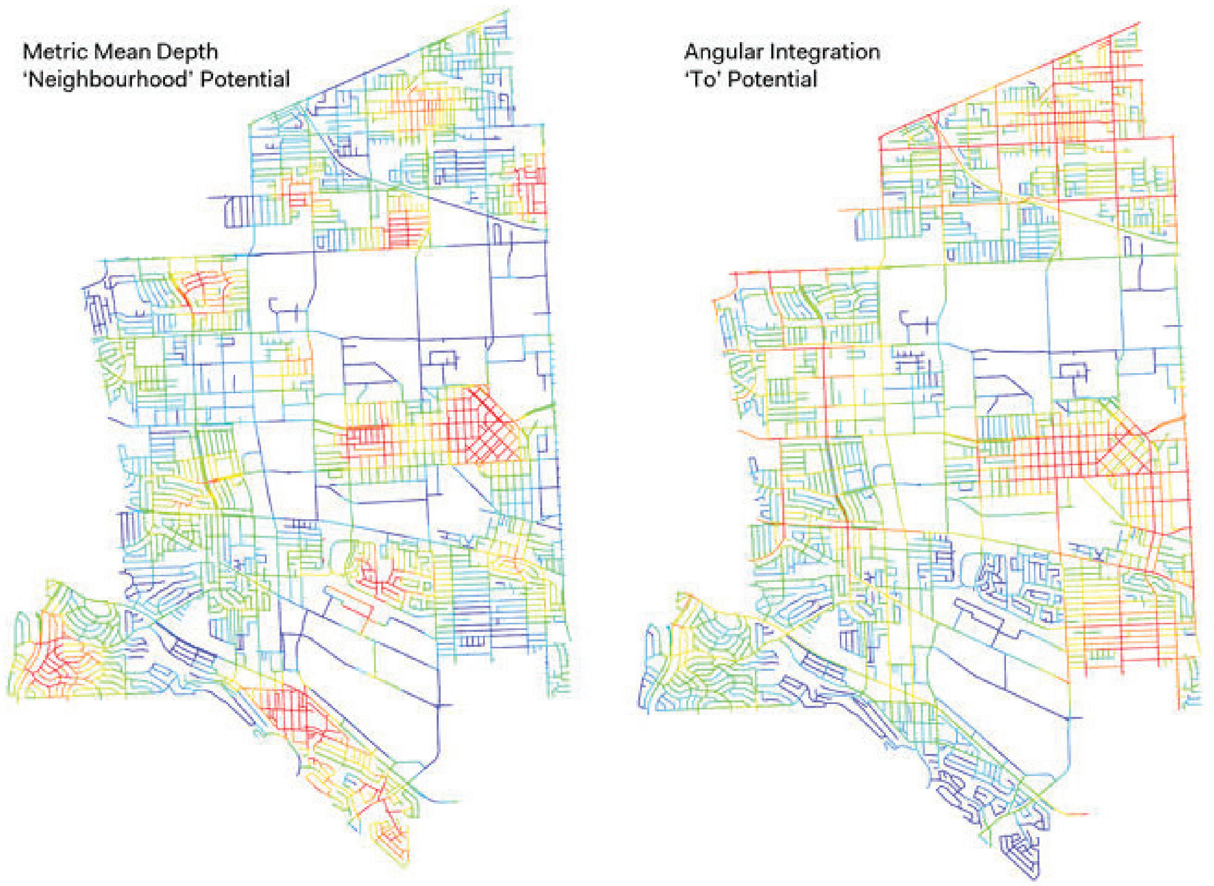


Fig 48. *Analysing Space syntax principles in DepthmapX. source: Transform Transport, 2020.*

3-2. DECISION-MAKING TOOLS

After utilizing computational tools in urban design, we often generate numerous design scenarios, each with its unique set of parameters and outcomes. This abundance of options can make the selection process challenging, as it requires evaluating complex trade-offs between various factors such as environmental impact, social equity, and economic feasibility. Traditionally, this decision-making process has been manual and time-consuming, often relying on static visualizations and subjective judgment.

However, the advent of AI-powered tools has revolutionized this aspect of urban planning. Platforms like UrbanistAI and ArkoAI enable designers to visualize multiple scenarios in real-time, allowing for dynamic comparisons and more informed decision-making. These tools facilitate the simultaneous consideration of various factors—such as light exposure, pedestrian flow, and accessibility by integrating them into a cohesive visualization. This capability not only enhances the precision of decisions but also supports a more holistic approach to urban design, ensuring that multiple objectives are balanced effectively. By leveraging AI, urban planners can navigate the complexity of multiple scenarios with greater ease and confidence, leading to more sustainable and equitable urban environments.

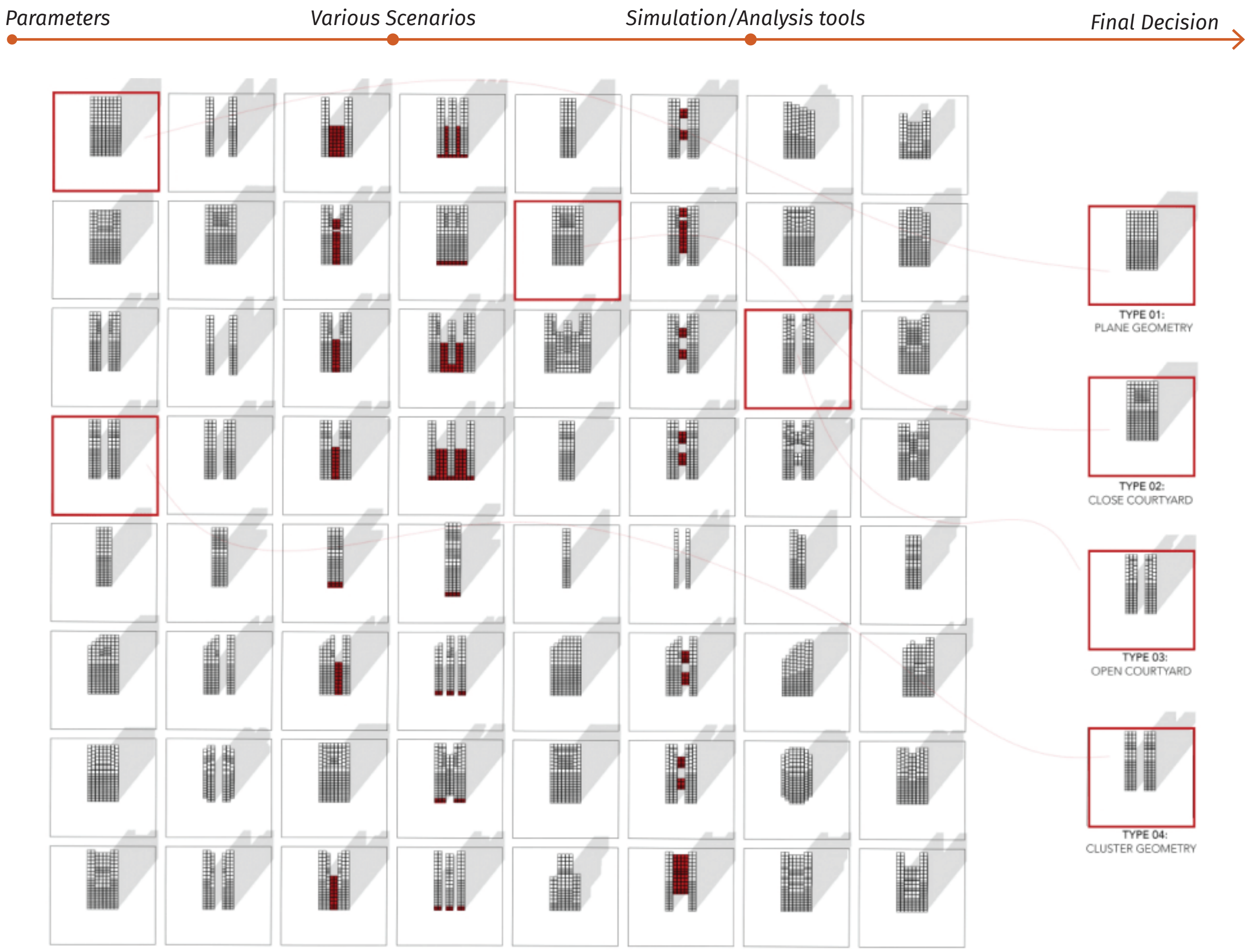


Fig 49. *Decision-making process through tools. Source: Author, 2023.*

3-2-1. Wallacei

Wallacei is a robust evolutionary multi-objective optimization engine designed as a plugin for Grasshopper 3D, enabling users to conduct comprehensive evolutionary simulations within the Rhino environment. Developed through extensive research, Wallacei integrates two main components: Wallacei X, the core evolutionary solver, and Wallacei Analytics, a suite of tools for in-depth analysis of simulation results. Users can define complex design problems with multiple objectives, run simulations, and analyze outcomes using advanced visualization tools such as parallel coordinate plots, objective space graphs, and standard deviation trend lines. These features facilitate a deeper understanding of the evolutionary process and assist in identifying optimal solutions.

In the context of urban parametric design, Wallacei offers significant benefits by allowing designers to explore a vast array of design alternatives and assess them against multiple performance criteria. Its integration with Grasshopper ensures seamless incorporation into existing parametric workflows, enabling real-time feedback and iterative design processes. Features like K-means clustering assist in categorizing solutions based on fitness values, simplifying the selection of representative designs for further development. Additionally, Wallacei's capability to reconstruct phenotypes post-simulation without the need to save all geometries reduces computational load and storage requirements. These functionalities make Wallacei an invaluable tool for architects and urban planners aiming to optimize designs for factors such as environmental performance, spatial efficiency, and user experience.

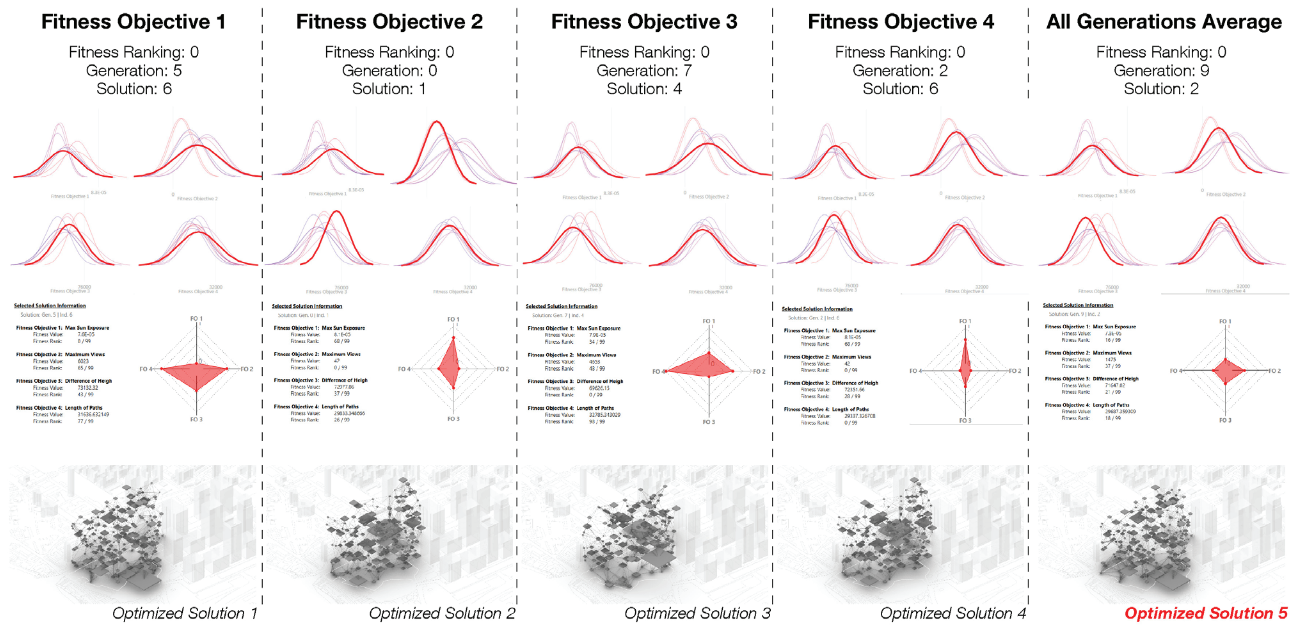


Fig 50. *Wallacei multi-objective analysis and optimized solution. Source: wallacei.com*

3-2-2. Opposum

Opossum is a free, open-source optimization plugin for Grasshopper, developed by the Institute for Computational Design and Construction (ICD) at the University of Stuttgart. It integrates advanced optimization algorithms, including model-based RBFOpt and RBFMOpt, as well as evolutionary algorithms like CMA-ES and NSGA-II, to efficiently solve both single- and multi-objective design problems. These algorithms are particularly effective for time-intensive simulations, such as daylighting and energy performance analyses, by reducing the number of required evaluations through surrogate modeling techniques. Opossum's user interface is designed to be intuitive, featuring a results table for easy comparison of solutions and a Performance Explorer for interactive visualization of the design space.

In urban parametric design, Opossum enhances the design process by enabling rapid exploration and optimization of complex design spaces. Its ability to handle multiple objectives allows designers to balance various performance criteria, such as environmental impact, spatial efficiency, and user comfort. The plugin's integration with Grasshopper ensures seamless incorporation into existing parametric workflows, facilitating iterative design and real-time feedback. By leveraging advanced optimization techniques, Opossum supports data-driven decision-making, leading to more informed and effective urban design solutions.

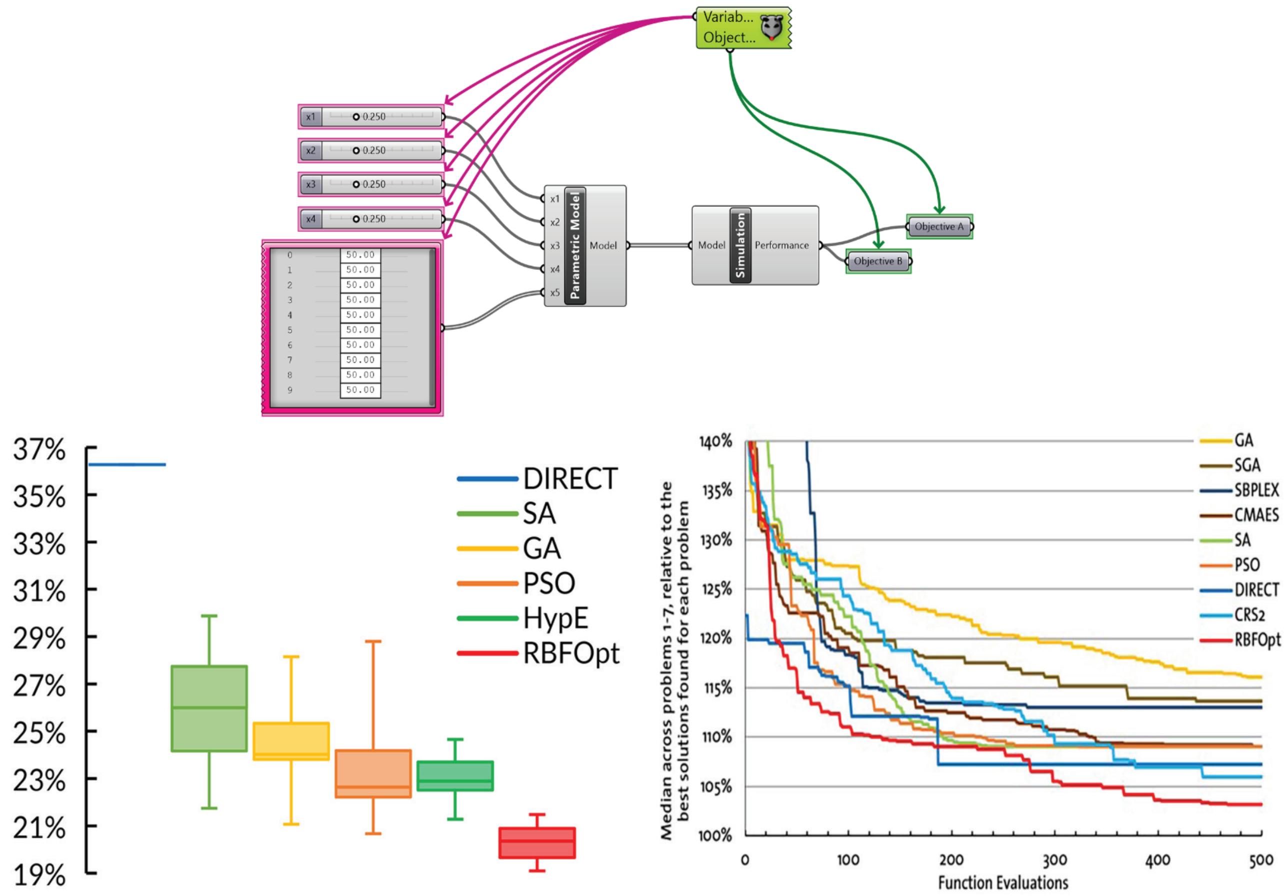


Fig 51. *Comparison tables of the different parameters. Source: icd.uni-stuttgart.de*

3-2-3. Lookx

LookX AI is an advanced AI-powered rendering platform tailored for architects, urban designers, and creatives seeking rapid, high-quality visualizations from sketches, 3D models, or textual prompts. Built on the ArchiNet database, which is rich in architectural semantics, LookX AI excels in interpreting design intents, enabling users to generate photorealistic images and animations with minimal input. The platform offers features such as real-time rendering, video generation, style adaptation, and custom model training, all accessible through an intuitive web interface and plugins for software like Rhino and SketchUp.

In urban parametric design, LookX AI enhances decision-making by allowing designers to quickly visualize and compare multiple design scenarios. Its real-time rendering capabilities enable rapid iteration, facilitating the assessment of various spatial configurations, materials, and lighting conditions. This accelerates the design process and supports more informed choices, ultimately leading to more effective and sustainable urban environments. By transforming simple sketches or massing models into detailed renderings, LookX AI aids in communicating design concepts to stakeholders, fostering collaborative decision-making.

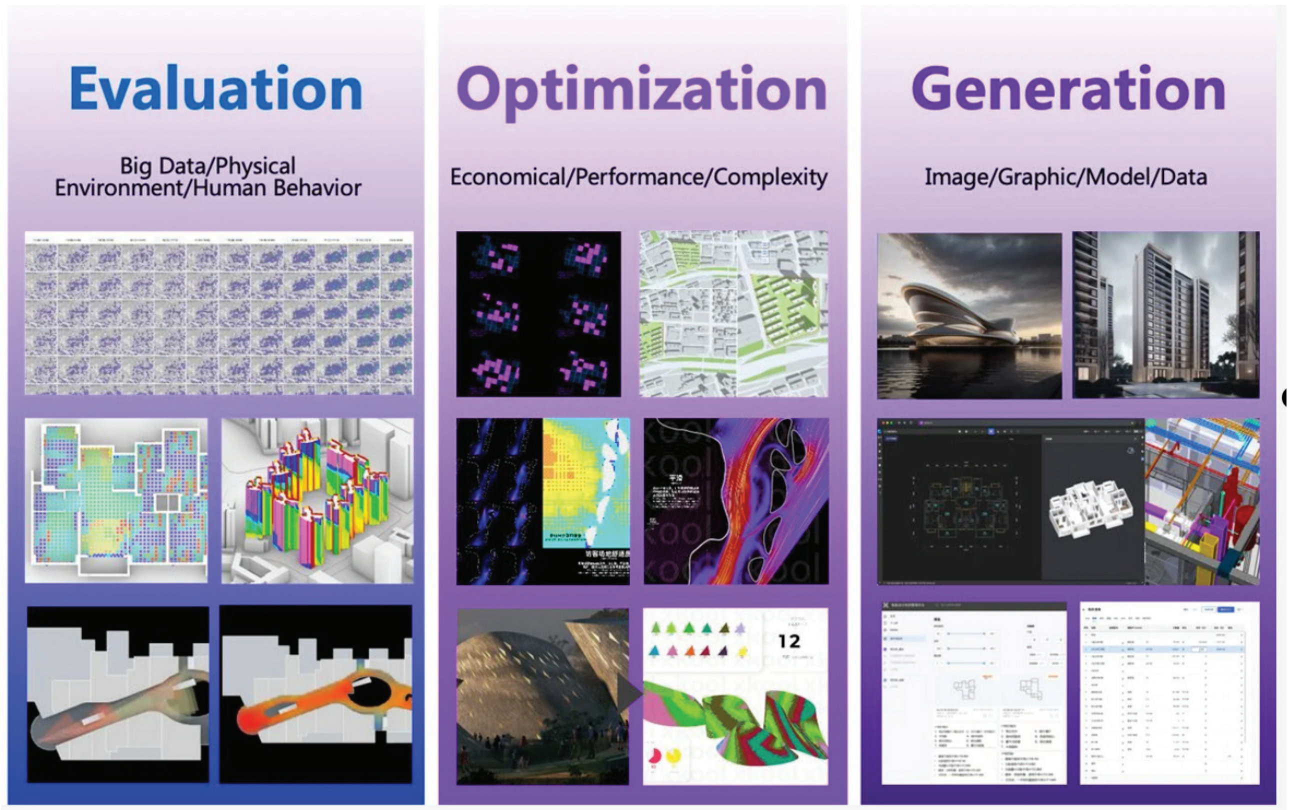


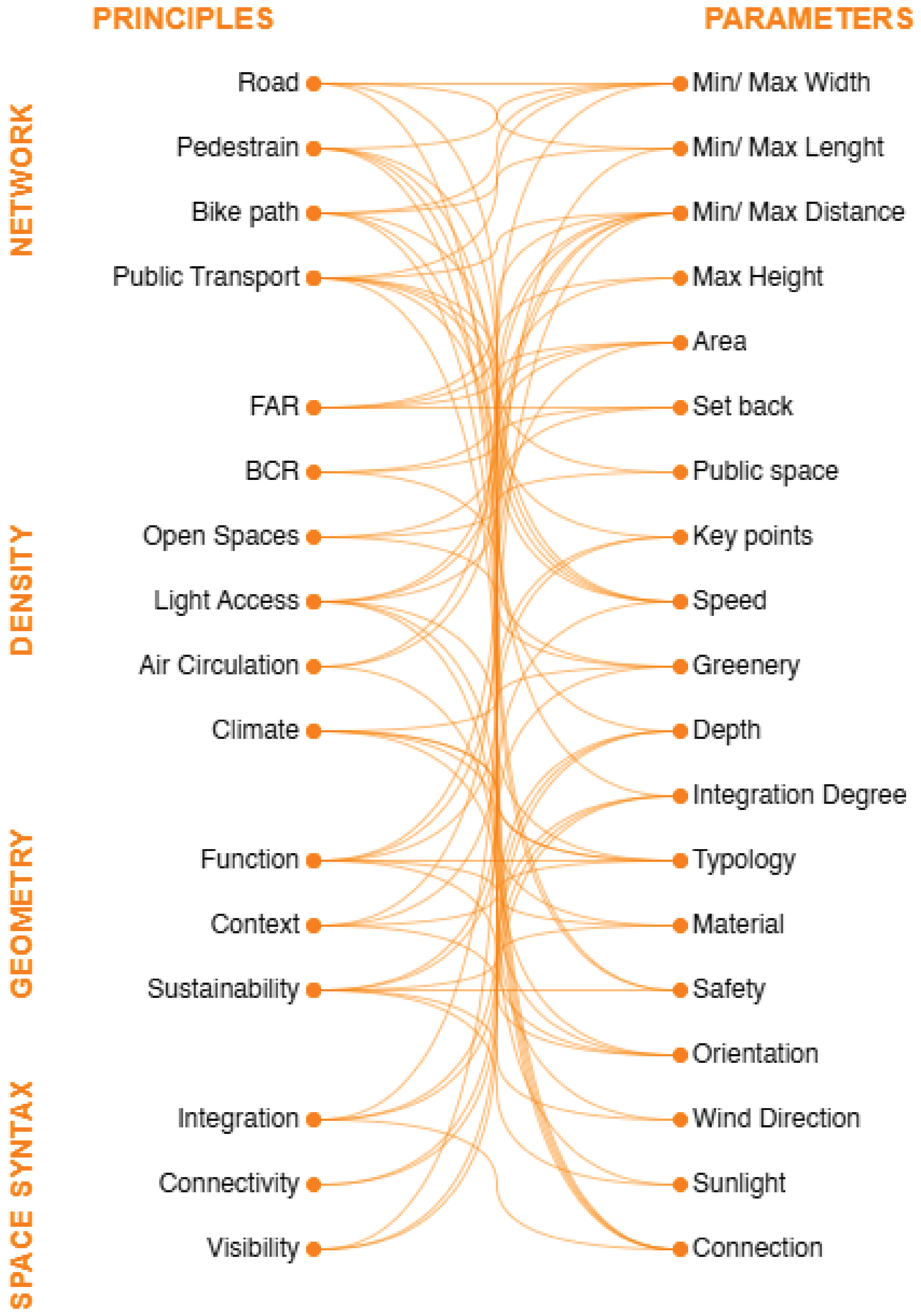
Fig 52. *Graphic outputs generated by AI to assess the final results. Source: lookx.ai*

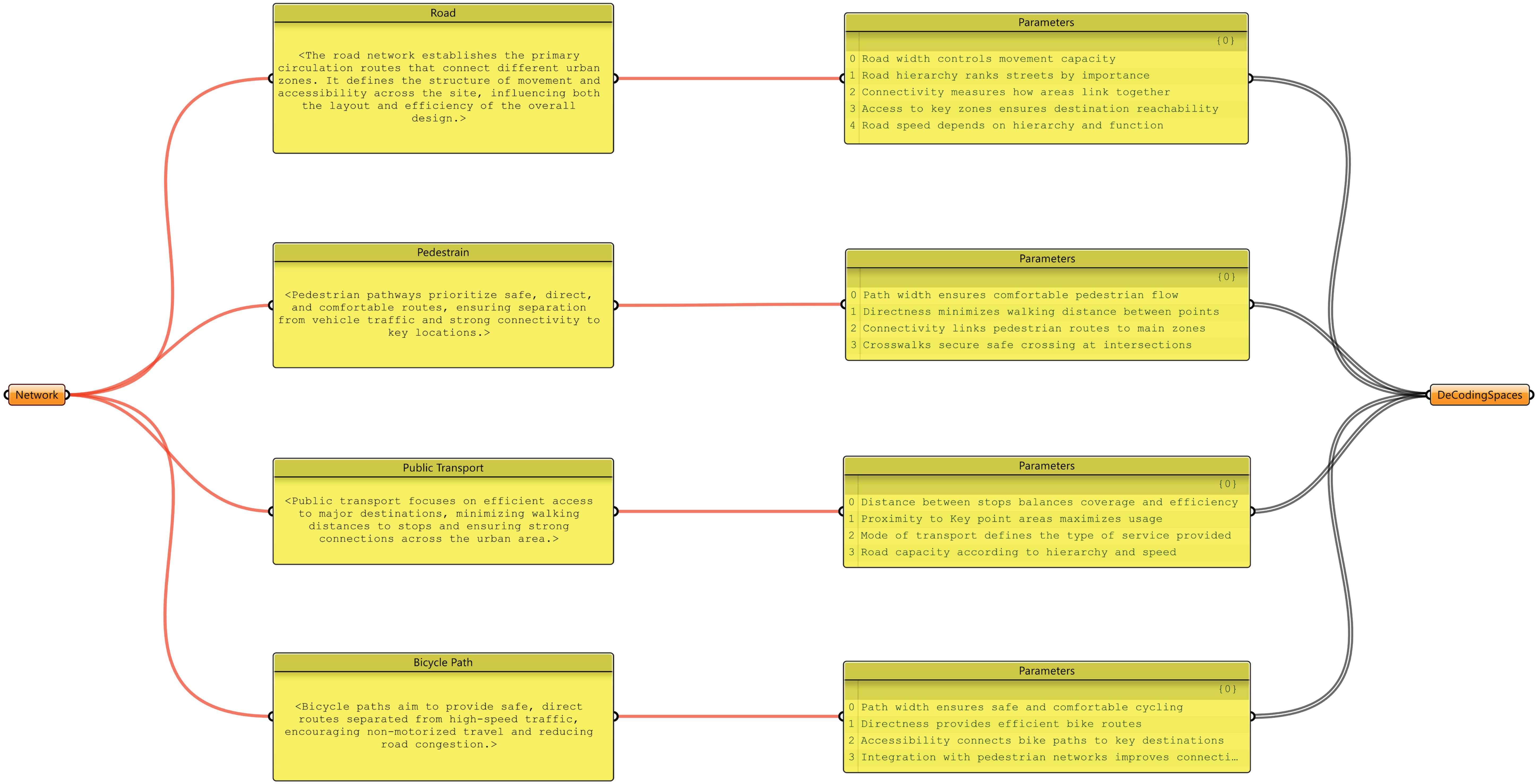
3-3. PRINCIPLES TO PARAMETERS

After selecting the appropriate parametric tool for each principle, the next step is to translate the principle into measurable parameters. These tools provide the necessary flexibility and functionality to break down broad urban or architectural concepts into specific, adjustable variables. Through this process, complex design intentions become manageable, quantifiable elements that can be systematically studied and applied within the design workflow.

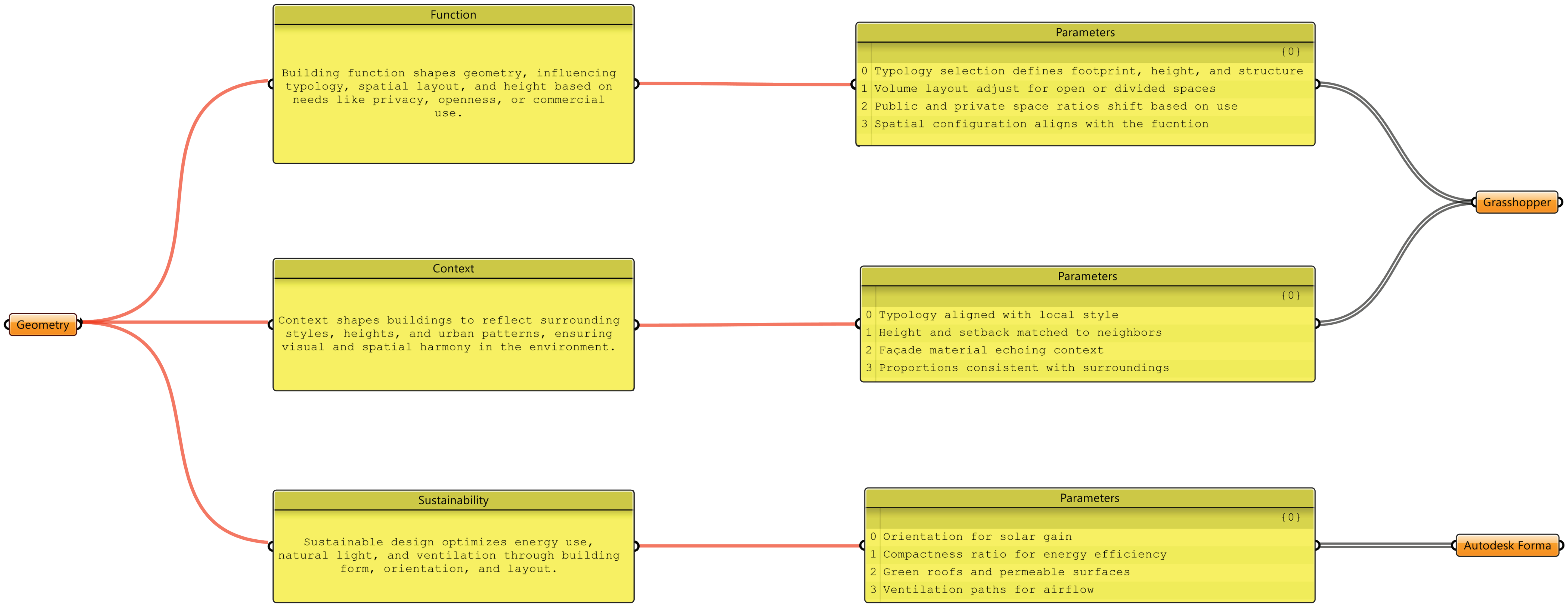
Each principle contributes to and influences several parameters, either directly or indirectly. For example, a principle such as "density" may directly define parameters like floor area ratio or building coverage, while also indirectly affecting aspects like sunlight access or airflow between buildings. This interconnectedness highlights the importance of carefully mapping how each principle manifests across different scales and categories of parameters, ensuring a comprehensive understanding of its impact within the design system.

In this section, we will explore in depth what each parameter represents and how it contributes to the realization of the intended principles. The goal is to cover as many relevant parameters as possible to achieve a robust and meaningful parametric model. However, it is important to acknowledge that due to the scope and limitations of a master's thesis, it may not be feasible to address every possible parameter in full detail. Therefore, the focus will be on covering the most critical and influential parameters while recognizing the areas that may require further development in future research.

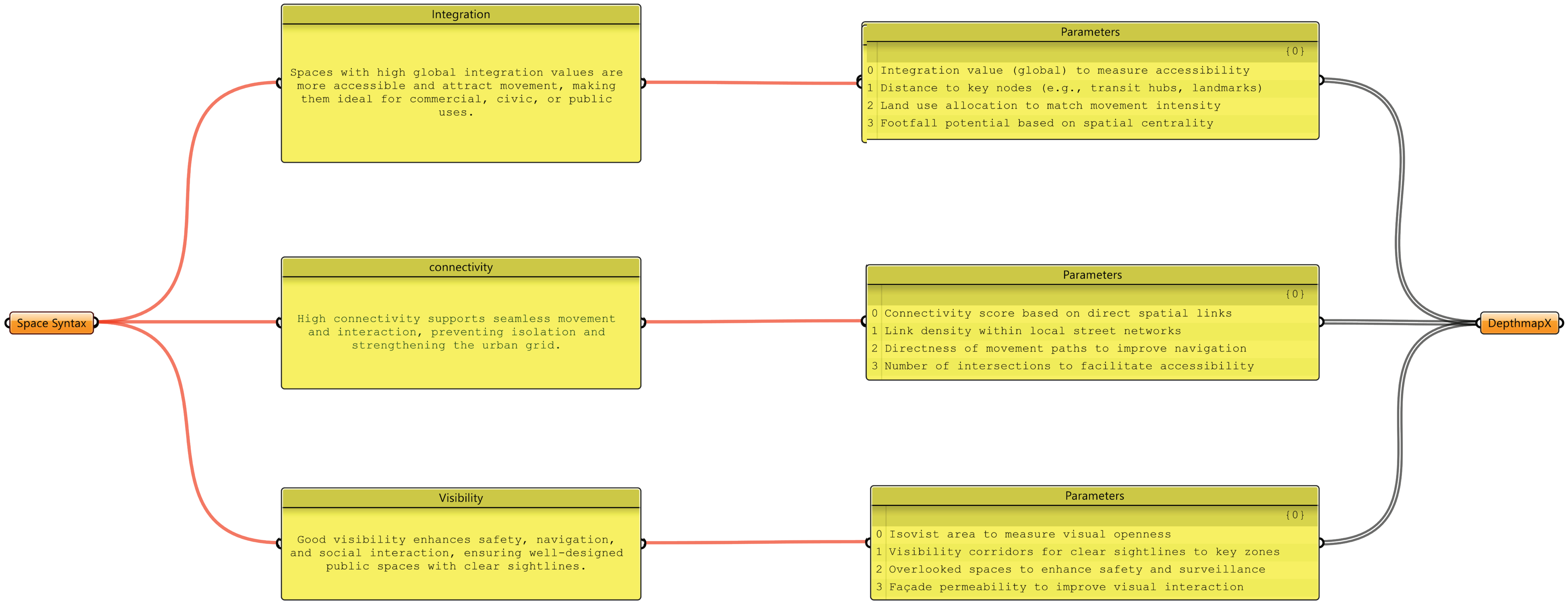



Network
Road
<The road network establishes the primary circulation routes that connect different urban zones. It defines the structure of movement and accessibility across the site, influencing both the layout and efficiency of the overall design.>
Pedestrain
<Pedestrian pathways prioritize safe, direct, and comfortable routes, ensuring separation from vehicle traffic and strong connectivity to key locations.>
Public Transport
<Public transport focuses on efficient access to major destinations, minimizing walking distances to stops and ensuring strong connections across the urban area.>
Bicycle Path
<Bicycle paths aim to provide safe, direct routes separated from high-speed traffic, encouraging non-motorized travel and reducing road congestion.>
Parameters
{0}
0 Road width controls movement capacity
1 Road hierarchy ranks streets by importance
2 Connectivity measures how areas link together
3 Access to key zones ensures destination reachability
4 Road speed depends on hierarchy and function
Parameters
{0}
0 Path width ensures comfortable pedestrian flow
1 Directness minimizes walking distance between points
2 Connectivity links pedestrian routes to main zones
3 Crosswalks secure safe crossing at intersections
Parameters
{0}
0 Distance between stops balances coverage and efficiency
1 Proximity to Key point areas maximizes usage
2 Mode of transport defines the type of service provided
3 Road capacity according to hierarchy and speed
Parameters
{0}
0 Path width ensures safe and comfortable cycling
1 Directness provides efficient bike routes
2 Accessibility connects bike paths to key destinations
3 Integration with pedestrian networks improves connecti…
DeCodingSpaces


FAR, BCR
FAR and BCR define how much can be built on a parcel. FAR controls total floor area, while BCR limits footprint size, both shaping building volume, open space, and urban density.
Parameters
{0}
0 Both Can be set as a ratio (e.g. 1.5)
1 Parcel size influences both total volume and coverage
2 Maximum floors adjust how FAR is distributed vertically
3 Open space rules limit footprint through BCR requirements
4 Zoning guidelines define allowed FAR/BCR based on land use
5 Building typology sets form and density expectations
DeCodingSpaces
Open Spaces
Open spaces improve livability by supporting light access, airflow, recreation, and social interaction, balancing built and unbuilt areas in urban design.
Parameters
{0}
0 Parcel percentage ensures a portion remains unbuilt
1 Proximity to amenities makes open space accessible
2 Orientation and setbacks improve sunlight and airflow
3 Typology defines use, like parks or plazas, and their nee…
Density
Light Access
Light access promotes well-lit buildings and spaces, supporting comfort and energy efficiency while minimizing overshadowing in dense urban areas.
Parameters
{0}
0 Building height and spacing reduce shadow impact
1 Orientation maximizes direct sunlight exposure
2 Sunlight hour targets ensure key areas stay well-lit
Air Circulation
Air circulation improves ventilation and comfort, reducing heat and pollution buildup, especially in dense or high-rise environments.
Parameters
{0}
0 Building height and orientation guide airflow
1 Spacing and green corridors allow wind to pass through
2 Alignment with wind patterns boosts natural ventilation
Autodesk Forma
Climate
Geographic climate shapes how buildings are placed and designed—hot climates need spacing and shade, while cold climates benefit from compact layouts for heat retention.
Parameters
{0}
0 density adjust to minimize heat or retain warmth
1 Shading and greenery reduce heat absorption
2 Orientation controls solar exposure based on climate needs
3 Façade design supports insulation or shading strategies



Geometry
Function
Building function shapes geometry, influencing typology, spatial layout, and height based on needs like privacy, openness, or commercial use.
Context
Context shapes buildings to reflect surrounding styles, heights, and urban patterns, ensuring visual and spatial harmony in the environment.
Sustainability
Sustainable design optimizes energy use, natural light, and ventilation through building form, orientation, and layout.
Parameters
{0}
0 Typology selection defines footprint, height, and structure
1 Volume layout adjust for open or divided spaces
2 Public and private space ratios shift based on use
3 Spatial configuration aligns with the fucntion
Parameters
{0}
0 Typology aligned with local style
1 Height and setback matched to neighbors
2 Façade material echoing context
3 Proportions consistent with surroundings
Parameters
{0}
0 Orientation for solar gain
1 Compactness ratio for energy efficiency
2 Green roofs and permeable surfaces
3 Ventilation paths for airflow
Grasshopper
Autodesk Forma


Space Syntax
Integration
Spaces with high global integration values are more accessible and attract movement, making them ideal for commercial, civic, or public uses.
connectivity
High connectivity supports seamless movement and interaction, preventing isolation and strengthening the urban grid.
Visibility
Good visibility enhances safety, navigation, and social interaction, ensuring well-designed public spaces with clear sightlines.
Parameters
{0}
0 Integration value (global) to measure accessibility
1 Distance to key nodes (e.g., transit hubs, landmarks)
2 Land use allocation to match movement intensity
3 Footfall potential based on spatial centrality
Parameters
{0}
0 Connectivity score based on direct spatial links
1 Link density within local street networks
2 Directness of movement paths to improve navigation
3 Number of intersections to facilitate accessibility
Parameters
{0}
0 Isovist area to measure visual openness
1 Visibility corridors for clear sightlines to key zones
2 Overlooked spaces to enhance safety and surveillance
3 Façade permeability to improve visual interaction
DepthmapX

Theory Part Conclusion

In this chapter, new parametric design tools and computational methods were explored to understand their capabilities and mechanisms. For example, we examined platforms such as Rhinoceros3D and its Grasshopper plug-in, which enable designers to generate three-dimensional urban models and visual simulations in real time. Grasshopper's node-based environment allows designers to link geometric and performance variables so that changing any numeric input such as geometry proportions, roof angles, or orientation—automatically updates the model and its analytic outputs. In this way, the tools demonstrate how design rules and parameters can be embedded directly into the modeling workflow, supporting dynamic, data-driven exploration of design alternatives.

Fundamental urban design principles and regulations were then translated into concrete, measurable parameter sets. Core guidelines such as those governing pedestrian connectivity, spatial proportions, or amenity distribution were encoded as quantitative metrics. For example, pedestrian comfort can be captured by height-to-street-width ratios or calculated walkability and amenity-accessibility scores. By framing rules in this way, abstract concepts become numeric thresholds. This process shows that normative design heuristics can be grounded in data-driven values, enabling objective evaluation and adaptation of design proposals.

Finally, to test the validity of the parameters and tools, it is necessary to apply them in a real-world design context. Existing studies underscore the value of case study validation for parametric frameworks. Following this approach, the next chapter will implement the developed parameters and tools on a specific urban project. This case study will illustrate how the various components integrate into a cohesive, holistic parametric design system, thereby bridging the gap between theoretical parameterization and practical urban design.

PART 5

DESIGN PRACTICE

EXPLORING A DESIGN PROCESS THROUGH PARAMETRIC URBANISM

To examine the concepts introduced in earlier chapters, this section applies them to a real site using a parametric urban design approach. The goal is not to create a single masterplan, but to develop **a flexible, adaptable design system** for the early stage of design. This approach addresses the growing need for urban design to be data-driven, responsive, and scalable.

By using parametric principles, the system can adjust to evolving constraints and generate multiple design scenarios. This allows for exploration and selection of the most context-sensitive and optimized solutions.

The design process is divided into three stages:

Site Analysis:
understanding context, rules, and constraints

Scenario Generation:
producing various configurations using parameters

Optimization and Selection:
evaluating options to find the best solution

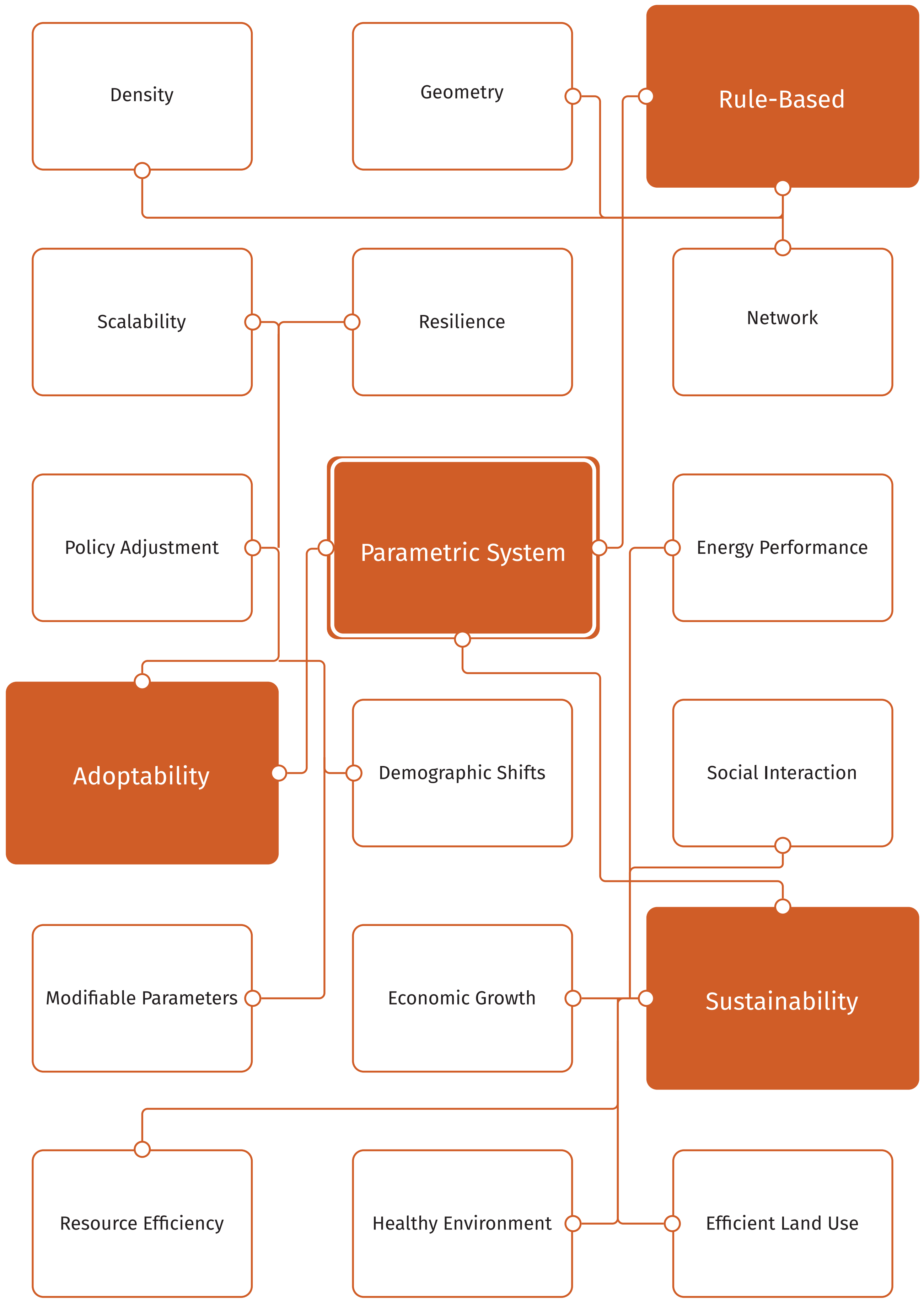
Design's main objectives

In this design phase, the central objective is to establish a framework that promotes **parametric urban development**, while ensuring that the system remains resilient and adaptable to future changes. Rather than focusing on a single masterplan, the aim is to construct a parametric system capable of generating multiple scenarios based on a range of urban principles, constraints, and site-specific data. This system-oriented approach not only reflects the complexity of contemporary urban environments, but also offers a flexible and scalable method applicable to various contexts beyond the chosen site in Turin.

The notion of sustainability in this framework goes beyond environmental considerations. It includes the **social, spatial, and ecological** dimensions of urban life. On one side, the design aims to enhance human experience through improved connectivity, active public spaces, increased opportunities for social interaction, and healthier environments. On the other side, the system seeks to optimize **energy performance** by improving solar access, natural ventilation, and microclimatic comfort. These layers are embedded into the parametric logic to ensure that every design scenario responds meaningfully to both human-scale livability and environmental performance.

At the same time, **adaptability** is a core characteristic of the proposed system. Cities are dynamic entities constantly affected by demographic shifts, climate change, evolving mobility systems, and social needs. Therefore, the design framework is built to remain responsive to change. By structuring the logic around modifiable parameters, the system can accommodate new rules, adjusted urban policies, or site-specific changes without collapsing the overall coherence of the plan. This makes the system not only generative but also resilient, enabling planners and designers to react intelligently to future uncertainties.

Throughout the design process, this combined goal of sustainability and adaptability serves as the main evaluative criterion. At every decision-making point — whether selecting between density configurations, road network alternatives, or building morphologies the option that aligns more closely with this goal will be considered preferable. In this way, the design outcome is not just the result of parametric exploration, but a deliberate convergence toward a system that creates **future-ready, human-centered, and ecologically responsible urban environments.**



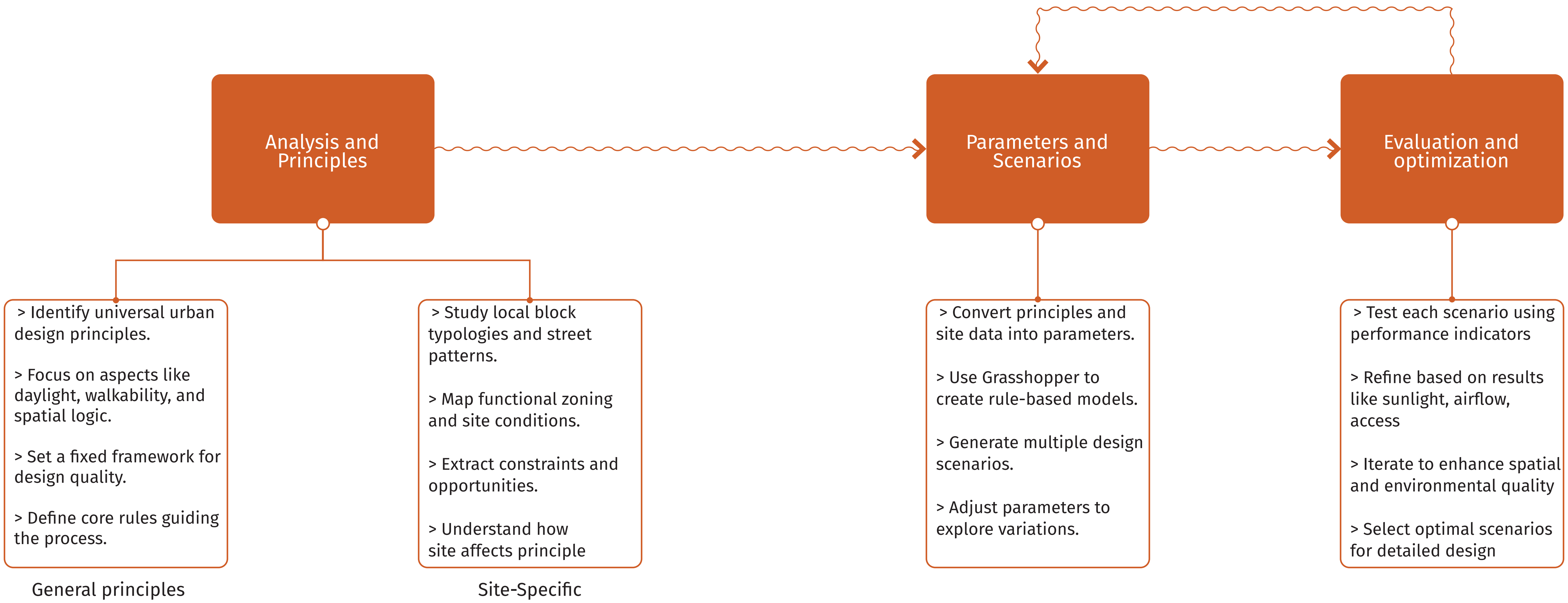
Design Methodology

This thesis employs a flexible, parametric design methodology that blends site analysis, principle definition, scenario generation, and iterative evaluation into a continuous and adaptable process. Rather than seeking a final masterplan from the outset, the objective is to construct a generative system capable of producing multiple, context-responsive urban scenarios.

1. Analysis and Principle Definition:
The process begins with a dual-layered analysis that distinguishes between general urban principles such as daylight access, walkability, mobility logic, and spatial coherence—and specific contextual conditions like block typologies, street patterns, or functional zoning of the site. This phase extracts key design drivers and constraints, which are then formulated as rules and parameters to feed into the next stages.

2. Parametrization and Scenario Development:
Identified principles are translated into a parametric rule-based system using tools such as Grasshopper and related plugins. Each urban layer (e.g. density, road network, building geometry) is assigned adjustable parameters, enabling the generation of a wide range of spatial configurations. These scenarios are not created in a fixed sequence but evolve in parallel allowing flexibility and responsiveness to changing priorities or constraints throughout the process.

3. Integrated Evaluation and Optimization:
Instead of being reserved for the final phase, evaluation is embedded throughout the design process. Each scenario is assessed using measurable performance indicators such as sunlight exposure, air circulation, accessibility, and functional balance. These evaluations inform ongoing refinements and guide the selection of the most context-sensitive and efficient outcomes. As the parametric rules remain adaptable, any shift in design goals can lead to quick re-generation and re-evaluation of scenarios.



4.1. SITE ANALYSIS

To apply the theoretical foundations and parametric strategies developed in earlier chapters, a specific urban site in the city of Turin has been selected for design exploration. This section presents a comprehensive analysis of the chosen site to identify its spatial characteristics, environmental conditions, and urban dynamics. The goal is to extract both quantitative data and qualitative insights that can inform and shape the rule-based parametric system developed in the design methodology.

The analysis serves multiple purposes:

• It uncovers the existing patterns, constraints, and opportunities embedded in the site.

• It provides the local input necessary to adapt general urban design principles, such as density, geometry, mobility, and spatial quality, to the specific context.

• It enables the translation of real-world conditions into parametric rules and variables that will drive the generation and evaluation of masterplan scenarios.

Importantly, the analysis distinguishes between site-specific characteristics (such as street layout, topography, and current land use) and universal urban principles (such as walkability, daylight access, and public space distribution). This dual approach ensures that the design remains rooted in the local context while maintaining a broader applicability and transferability.

Ex Scalo Vanchiglia

Fig 53. *Site location in the Turin urban fabric. Source: Google Earth*

Fig 54. *Abandoned Scalo Vanchiglia. Source: Google Earth*

Fig 55. *Former freight yard. Source: Google Earth*

Fig 56. *Turin Cemetery entrance. Source: cimiteritorino.it*

Fig 57. *Turin Cemetery inside . Source: cimiteritorino.it*

Fig 58. *Corso Regio Parco. Source: Google Earth*

Fig 59. *Corso Novara. Source: Google Earth*

Fig 60. *Via Giuseppe Regaldi. Source: Google Earth*

Fig 61. *Industrial neighborhood. Source: Google Earth*

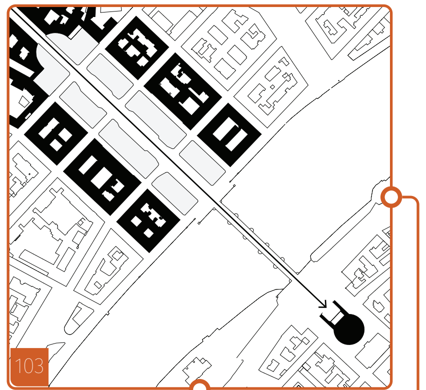
The chosen site for this design study is the former Vanchiglia freight yard (Scalo Vanchiglia) in Turin, Italy. Historically a major freight terminal since its opening in 1926, the area played a key role in supporting the industrial growth of northeastern Turin. Located within the Barriera di Milano district, the yard was connected to the main Turin–Milan **railway line** and served nearby manufacturing zones and factories until its decommissioning in the late 1990s. Since then, the site has remained underutilized, awaiting redevelopment as part of a long-term urban recovery vision. The area has been included in multiple regeneration proposals, such as the 2010 "**Regaldi Plan**," aimed at transforming it into a vibrant urban extension integrating **green areas, housing, services, and public infrastructure**.

Today, the site is surrounded by a highly mixed urban context. To the south lies a monumental **cemetery**, while the northern zone contains industrial and commercial buildings with some residential presence. The western edge transitions into more traditional residential blocks moving toward the city center, while the eastern boundary opens into **green parks** and the **Po River**. This flat terrain offers a unique spatial condition, connecting both urban density and natural landscapes. Despite the lack of strong pedestrian and bicycle infrastructure, the site is well integrated into the city's mobility network, with future plans for two to three **metro stops** directly adjacent to the site.

In terms of architectural and morphological context, the surrounding blocks show a mix of typologies from traditional courtyard-based urban blocks to modern linear developments. This diversity highlights the complexity and adaptability of the site, offering the potential to introduce new urban strategies that balance history, accessibility, human-centered design, and sustainability.

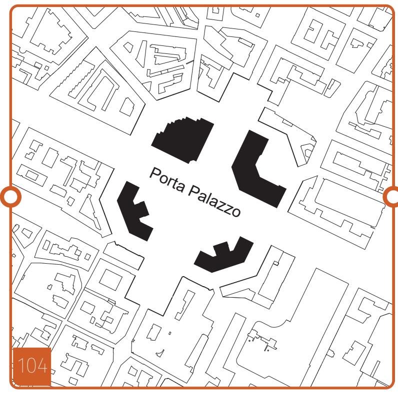
4.1.1. Urban Context and Morphology

In the urban context analysis, the focus will first be on the city scale, examining key elements that shape the broader environment, with an emphasis on aspects that can be parameterized. This includes identifying important **landmarks** and **monuments**, which can influence the overall aesthetic and identity of the area. The main **block typologies** within the city will also be explored, as these define the architectural and urban fabric of the city, contributing to its unique character. Additionally, the existing density across the city will be considered to understand how population distribution and building volume are spread, providing insights into the urban form. At the neighborhood scale, the analysis will zoom in on the areas adjacent to the site, investigating the neighboring block typologies and their relation to the site itself. The goal is to identify patterns and relationships that can be translated into parametric models for future development, ensuring that the design responds to the existing urban conditions.



Open Markets

There are several open markets in Turin city, which still work very well. This type of commercial spaces, make vibrant and social points.

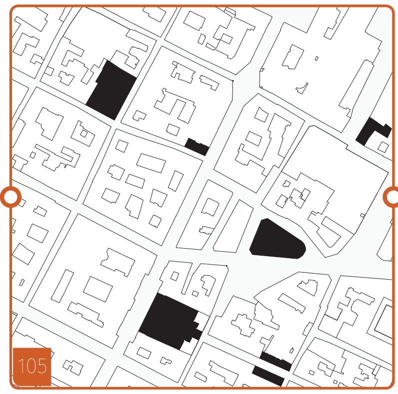


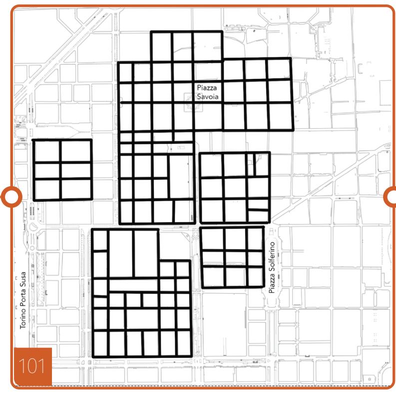
Focal Point

In many cases, main networks and important paths end with a monumental building or space. These path usually have symmetrical sides to focus more at the end points.

Corners/Buffers

within historic fabric and even some new parts, corners and the the intersections, usually become social and open spaces for public. This work very well as a buffer zones within residential areas.

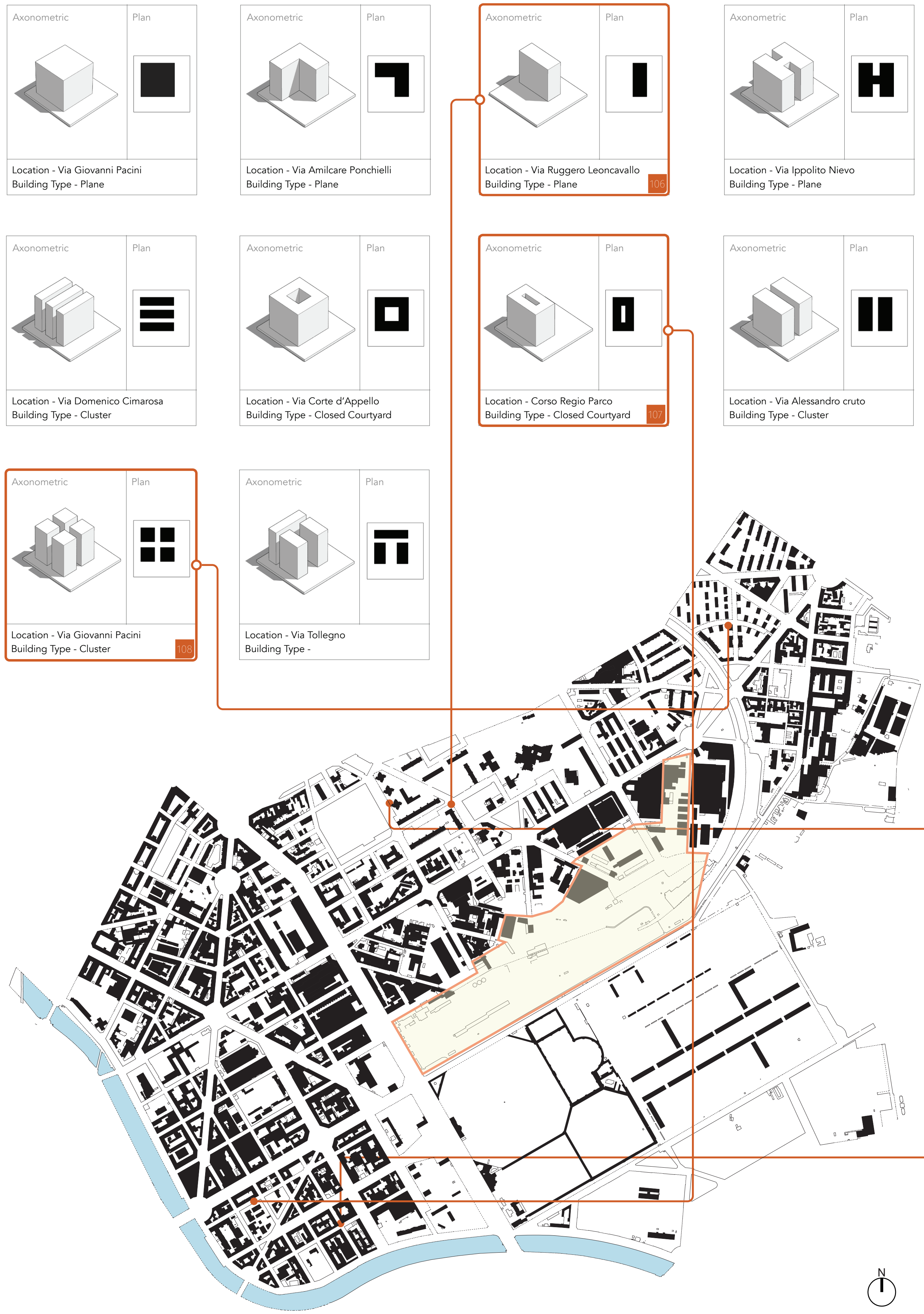


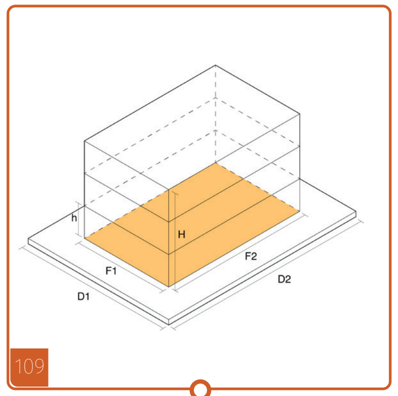


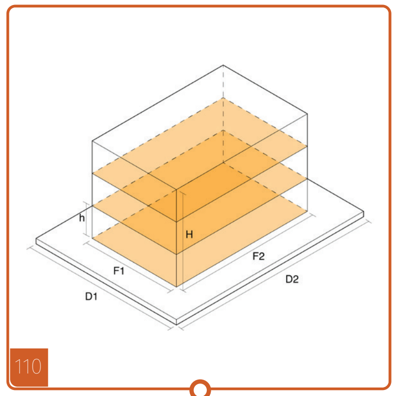
Grid

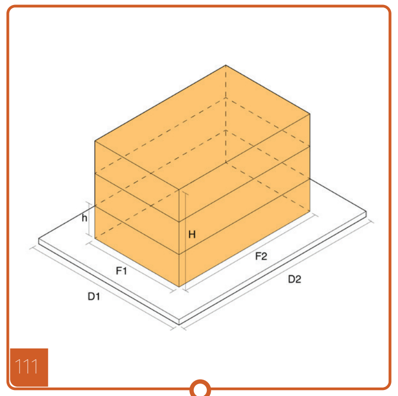
In Turin City, Roman grid in historic center, can seen in many part of city. This grid in some cases can be splited by important axis.

Fig 62. *Turin Urban Map. Source: geoportale.comune.torino.it*









Block Coverage Ratio

Existing min BCR: 0.16
Existing max BCR:0.40
Average city BCR: 0.33

Expected BCR: 0.35

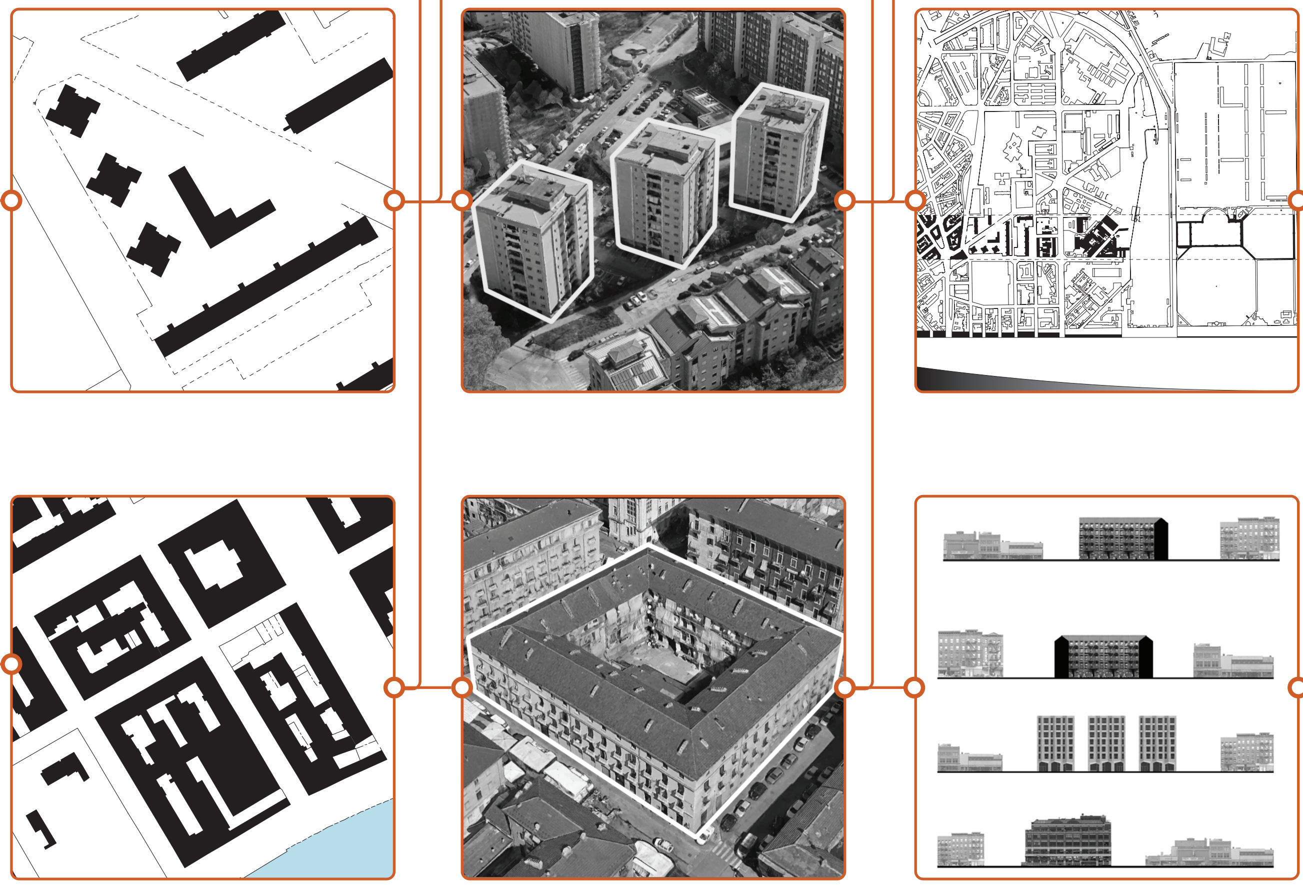
Floor Area Ratio

Existing min FAR: 1.5
Existing max FAR: 3
Average city FAR: 1.5

municipality rule for this site: 160,000 GFA

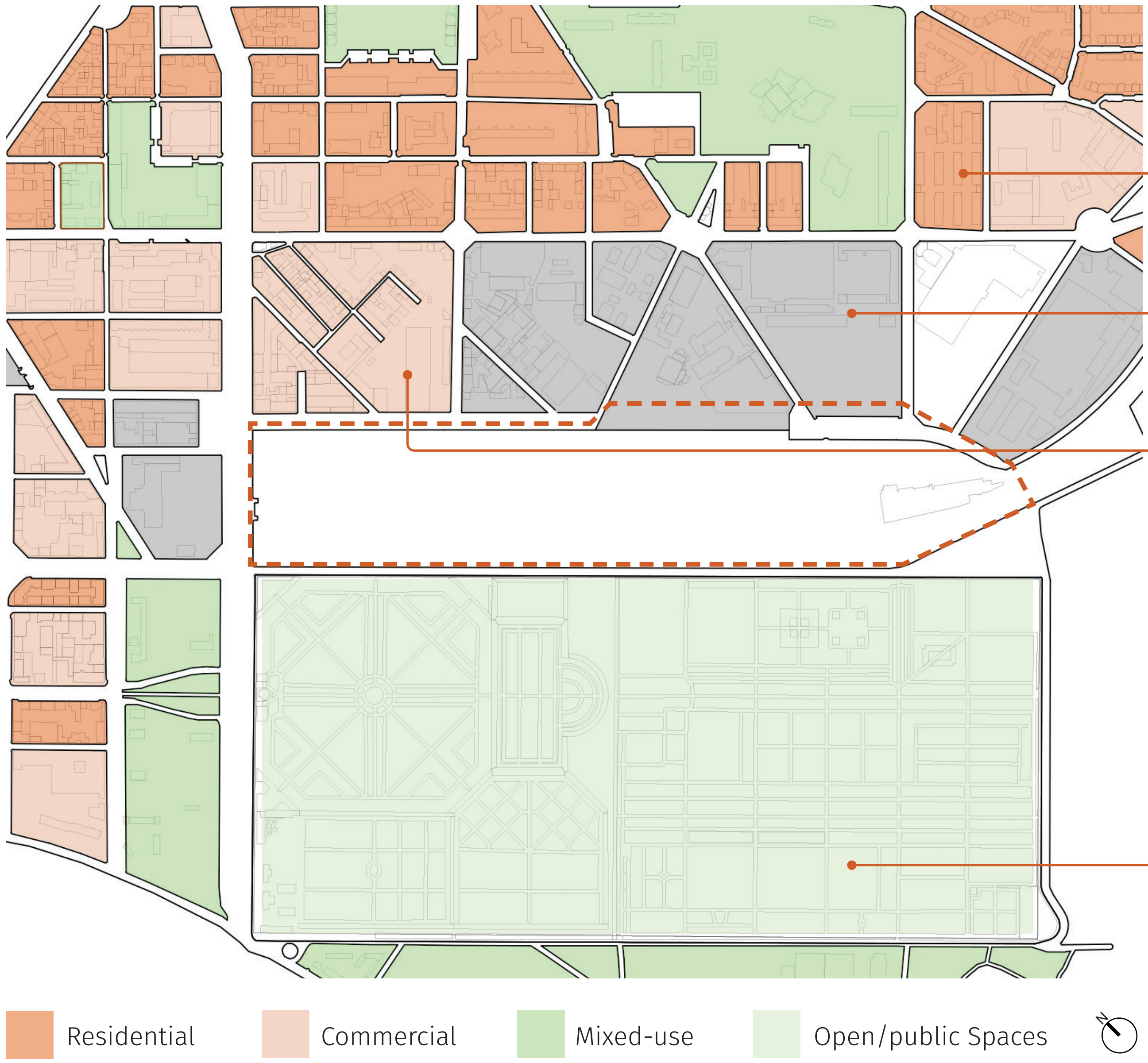
Building Height

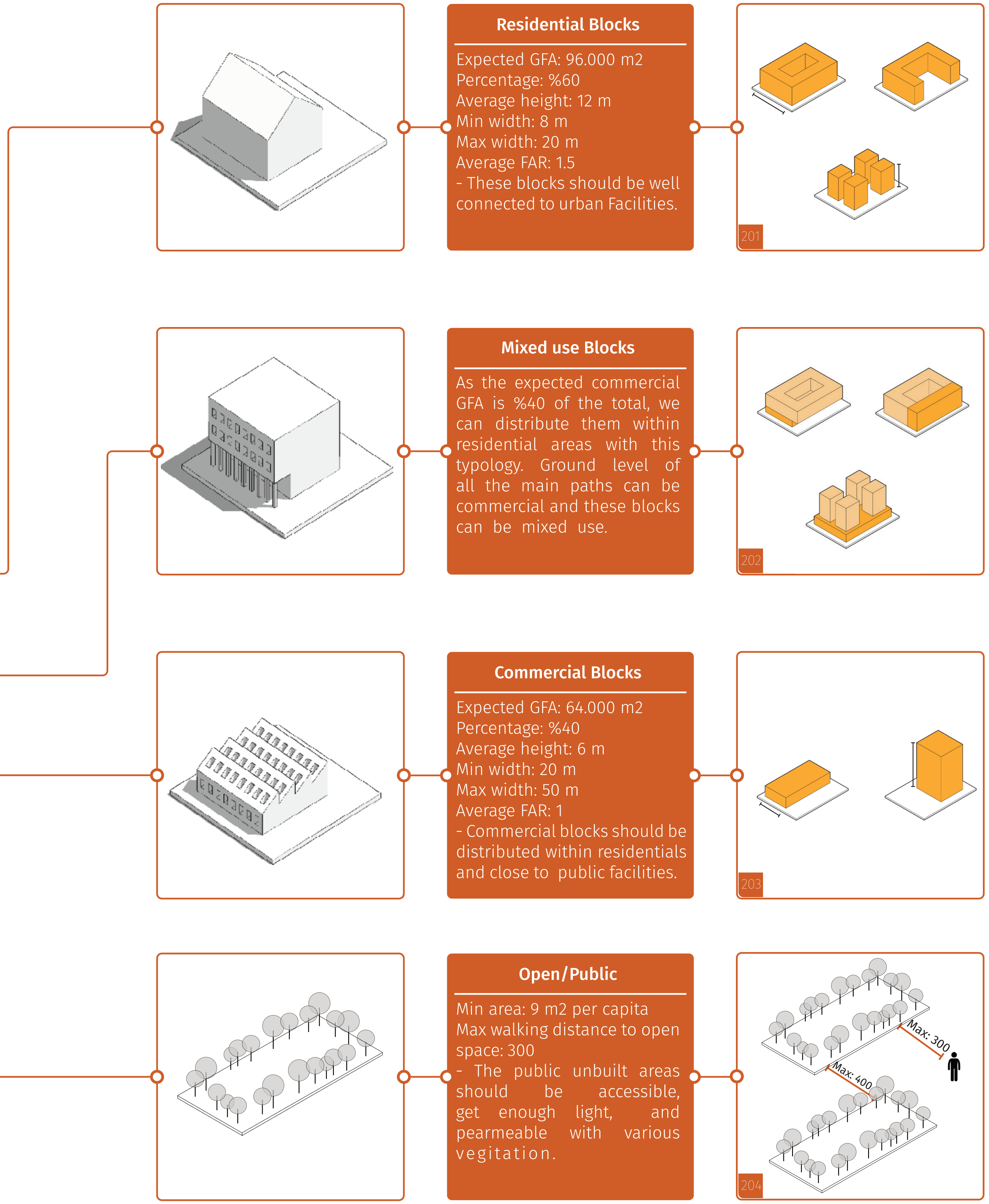
According to the site height transition, to have a better connection with the sorrunding and light access, the prefered maximum heigh is 18 or 6 floors.



4.1.2. Function and Land Use

In the functional analysis, the aim is to understand how different land uses are distributed within the city and around the site. This includes identifying major activity zones, such as commercial, residential, institutional, and mixed-use areas, and their proximity to the site. At the city scale, broader functional zones help determine the role of the site within the urban system. Additionally, municipal policies regarding land use and density are considered, providing clear guidelines that shape the permitted functions and building intensities. At the neighborhood scale, the analysis reveals how local block uses relate to the site and inform the geometry of the buildings and blocks. These functional parameters play a critical role in shaping spatial organization and are directly linked to the form, scale, and performance of future urban configurations.



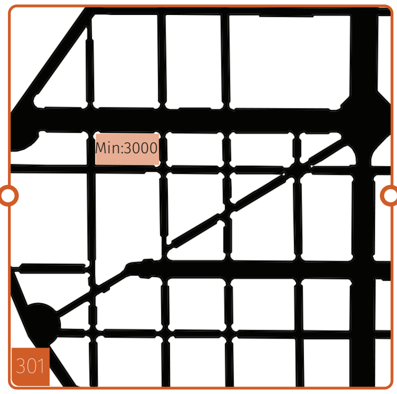


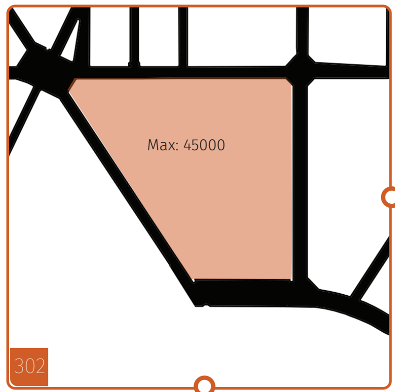
4.1.3. Mobility

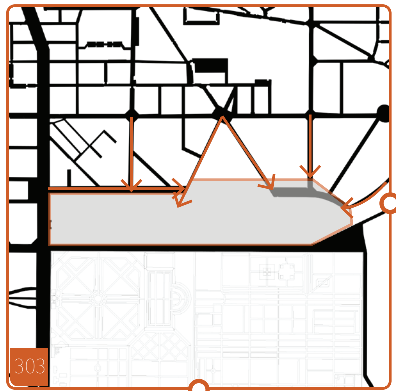
The mobility analysis focuses on understanding the **accessibility** and **movement** systems that shape the site and its surroundings. At the city scale, major transportation routes, public transit lines, and multimodal connections are mapped to assess regional connectivity. At the neighborhood scale, the connection between the site and the existing urban grid becomes critical, particularly at the borders where new and old systems meet. Key parameters include maximum and minimum street lengths and desired block sizes, based on existing patterns and mobility principles. The use of spatial analysis tools like Space Syntax can help quantify **connectivity and integration**, supporting more coherent and accessible urban layouts in the design phase.

Block Size

The network shape the blocks and it is important to check if these blocks have similar sizes with the existing fabric and to avoid too small or too large blocks

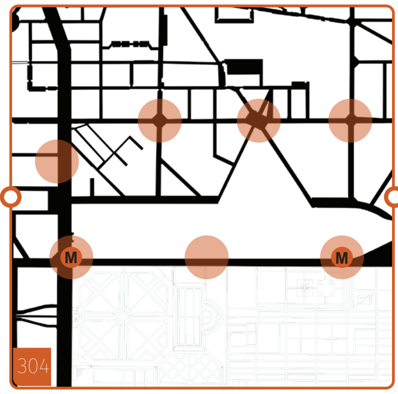






Public Transport

The existing bus stops works as attractions spots, and umpcoming metro station will bring more population to this area. Considering this point to shape the services and residences close by is very important

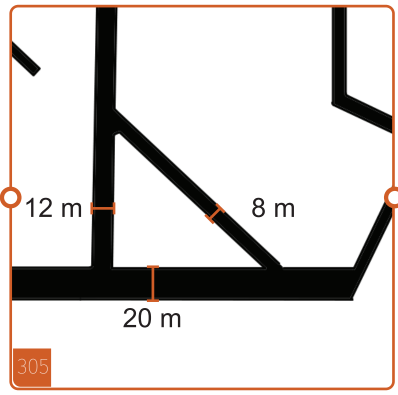


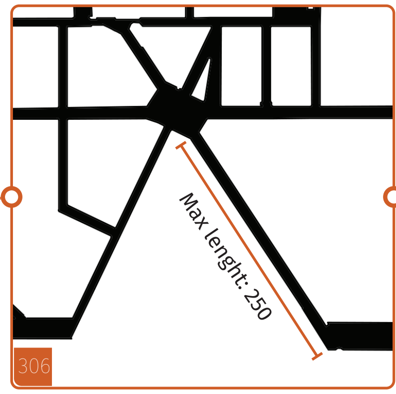
Boundary Connection

Apart from the streets on the boundary of the site, the intersection of existing grids with the boundary are important points to shape the grid inside the site boundary.

Hierarchy

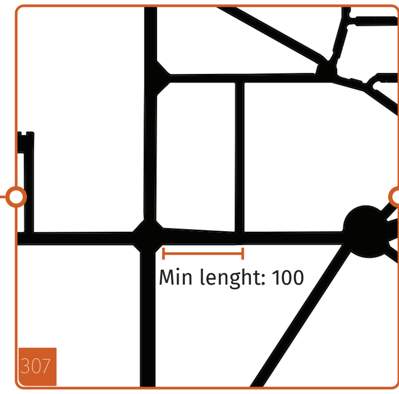
In our site location we have 3 types of road including; secondary, tertiary, and local streets. each side of these roades pedestrian path with 2 meters widths should be considered.
there can be also No Car steets, only for pedestrians.

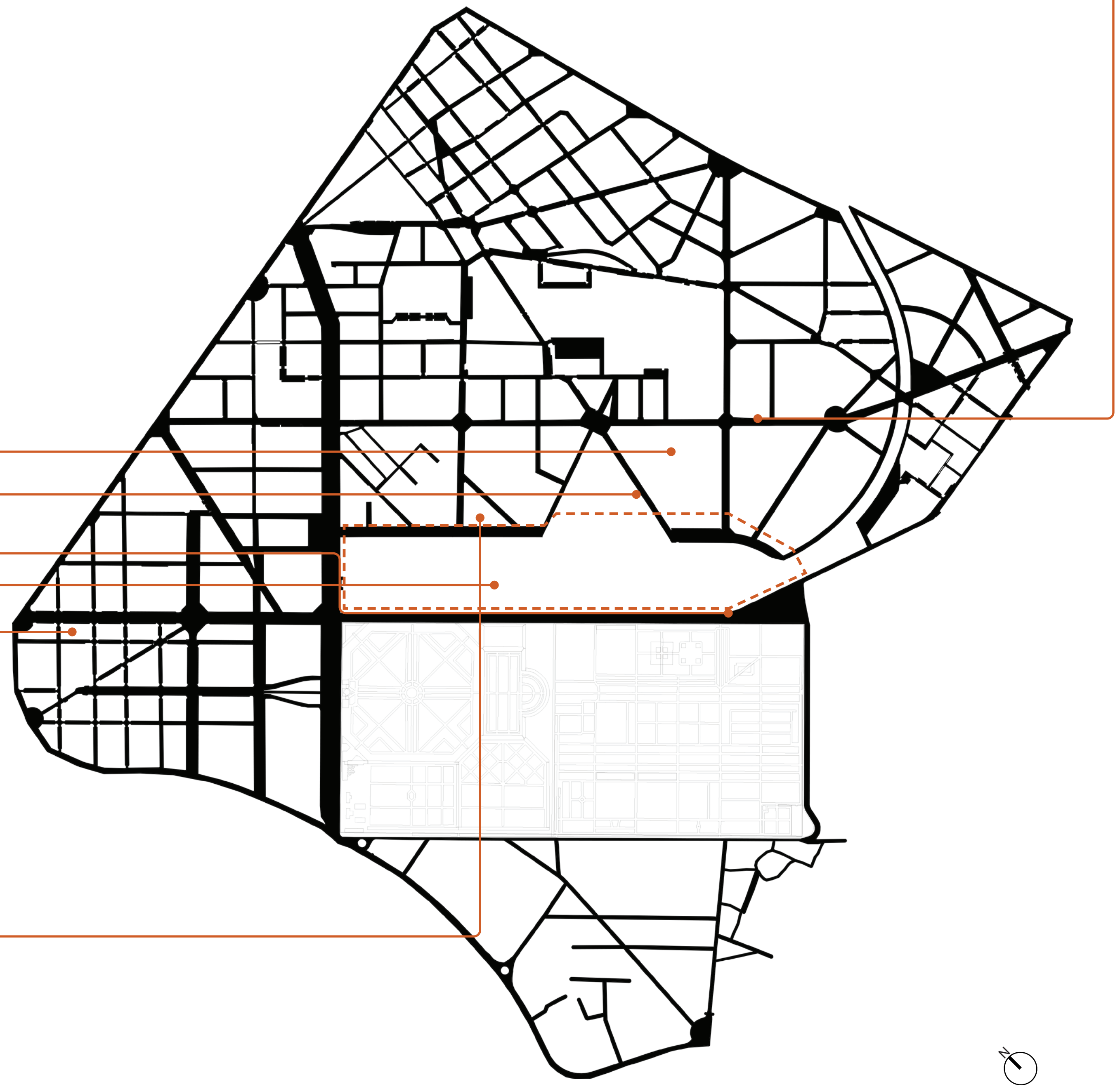




Street lenght

In Turin City, Roman grid in historic center, can seen in many part of city. This grid in some cases can be splited by important axis.





4.1.4. Environment and Sustainability

This section examines environmental and **climatic conditions** that influence both constraints and opportunities for sustainable urban design. Key factors include topography, sunlight exposure, wind direction, and proximity to green or blue infrastructure. At both city and neighborhood scales, these elements inform critical design parameters. In particular, environmental factors influence the minimum and maximum distances between blocks to ensure adequate **light** and **wind** access. The geometry and orientation of blocks also play a role in responding to climate conditions. These considerations help shape a resilient urban form that supports passive strategies and environmental comfort.

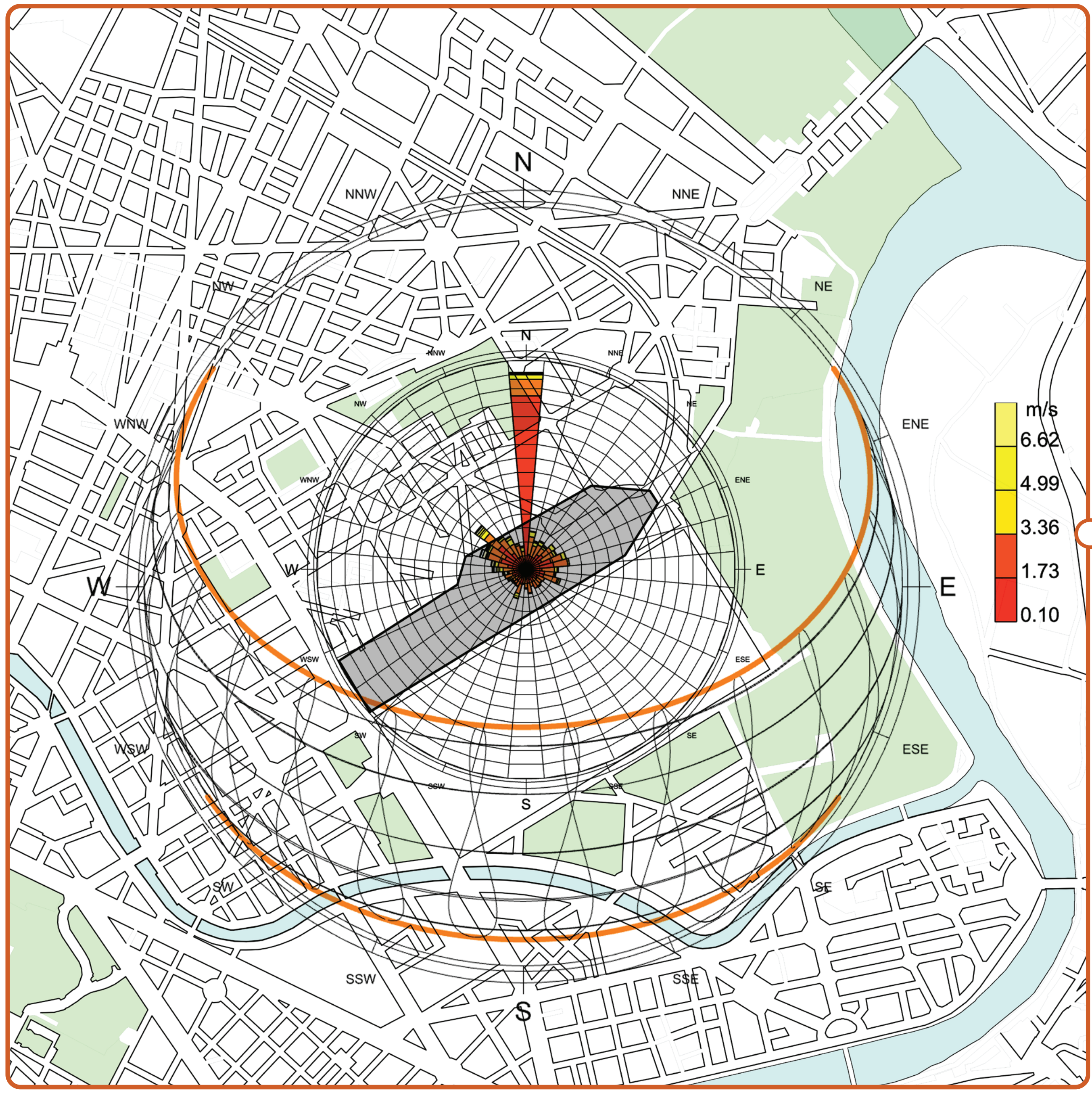
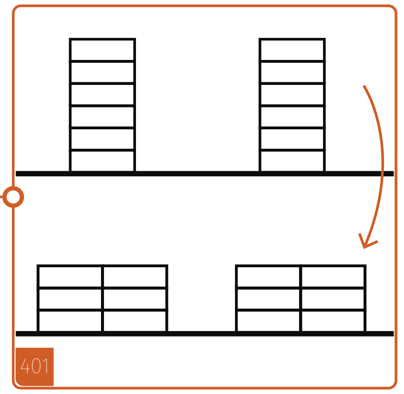
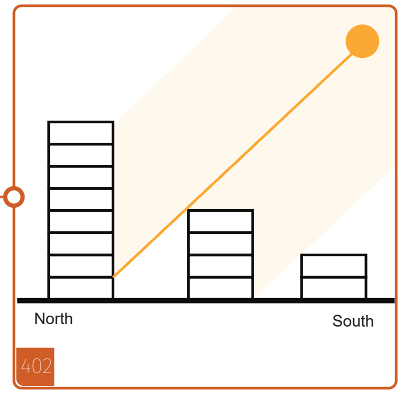


Fig 63. *Yearly wind speed/direction and Sun path of the site. Source: EPWmap*

Climate

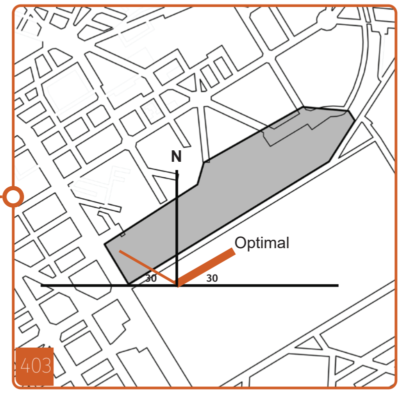
Since the climate of Turin is moderate cold, it is recommended to have dense buiding attached to each other rather than free standing buildings. This helps to reduce heat loss and increase heat gain from sun exposure. (The FAR is the same)

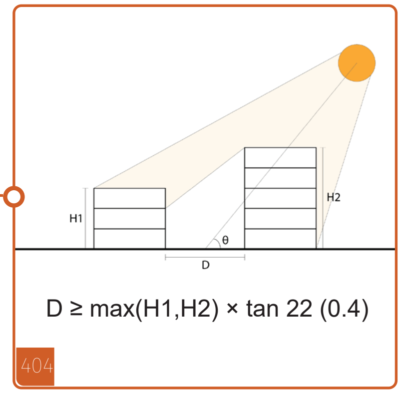




Sun Exposure

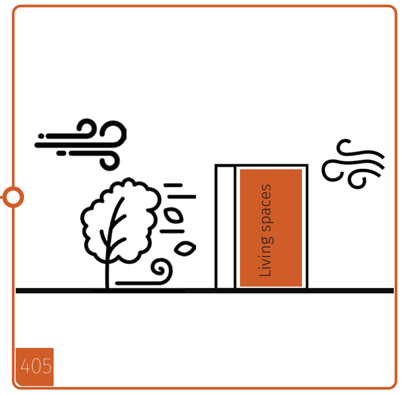
To increase sun exposure in this climate, we need to use the optimal orientation of the buildings, decrease inter-shading of the buildings, use steped geometry for the blocks toward south.





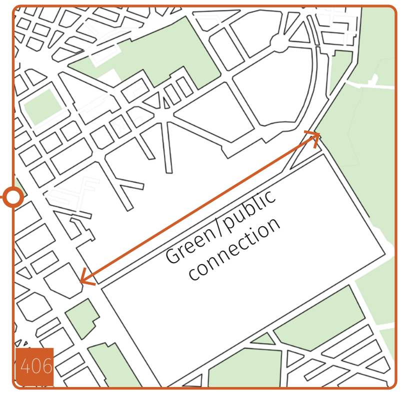
Wind

There area two prodominant winds, one is winter wind from north which we have to try to block it, while the summer breeze form south can move overheated air among the blocks and we should place the living spaces toward them.



Open/Public Space

The existing green space can be connected along our site, which is also asked by the design question to have at least 50 m distance from the cemetry. the various public functions can enrich the social connectivityandsustainabilty.



4.2. GENERATION

In this chapter, the focus shifts from analytical findings to the generative phase of design, where planning codes and urban principles are translated into parametric logic. This stage marks the beginning of a **systematic**, **data-driven** approach to masterplanning, primarily developed through Grasshopper and a series of complementary plugins. The goal is to transform static regulations and codes into flexible parameters that can generate and evaluate a wide range of spatial scenarios.

Each step in the process begins by inputting relevant planning data such as density requirements, functional zoning, or street hierarchy into parametric tools. These inputs form the rules and constraints that define possible urban configurations. In addition to deterministic inputs, a randomization element, known as the Seed, is used to produce variation across iterations, allowing the exploration of design alternatives within the defined boundaries.

The result is a set of design scenarios that respond to the same planning criteria but differ in their spatial arrangements. These alternatives are then subjected to performance analysis, using predefined evaluation criteria such as access to light, air circulation, connectivity, open space ratio, or FAR/BCR compliance. Through this iterative loop, the most optimal scenario is identified and selected as the foundation for the next design step.

This process is repeated across multiple layers of urban design geometry, infrastructure, and density allowing each decision to be informed by both regulatory codes and contextual performance. As the iterations accumulate, a holistic and coherent masterplan gradually emerges.

More than a one-time design tool, this parametrization system is intended to be adaptable and replicable. By simply adjusting the input data, the same logic can be applied to other sites, offering a robust framework for urban planning that balances regulation, creativity, and performance-based decision making.

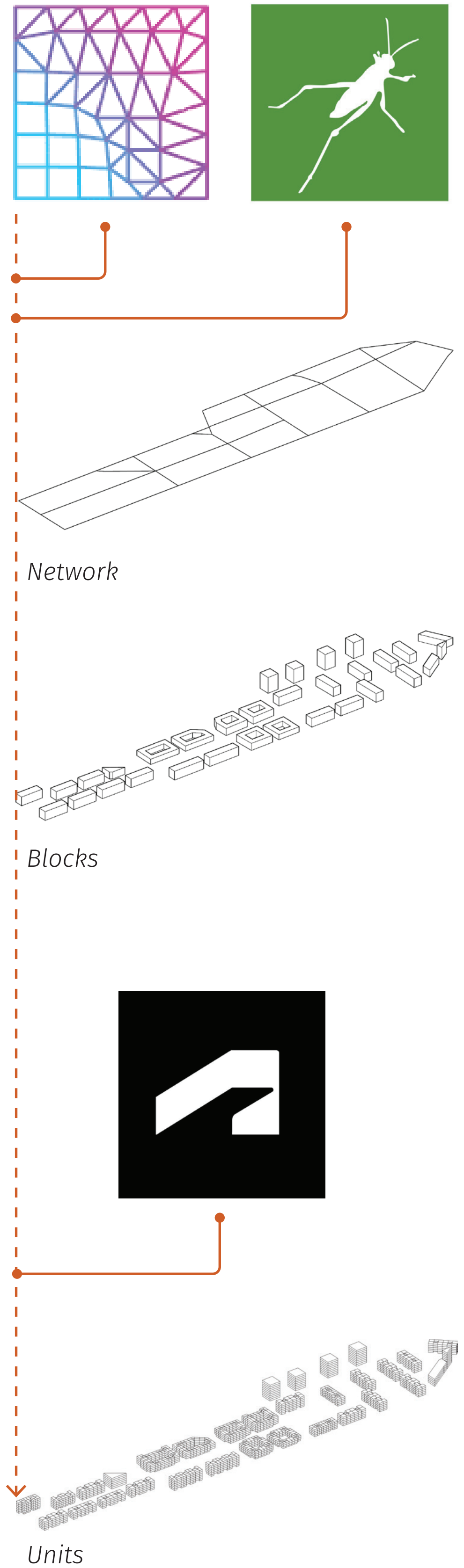
Tools

Before initiating the parametrization process, a set of digital tools was selected to support a structured and data-informed urban design workflow. At the core of this system is **Grasshopper** for Rhino, a powerful visual programming environment that enables the creation and control of complex parametric relationships. Its modular structure and interoperability make i well-suited for integrating urban design logic wit performance-driven criteria.

Within Grasshopper, the **DecodingSpaces** toolki plays a key role. It offers components specificall designed for urban-scale applications, includin street network generation, spatial network analysis, and the automatic creation of urban elements such as blocks, plots, and buildings. These tools support the definition and testing of different urban configurations while allowing for flexibility in typology and density. The built-in network analysis functions help identify well-connected and integrated layouts, providing a foundation for informed design decisions.

Once preliminary configurations are established, **Autodesk Forma** is employed to evaluate design scenarios based on environmental and climatic performance. The platform offers real-time feedback on parameters such as daylight access, wind flow, and energy efficiency. In addition, it supports capacity analysis by estimating the number and distribution of residential units within a given scenario.

To support final evaluations and communication of the masterplan, **AI-generated visualizations** are produced. These renderings provide a realistic impression of the spatial qualities and atmosphere of the proposed development, aiding both in internal assessment and stakeholder communication.



4.2.1. Generative Network

Design starts with the network because understanding the grid system and block formation is essential in the early design stage. Key connections to the existing grid around the site must be identified, while the internal network will be shaped by other urban principles. This section presents a step-by-step process using parametric tools, mainly the Decoding Spaces plugin in Grasshopper.

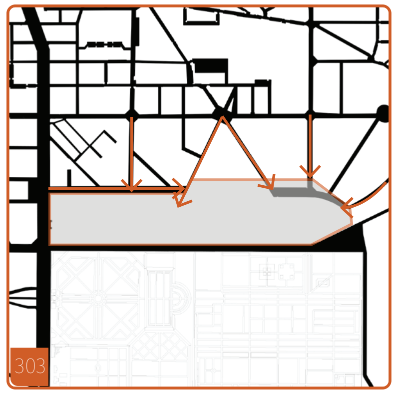
> After importing the **site boundary** and existing urban fabric, we draw the centerlines of streets that pass through or intersect with our boundary. These lines should originate outside and continue through the boundary. Their angle must align with existing streets to ensure a coherent network inside and outside the boundary.

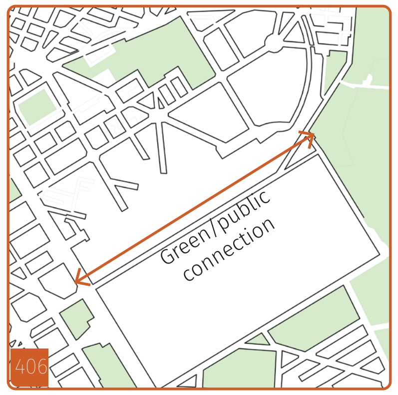
> Note that the boundary line is also treated as a street. So, if it only defines the site limit, we must draw an outer boundary to input correctly into the components.

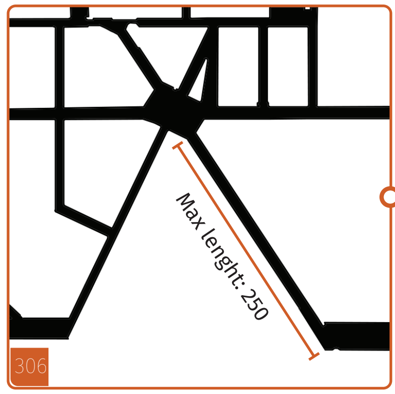
> The Network Generation component starts drawing a proposed network based solely on the existing grid. However, we can also input data like the **minimum and maximum distance** between intersections, controlling the length of each street segment.

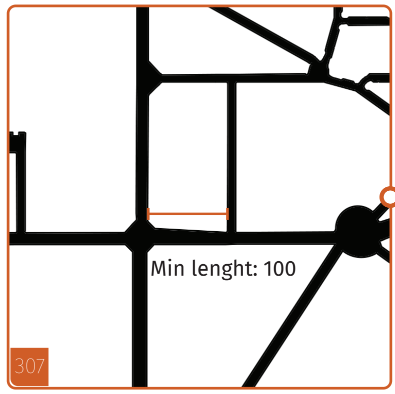
> Other parameters include the **random angle**, which rotates street directions. Since our site orientation is already suitable, we keep this value at 0.

> The **Max Arms** and **Tree Depth** parameters define how many streets can connect to each intersection and how many branching levels are created. In general planning, both are typically set to 4, as this is considered the most efficient configuration.









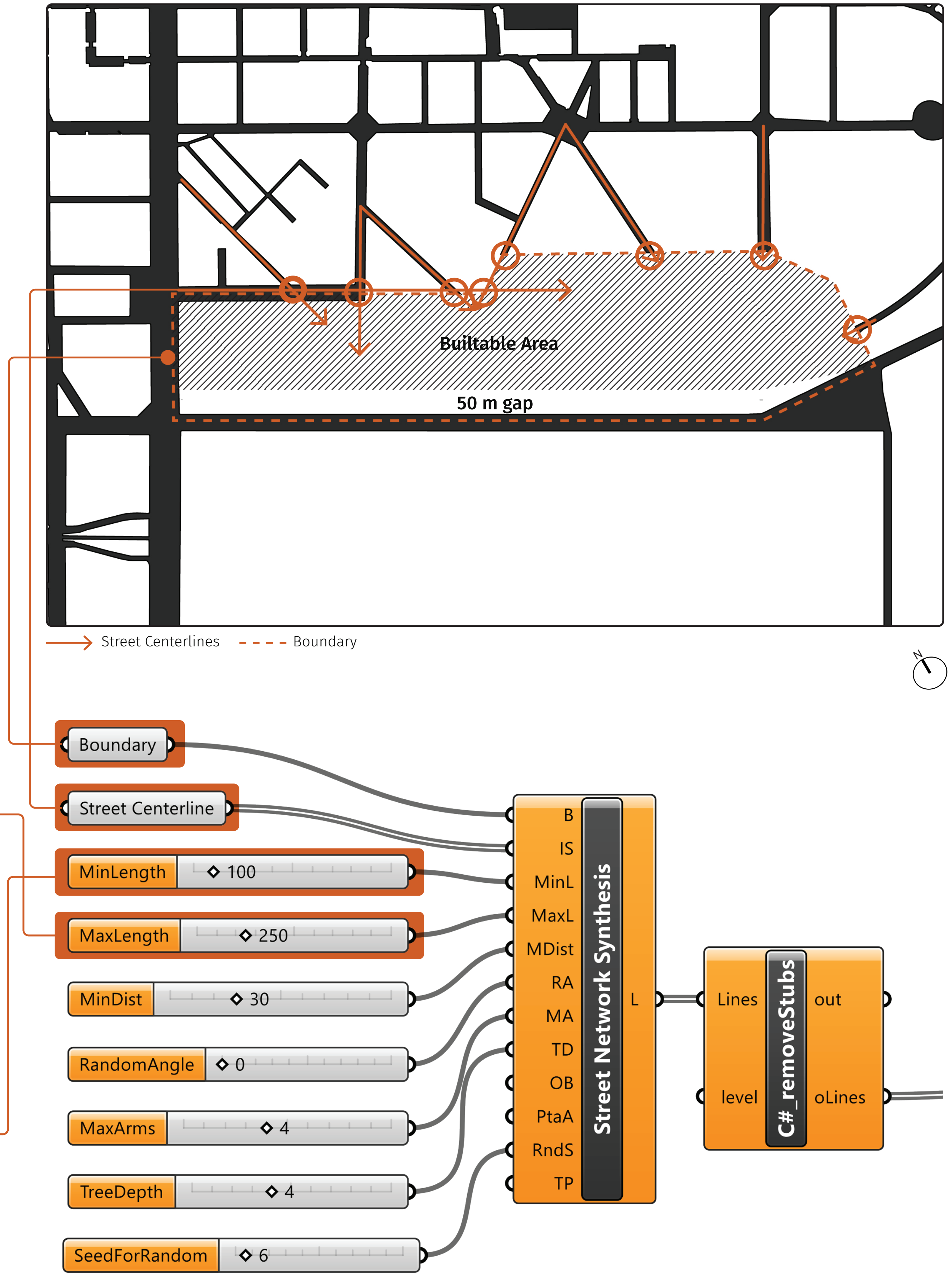
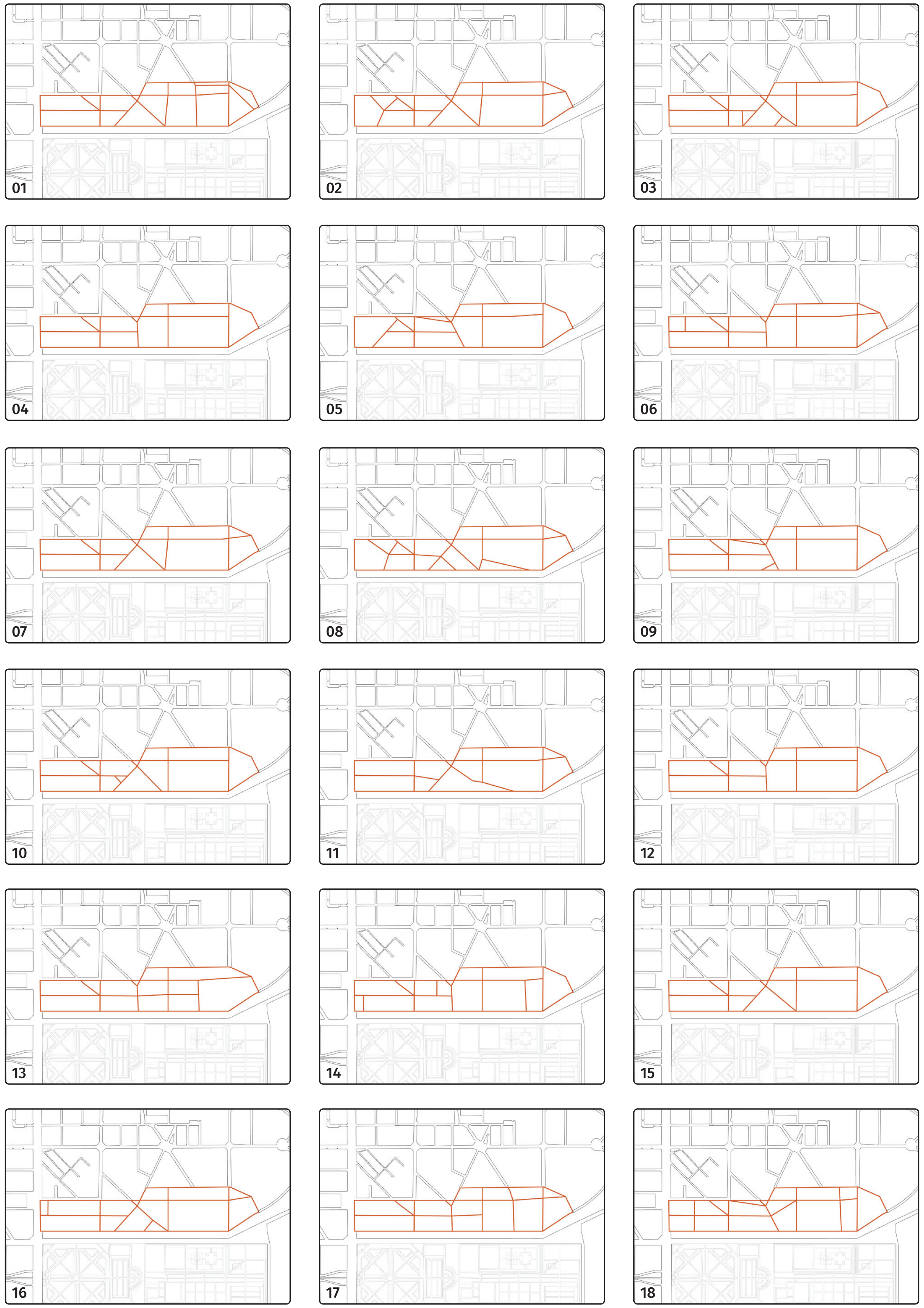
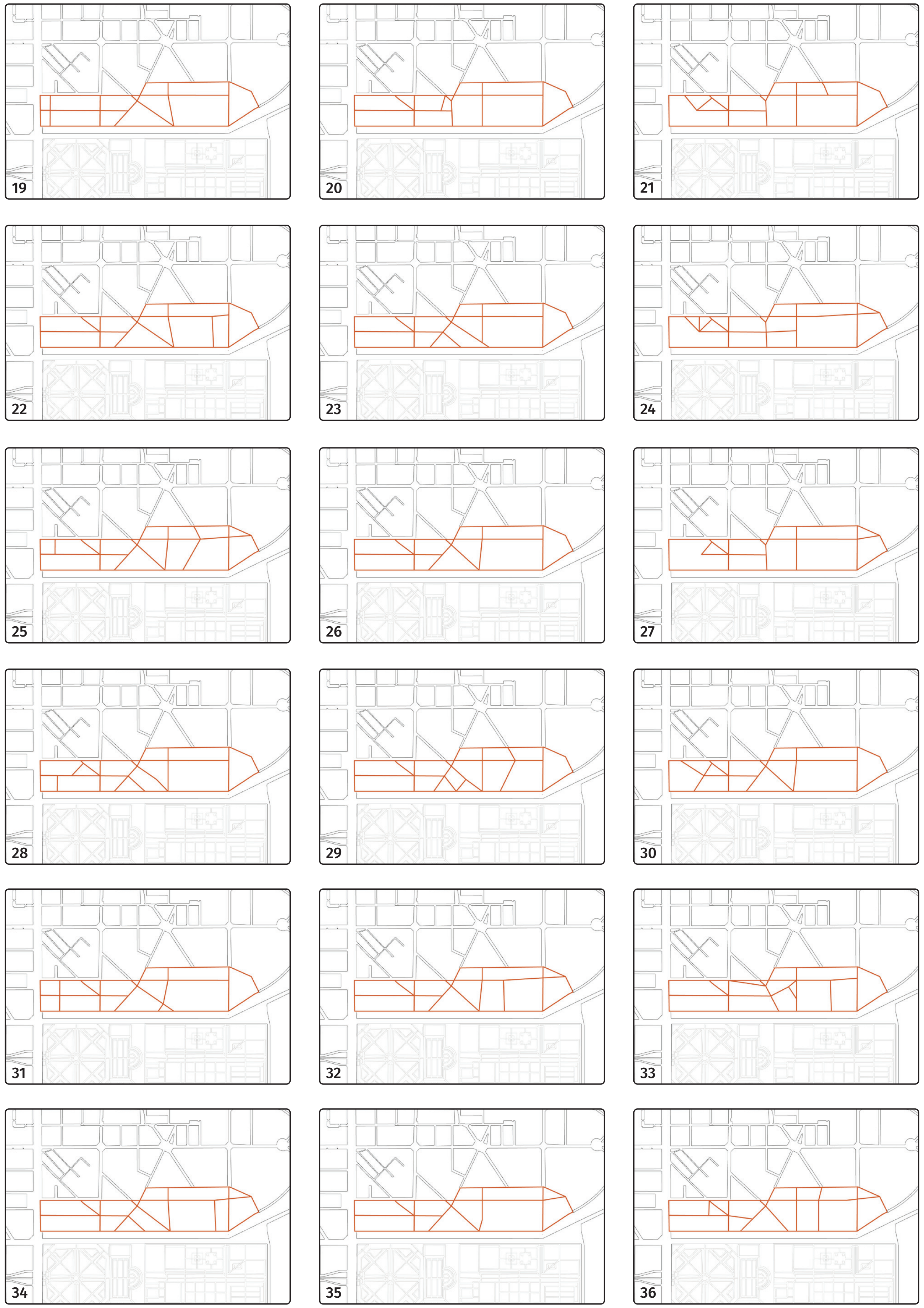


Fig 64. *Street Network Generator component in DeCodingSpaces toolkit. Source: Author.*

Abacus of Iteration



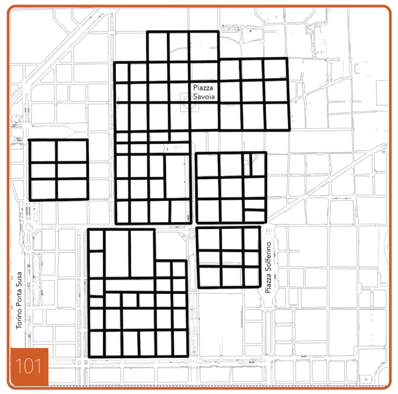


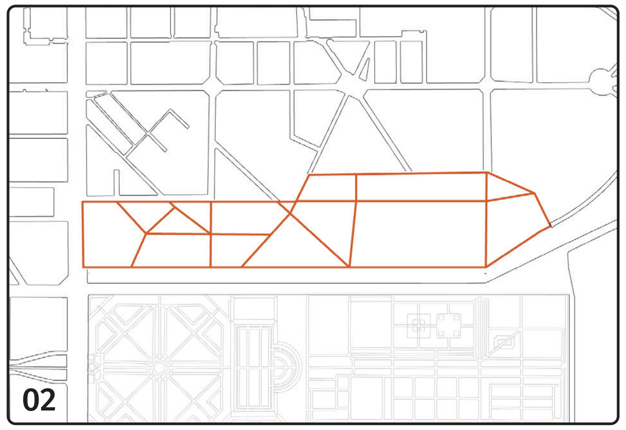
Short listed scenarios

In the next phase, the parametric tool generates multiple scenarios based on the input parameters. From these, we selected eight scenarios that appeared more reasonable in terms of spatial structure and connectivity. These scenarios currently represent only the **centerlines** of the proposed mobility network, serving as a preliminary framework. The full definition of the street network—including hierarchy, width, and function—will be developed in the following steps.

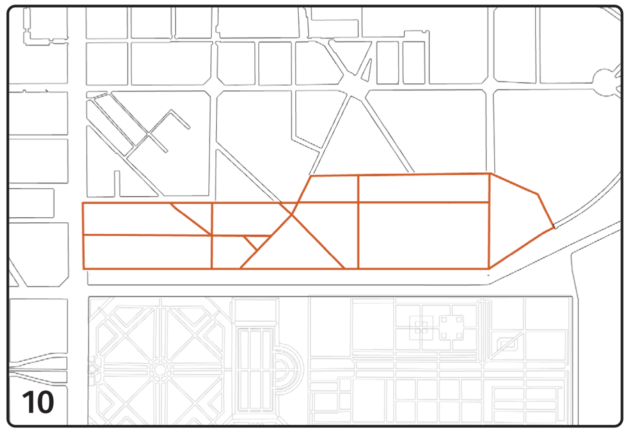
At this stage, all variations were produced solely through **randomization**, controlled by the **Seed** parameter in Grasshopper. The Seed introduces subtle changes in the generation process, leading to different configurations each time it is modified. However, randomness is only one method of generating diverse options. We can also explore alternative scenarios by adjusting other design parameters, such as the minimum and maximum distance between intersections, the **number of arms per intersection**, or the **tree depth**. These variables are not fixed and allow for a wide range of spatial outcomes, making it possible to test different structural strategies for the network.

To select the most suitable scenario, we need to perform a **analysis** of all generated options based on specific evaluation criteria, which include connectivity, accessibility, and integration with the surrounding context, and block size. The selected scenario will act as the foundation for the next stages of the design process. However, this does not imply that the other scenarios are irrelevant. They remain as alternatives that can be further developed or optimized if needed, especially in the final stages of the master plan where flexibility and adaptability are important.

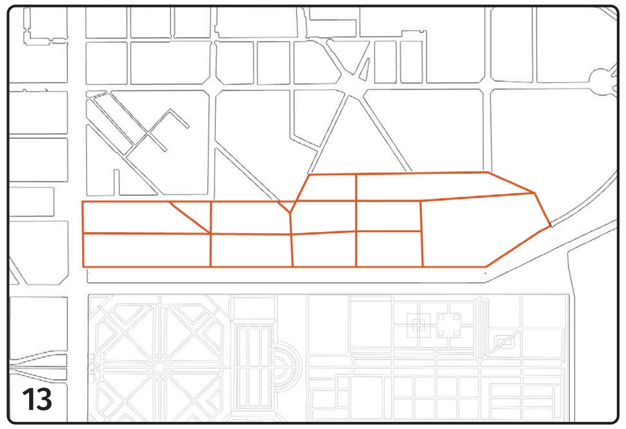




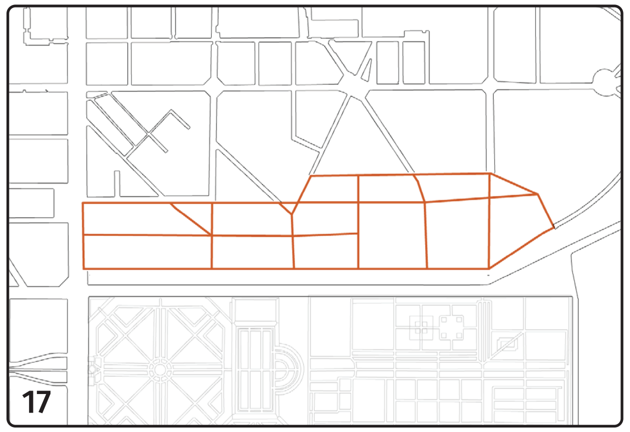
Orthogonal connection to key points



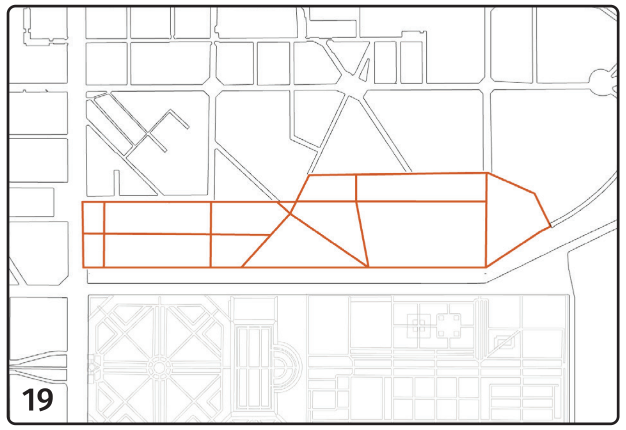
Variety of block sizes



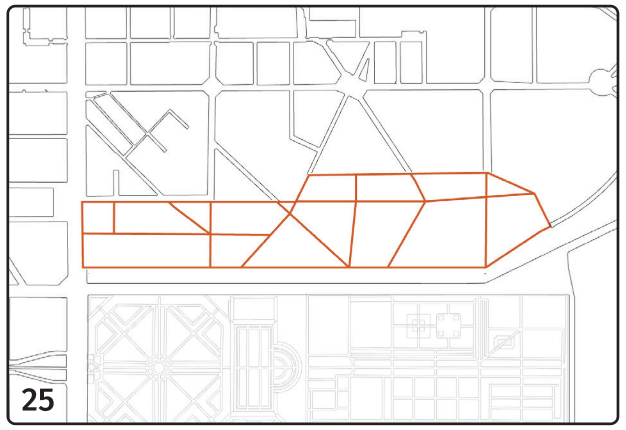
Rational Grid



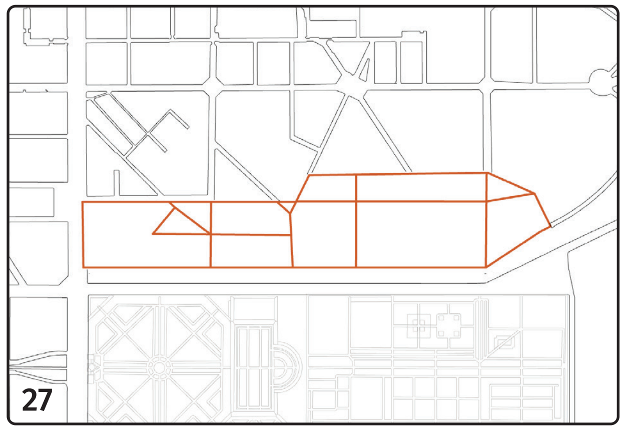
Standard block sizes



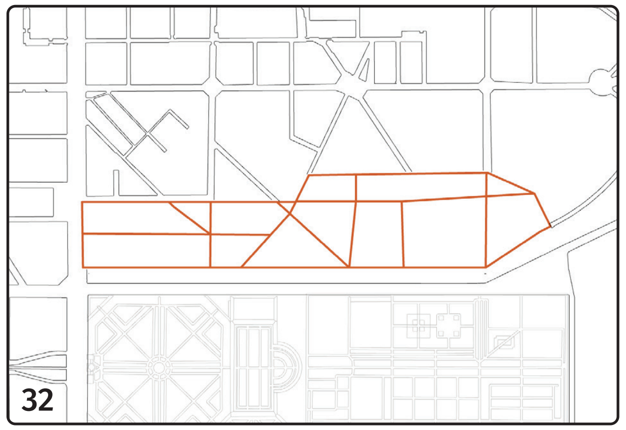
Well connected to the city



Different block shapes



Separated Zoning



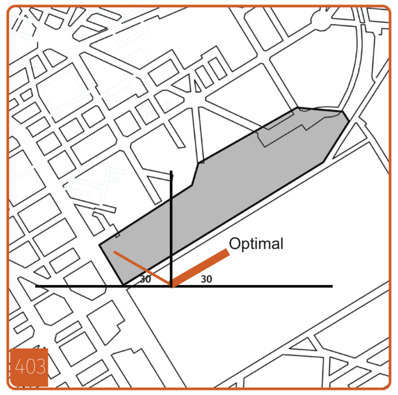
High integrity and rationality

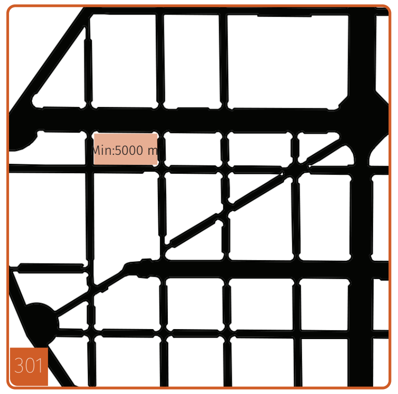
Assessment

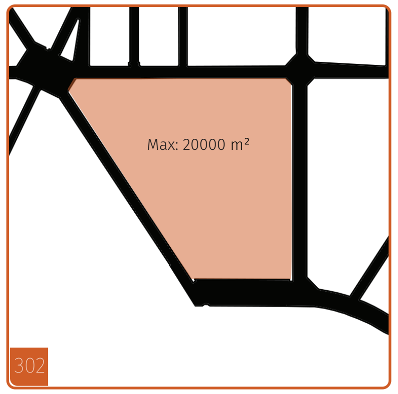
In order to choose the best scenario among the eight generated, we need to assess them based on specific principles and criteria. Several parametric tools assist in evaluating particular aspects of urban form, and **DecodingSpaces** provides the ability to assess the network by examining **connectivity** and **centrality**. In addition, as discussed in the site analysis section, **block size** is a crucial factor that must align with both the surrounding urban fabric and the predefined parameters established earlier in the process.

Through analyzing these three factors, we can arrive at the desired scenario. This can be achieved by either eliminating scenarios that do not comply with our principles, or by comparing the analysis results and selecting the scenario with the highest average score across all evaluation criteria.

>Block size: First, we examine the average block size. To evaluate this factor accurately, we must exclude blocks that are too small, as these are often generated unintentionally by the components and may be allocated later for open spaces or facilities as non-buildable blocks. Once these are excluded, the remaining block sizes should either remain below the maximum allowed size or have an average size that aligns with the **existing block dimensions** in the surrounding context. Analysis of the city and this zone show the average block size is somthing between 5000 to 20000 square meter.



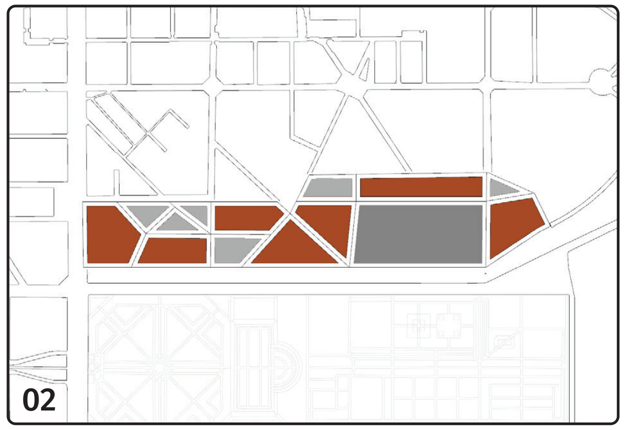




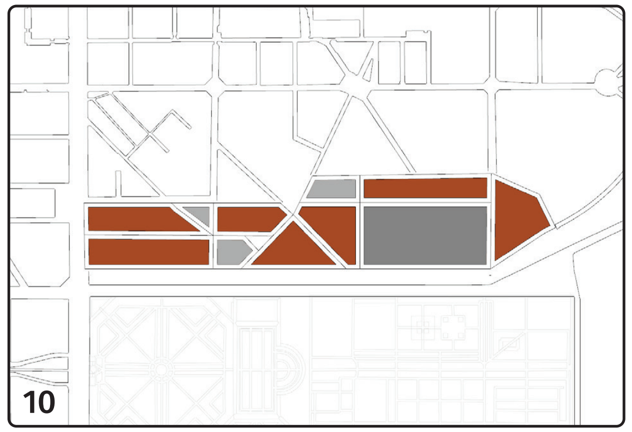
Under minimum size

Above maximum size

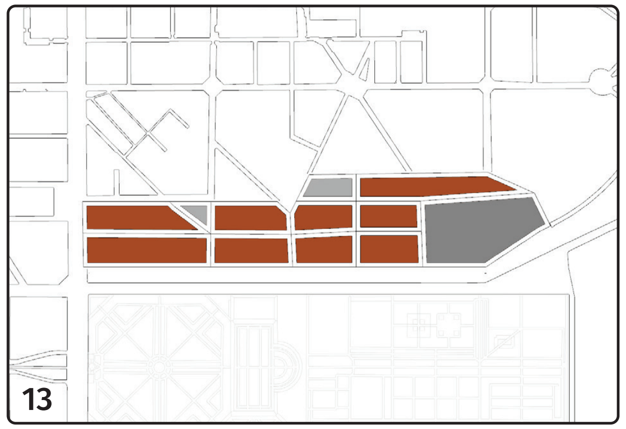
Adequate size



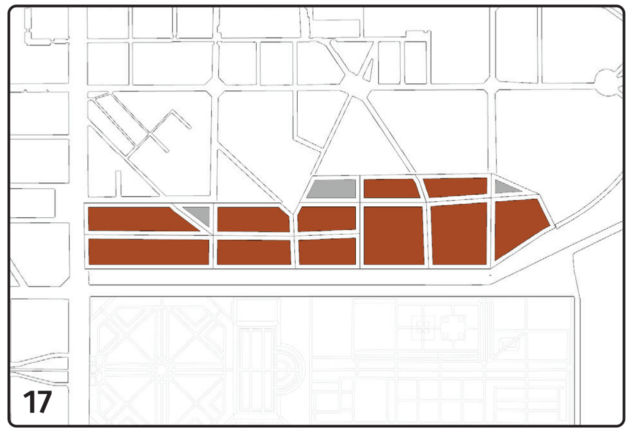
Total buildable area: 75720 m²



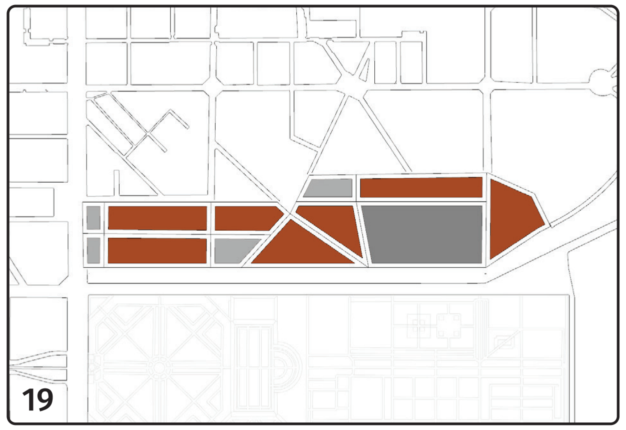
Total buildable area: 86660 m²



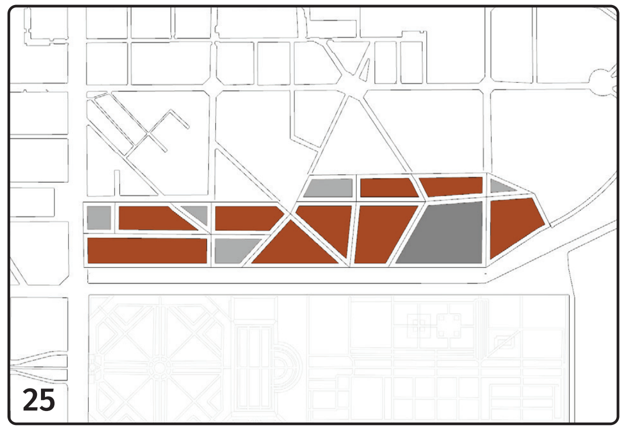
Total buildable area: 93414 m²



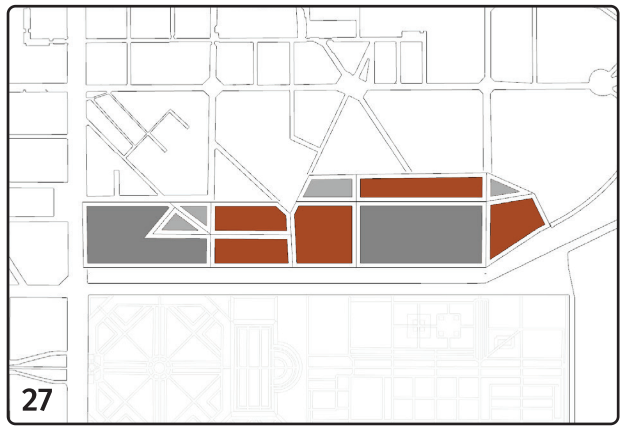
Total buildable area: 124131 m²



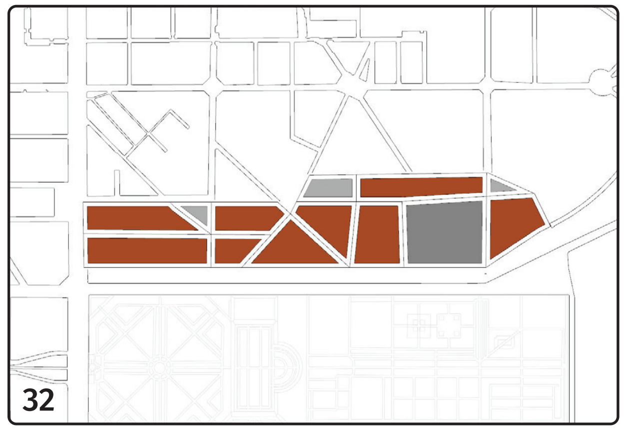
Total buildable area: 85135 m²



Total buildable area: 91124 m²



Total buildable area: 61839 m²



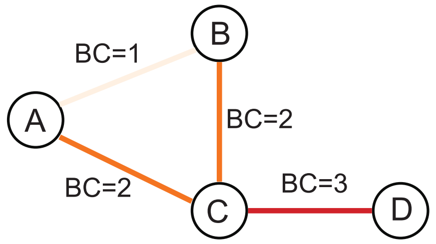
Total buildable area: 94853 m²

Assessment

> Betweenness Centerality: quantifies the importance of a node within a network based on its position along the **shortest paths** between other nodes. Specifically, a node's betweenness centrality is determined by the number of these shortest paths that pass through it, indicating its potential to control or facilitate interactions between disparate parts of the network. This measure highlights nodes that serve as **critical intermediaries or bridges**, possessing the capacity to influence the flow of information or resources within the network. (Freeman, 1977)

> In **space syntax**, Freeman's betweenness centrality is adapted into the **"choice"** measure, which quantifies how often a street segment lies on the shortest paths between all pairs of segments in a spatial network. High choice values indicate segments likely to experience significant movement flow, serving as common routes through the network. This adaptation helps urban planners identify key pathways that facilitate movement and connectivity within urban environments.

> To assess the uniformity of **traffic distribution** across different network scenarios, the **standard deviation** of betweenness centrality values can be analyzed. A lower standard deviation suggests a more balanced network where traffic is evenly distributed, reducing the likelihood of congestion in specific areas and underutilization in others. Conversely, a higher standard deviation indicates a concentration of traffic flow through certain nodes, potentially leading to inefficiencies and increased vulnerability to disruptions. This analytical approach aids in designing transportation networks that promote equitable traffic distribution and enhance overall network resilience.



Nodes: Intersections

Edges: Streets

Higher BC → Important rout, traffic

Less BC → Segregated, minor route

To avoid sagregation or traffic

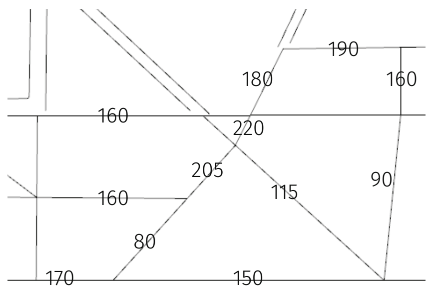
↓

Balanced network system

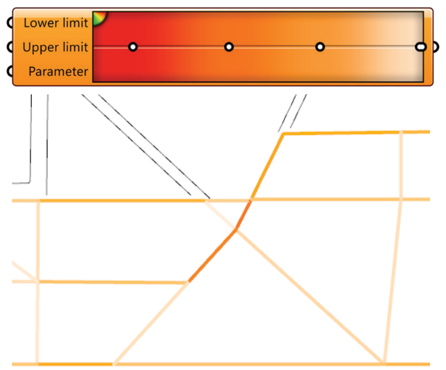
↓

Less standard deviation

> BC analysis example:



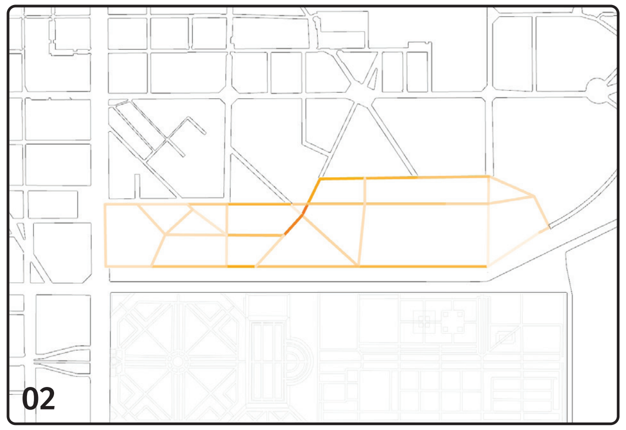
1> Measuring BC by software



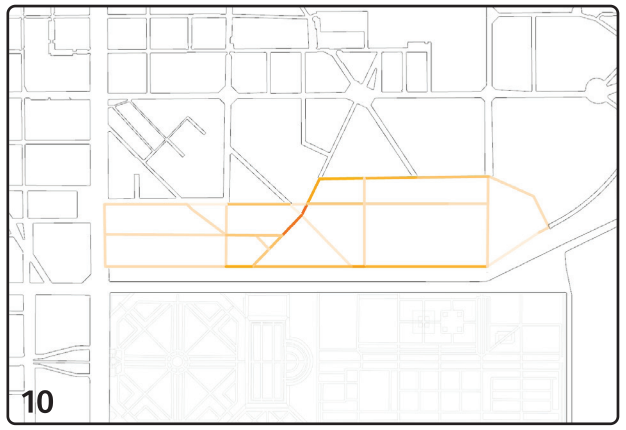
2> Visualising the results

$s = \sqrt{\Sigma(x_i - \bar{x})^2 / (n - 1)}$

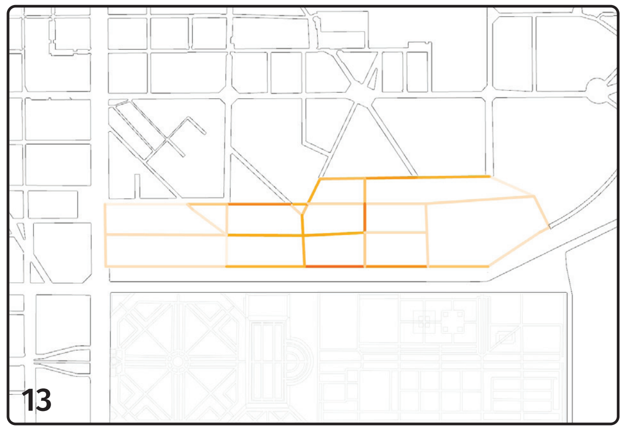
3> Calculating Standard deviation



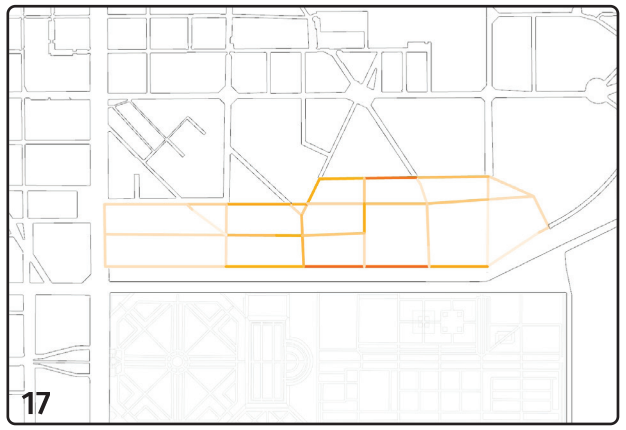
Standard Deviation: 119.8



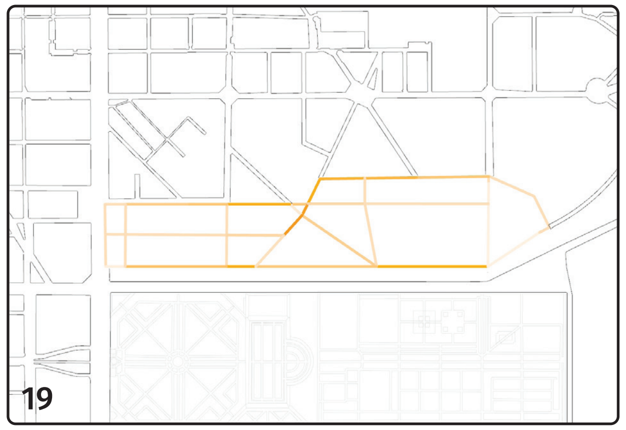
Standard Deviation: 116.5



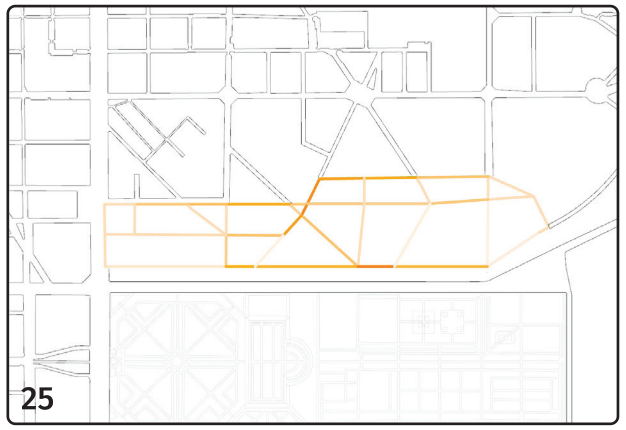
Standard Deviation: 78.3



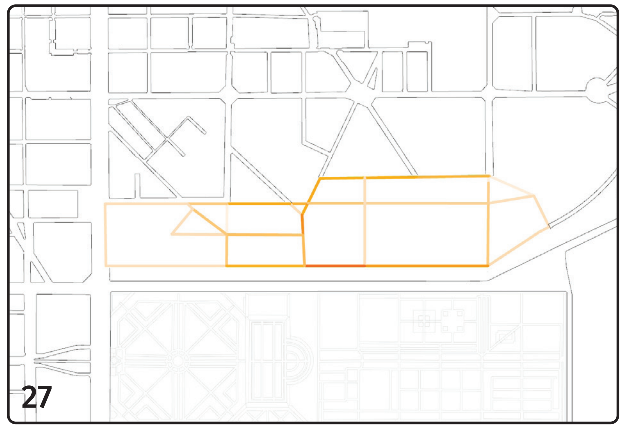
Standard Deviation: 101.7



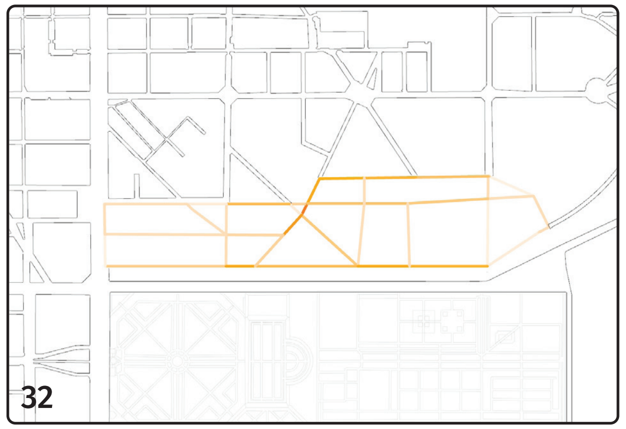
Standard Deviation: 95.3



Standard Deviation: 129



Standard Deviation: 87



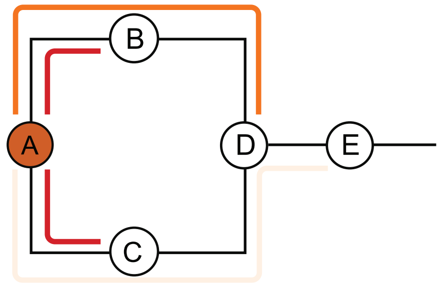
Standard Deviation: 105.5

Assessment

> **Closeness Centrality:** is a network metric that quantifies how near a node is to all other nodes within a graph. It is calculated as the **reciprocal** of the sum of the shortest path distances from a given node to all others, indicating the **efficiency** with which information or resources can be disseminated from that node to the entire network. Nodes with high closeness centrality are considered more central, as they can reach other nodes more quickly, facilitating faster communication or transfer within the network. (Bavelas, 1950)

> In space syntax, closeness centrality is closely related to the concept of **"integration,"** which measures how easily a space can be reached from all other spaces in a spatial network. High integration values suggest that a space is more accessible and likely to experience higher levels of movement and interaction. This measure is instrumental in urban planning and architectural design, as it helps identify areas that are naturally more connected and can inform decisions to enhance spatial accessibility and social interaction within the built environment.

> To compare different network scenarios based on closeness centrality, one effective method is to compute the **average closeness centrality** for all segments within each scenario. This approach provides a quantitative measure of the overall accessibility of the network, indicating how efficiently information or movement can flow across the entire system. By comparing these average values, one can identify which scenario exhibits the most well-integrated segments, reflecting a network design that facilitates shorter paths and enhanced connectivity. This comparative analysis aids in evaluating and selecting network configurations that optimize accessibility and efficiency.



Nodes: Street mid points

Edges: Streets

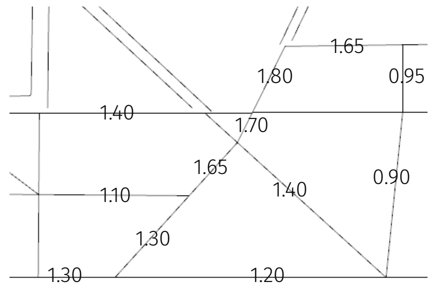
Higher CC → less distance

Less CC → higher distance

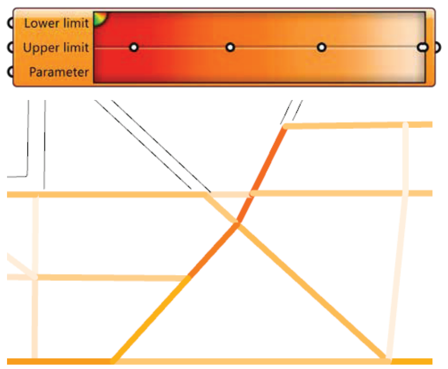
Integerated network system
↓
More centerilzed street segments
↓
Higher Closeness average

> **CC analysis example:**

C(v) = (n - 1) / Σd(v, i)



1> Measuring CC by software



2> Visualising the results

$$\text{Average} = \frac{\text{sum all segment closeness value}}{\text{number of segments}}$$

3> Calculating closeness average

Average Closeness Centrality: 1.398

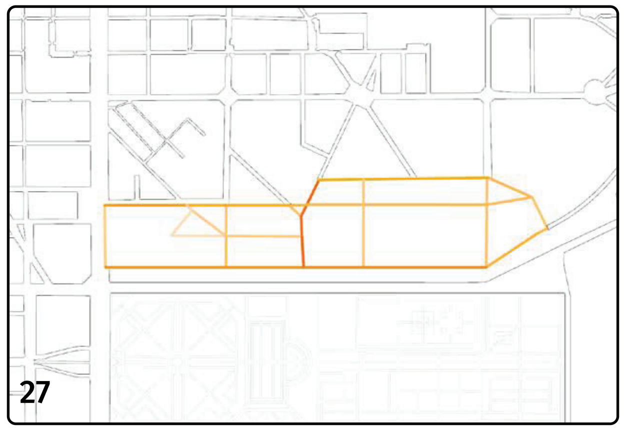
Average Closeness Centrality: 1.412

Average Closeness Centrality: 1.347

Average Closeness Centrality: 1.301

Average Closeness Centrality: 1.44

Average Closeness Centrality: 1.386



Average Closeness Centrality: 1.279

Average Closeness Centrality: 1.418

Evaluation

> Comparison methodology: To identify the most suitable scenario, the results of the scenario analysis must be evaluated through a **scoring system** that allows for direct comparison. This process involves selecting key performance parameters that reflect the core planning principles. The four chosen parameters are: total buildable area, standard deviation of betweenness centrality, average closeness centrality, and visual alignment. Each parameter contributes differently to the overall urban performance, so they are **weighted** according to their relative importance: buildable area (0.35), standard deviation of betweenness centrality (0.25), average closeness centrality (0.25), and visual alignment (0.15). These values will be **normalized** and combined to generate a final score for each scenario, enabling a structured and objective comparison to select the optimum option.

Therefore, the raw values of each parameter are first normalized to a common scale to ensure comparability. Based on their nature, higher values are considered better for buildable area, average closeness centrality, and visual alignment, while lower values are preferable for the standard deviation of betweenness centrality. After normalization, each score is multiplied by its assigned weight to reflect its significance in the overall evaluation. The weighted scores are then summed to calculate a final score for each scenario. These results are compiled into a comparison table, allowing for a clear assessment of performance and the selection of the most balanced and efficient scenario.

> Total buildable area: To evaluate the suitability of block sizes in each scenario, we considered the total buildable area, as it indicates how effectively the blocks can accommodate buildings and how well they align with the existing urban fabric. A higher buildable area typically reflects more **efficient land use** and better compatibility with the context. To compare scenarios, we normalized the buildable area values using the formula:

Normalized Score = (X - Xmin) / (Xmax - Xmin)
Weighted Score = Normalized Score × Weight

X: buildable area of the scenario
Xmin: minimum builable area= 61,839
Xmax: maximum buildable area= 124,131
weight= 0.35

Scenario	Buildable Area	Normalized Score (0-1)	Weighted Score (0-0.35)
2	75,720	0.223	0.078
10	86,660	0.398	0.139
13	93,414	0.507	0.177
17	124,131	1.000	0.350
19	85,135	0.374	0.131
25	91,124	0.470	0.165
27	61,839	0.000	0.000
32	94,853	0.530	0.185

Table 1. *Buildable area scores. Source: Author.*

> Standard deviation of betweenness centrality: This parameter reflects how evenly the traffic flow is distributed across the street network. A lower standard deviation indicates a more **balanced distribution**, reducing the likelihood of congestion or underused routes. In contrast, higher values suggest traffic concentrates on specific paths, potentially creating bottlenecks. Since lower values are more desirable, we reverse the normalization formula to give higher scores to better-performing scenarios:

Normalized Score = (Xmax - X) / (Xmax - Xmin)
Weighted Score = Normalized Score × Weight

X: St. dev. of betweenness centrality of the scenario
Xmin: Minimum St. Dev. of betweenness 78.3
Xmax: Maximum St. Dev. of betweenness 129
eight= 0.25

Scenario	St. dev. BC	Normalized Score (0-1)	Weighted Score (0-0.25)
2	119.8	0.180	0.045
10	116.5	0.246	0.061
13	78.3	1.000	0.250
17	101.7	0.535	0.134
19	95.3	0.660	0.165
25	129	0.000	0.000
27	87	0.824	0.206
32	105.5	0.460	0.115

Table 2. *Betweenness Centrality scores. Source: Author.*

> Average closeness centrality: Closeness centrality measures how easily each point in the network can be reached from others. A higher average closeness centrality value indicates a more **integrated street network**, where most places are accessible with fewer steps. This improves connectivity and walkability. Since higher values are more desirable, we use a direct normalization formula:

Normalized Score = (X - Xmin) / (Xmax - Xmin)
Weighted Score = Normalized Score × Weight

X: Average closeness centrality of the scenario
Xmin: minimum average closeness 1.279
Xmax: maximum average closeness 1.44
Weight: 0.25

Scenario	average CC	Normalized Score (0-1)	Weighted Score (0-0.25)
2	1.398	0.740	0.185
10	1.412	0.826	0.207
13	1.347	0.423	0.106
17	1.301	0.137	0.034
19	1.44	1.000	0.250
25	1.386	0.664	0.166
27	1.279	0.000	0.000
32	1.418	0.862	0.216

Table 3. *Closeness Centrality scores. Source: Author.*

> Visual alignment with surrounding: Visual alignment refers to how well the generated street networks correspond to both the spatial distribution of movement and the urban context. Since this criterion is not purely numerical, it is assessed based on observations from the closeness and betweenness centrality maps, alongside earlier site analysis. The focus of network integration—represented by warmer colors in the maps—should ideally align with key urban elements such as the two metro stations and the bus station located on the south side of the site. In addition, the network's orient ation and connectivity are visually assessed in relation to the existing surrounding urban fabric. Based on this **qualitative analysis,** we ranked the scenarios from best to worst, then normalized and weighted their scores for comparison.

Scenario	Rank	Normalized Score (0-1)	Weighted Score (0-0.15)
2	8	0.000	0.000
10	7	0.143	0.021
13	2	0.857	0.129
17	1	1.000	0.150
19	4	0.571	0.086
25	5	0.429	0.064
27	6	0.286	0.043
32	3	0.714	0.107

Table 4. *Visual alignment with surrounding scores. Source: Author.*

Selection

> Optimum scenario : To select the most suitable scenario, we assessed all alternatives based on four key parameters—total buildable area, standard deviation of betweenness centrality, average closeness centrality, and visual alignment with the context. Each parameter was weighted according to its importance and normalized to allow fair comparison across different value ranges. **Scenario 17** achieved the highest final score, indicating a well-balanced performance across all criteria. This scenario was generated using the DecodingSpaces tool, where our core urban principles and design codes were already embedded in the generation process. The second round of analysis served to verify the outcome, ensuring that the chosen scenario not only aligns with the predefined rules but also performs well when tested through independent, data-based assessment.

However, other scenarios—such as 13, 19, and 32—also achieved high scores and show strong alignment with the desired principles. These alternatives share similar qualities with the selected scenario and could also be considered valid solutions. Their close performance indicates that the generative process offers multiple **viable options**, giving flexibility for refinement or adaptation in later design phases.

Scenario	Buildable	BC Std Dev	Closeness	Visual Alignment	Final Score (10–0)
2	0.078	0.045	0.185	0.000	3.08
10	0.139	0.061	0.207	0.021	4.28
13	0.177	0.250	0.106	0.129	6.62
17	0.350	0.134	0.034	0.150	6.68
19	0.131	0.165	0.250	0.086	6.32
25	0.165	0.000	0.166	0.064	3.95
27	0.000	0.206	0.000	0.043	2.49
32	0.185	0.115	0.216	0.107	6.23

Table 5. *Final scores of scenarios based on their weighted scores of 4 metrics. Source: Author.*

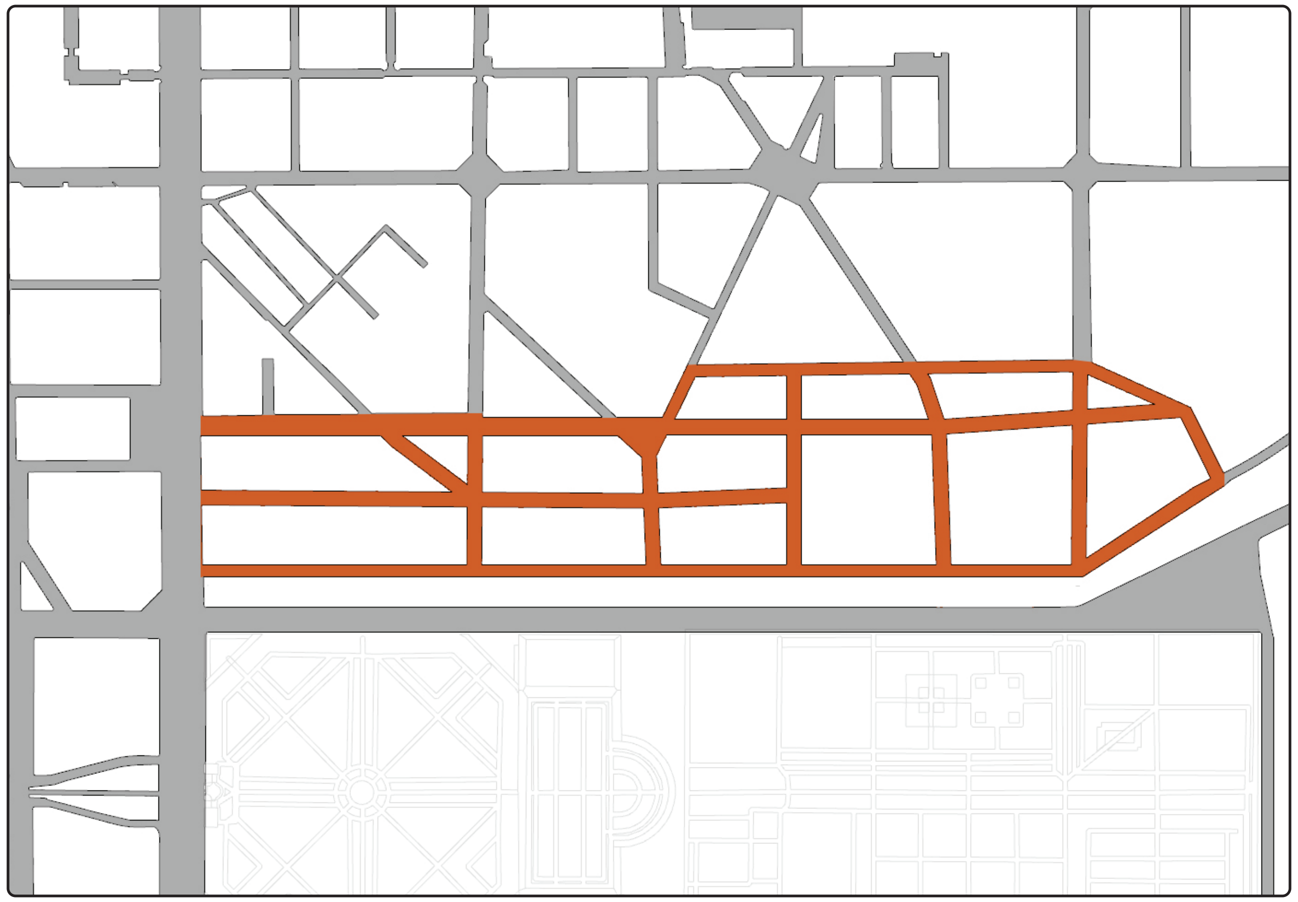


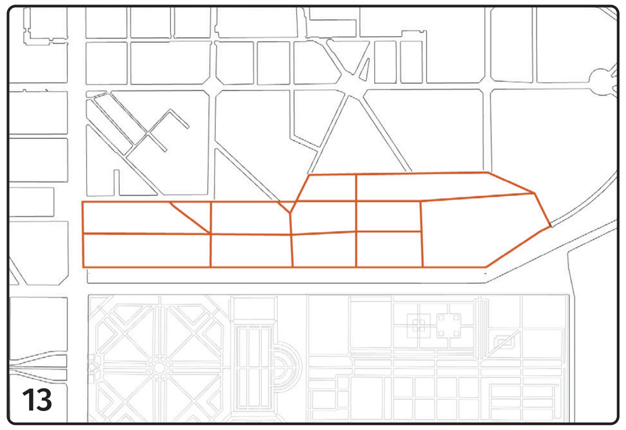
Fig 65. *Selected network (scenario 17). Source: Author.*

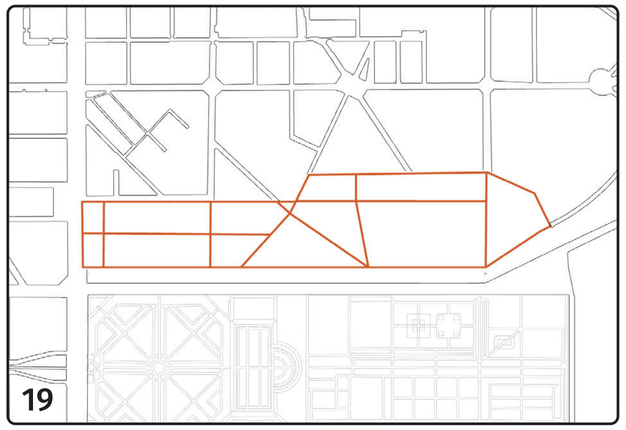
Insights

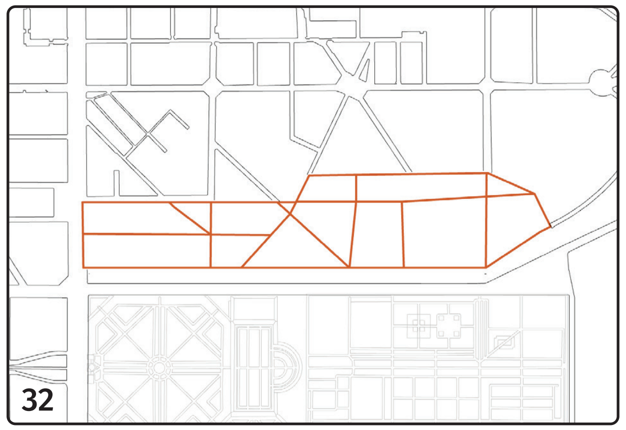
> Designer Preference: This thesis aims to establish a computational design process grounded in codes and principles derived from both academic literature and site-specific data. As a result, the influence of personal design preferences is intentionally minimized. While subjective choices can often have a strong impact sometimes even more than quantitative parameters, this work prioritizes **objectivity** and **replicability**.

For instance, out of 36 generated scenarios, the selected one exhibits a more **rational** and regular configuration. This choice is justified by its performance in relation to established principles and technical analyses, such as betweenness and closeness centrality. However, the evaluation also includes a parameter labeled visual alignment, which reflects the designer's aesthetic preferences and spatial intuition. If the weighting of this parameter were increased, the outcome could shift three other scenarios, currently ranked just below the selected one, demonstrate strong scores and could be preferable if greater emphasis were placed on human experience and **designer sensibility**.

This illustrates that factors like rationality, efficiency, human experience, and design preference can all be encoded and managed within a parametric framework. However, the primary focus of this thesis remains on quantitative outcomes and the underlying design logic defined by clear, reproducible rules.

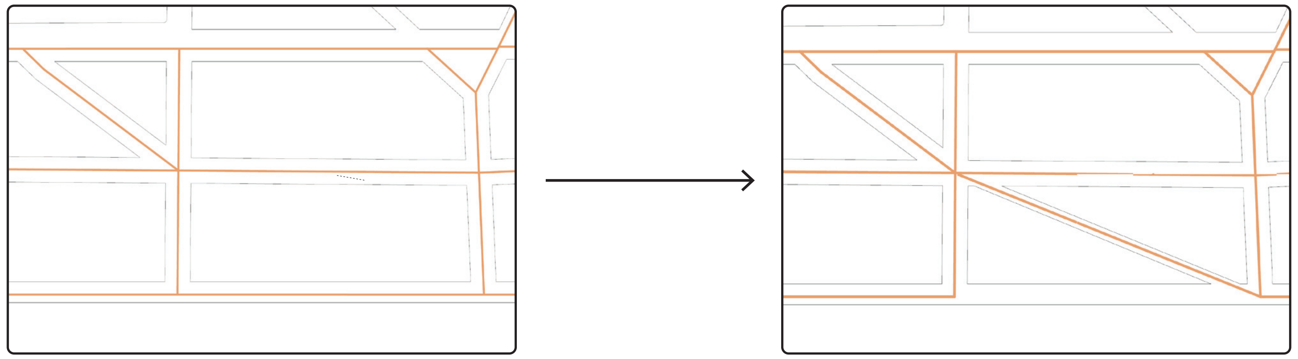




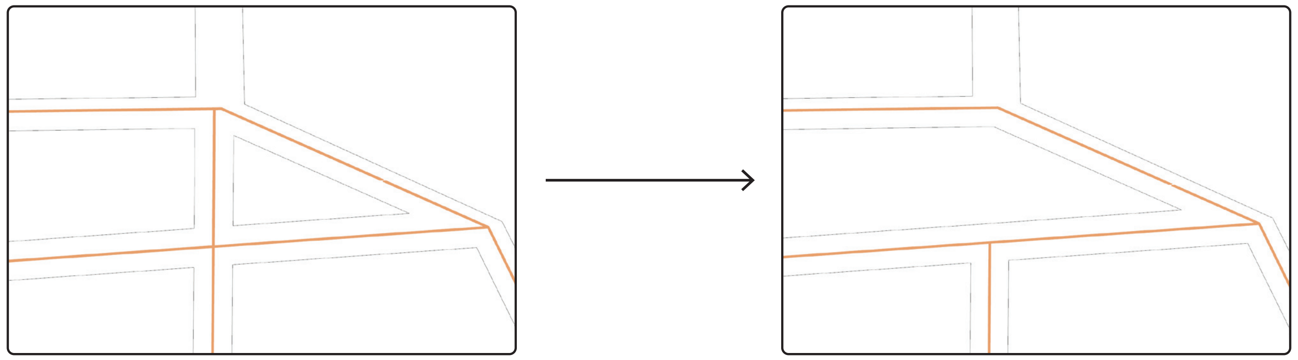


> Manual adjustments: After the selection of the scenario(s), it is also possibleand often necessary to adjust what the parametric tools have generated. In some cases, the designer may not have full **control** over every component of the output, or issues identified during the assessment process may require targeted modifications. Therefore, manual adjustments by the designer can play a critical role in improving the **quality** and **performance** of the design at each stage.

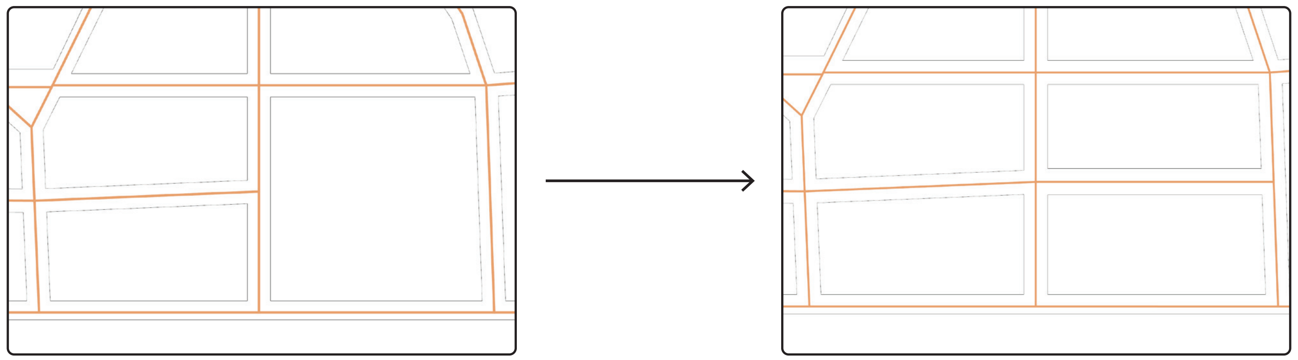
However, since the primary aim of this thesis is to explore the process rather than propose a specific design outcome, manual **interventions** have been intentionally avoided. Instead, the workflow adheres strictly to the defined principles, parameters, and outputs produced by the parametric tools. This approach allows for a clearer evaluation of the capabilities and limitations of parametric techniques, emphasizing their role as supportive instruments in the decision-making process rather than as tools for refining a finalized design.



street modification



Removing Street



Adding Street

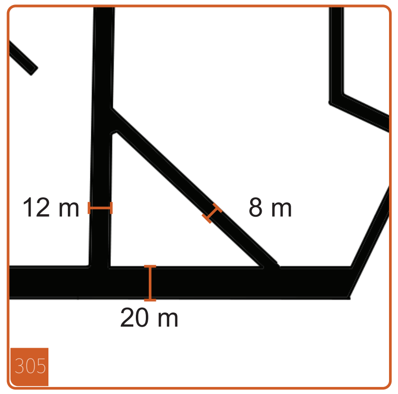
4.2.2. Block Synthesis

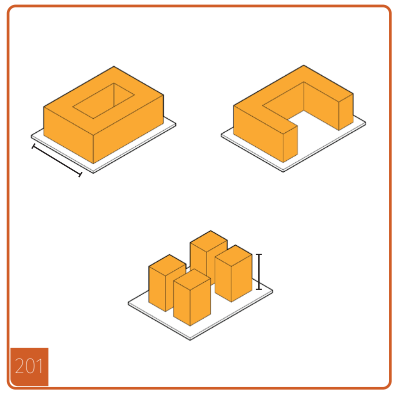
After defining the network and the main block subdivisions, the next step is to divide these blocks into parcels, understand how BCR and FAR are distributed across the site, and define the **building footprints** and forms. This process begins by generating parcels based on our earlier principles and identifying the buildable area within each.

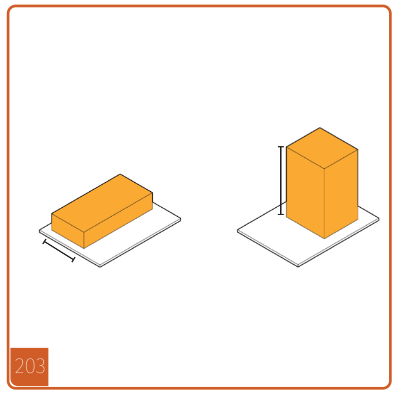
> The blocks generated from the street network are too large to host a single building. In real urban settings, blocks are typically divided into smaller parcels with distinct **property boundaries**. Using the DeCodingSpaces plugin in Grasshopper, we can input the block boundaries and generate parcel divisions. This component also allows for the definition of street **setbacks**, which determines the width of the adjacent street width. In our case we consider every streets 20 meter which is the maximum in order to avoid sun shading and the later possibility of buffer between pedestrian part and cars.

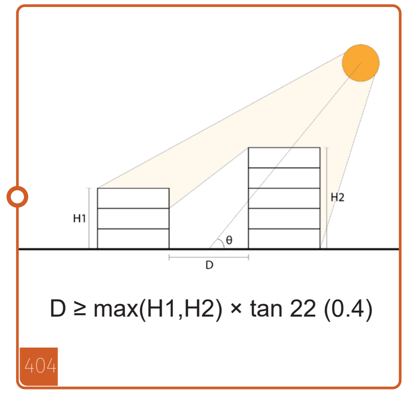
> We also define **parcel widths**; based on local analysis, residential parcels should not exceed 20 meters and commercial parcels up to 50 meters. For our mixed-use development, a 40-meter width is chosen to allow for flexible functional assignment later.

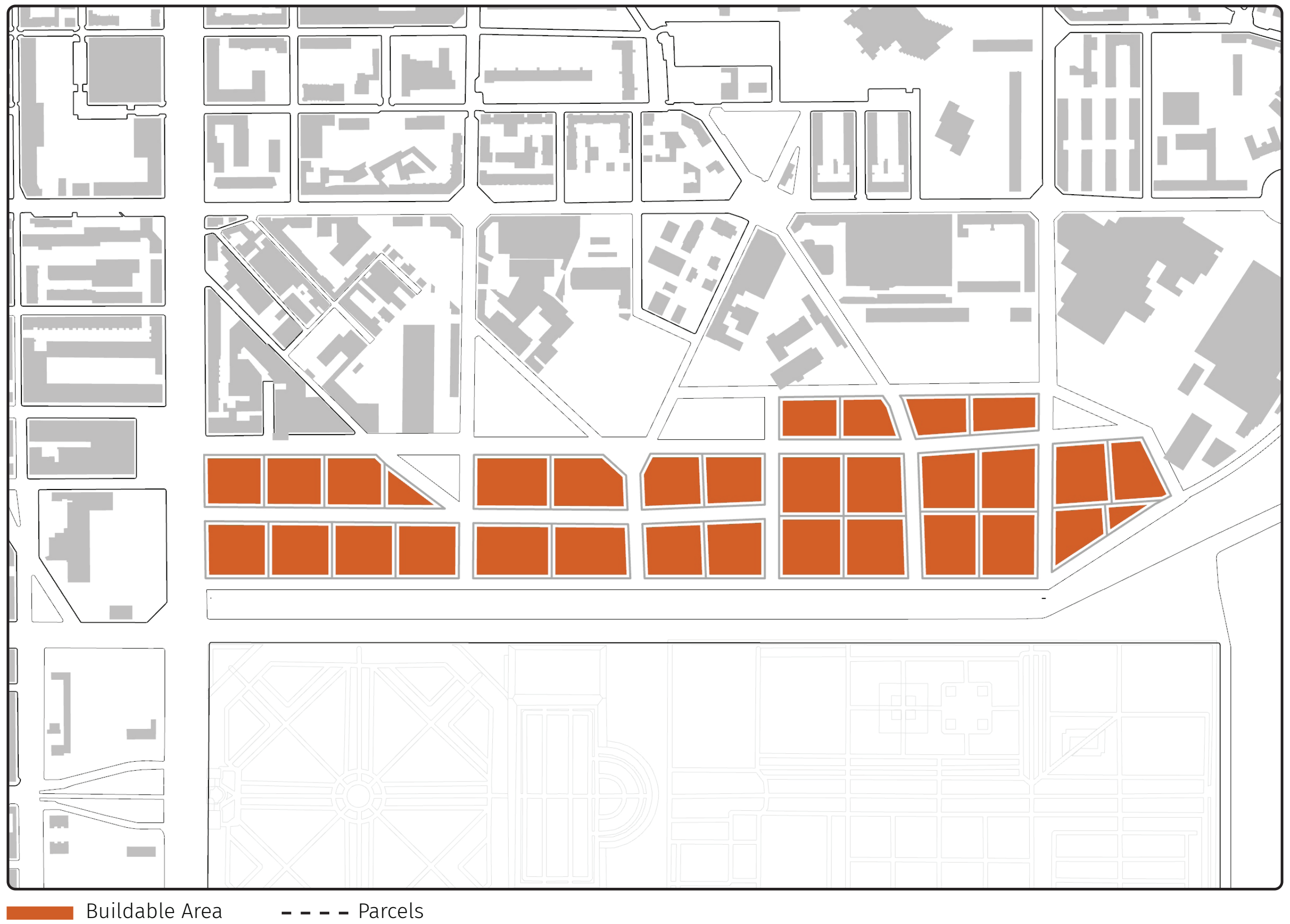
> The buildable area within each parcel is defined by the minimum **required distance** between buildings especially when they're not attached and no street separates them. Based on the analysis, a 6-meter gap is needed, derived from the sun orientation in Turin (22°) and a maximum building height of 15 meters, ensuring proper daylight and ventilation. in our case we consider 8 meters distance to be sure about the sun access and also 4 meters of pedestrian part and bike lane for each side.











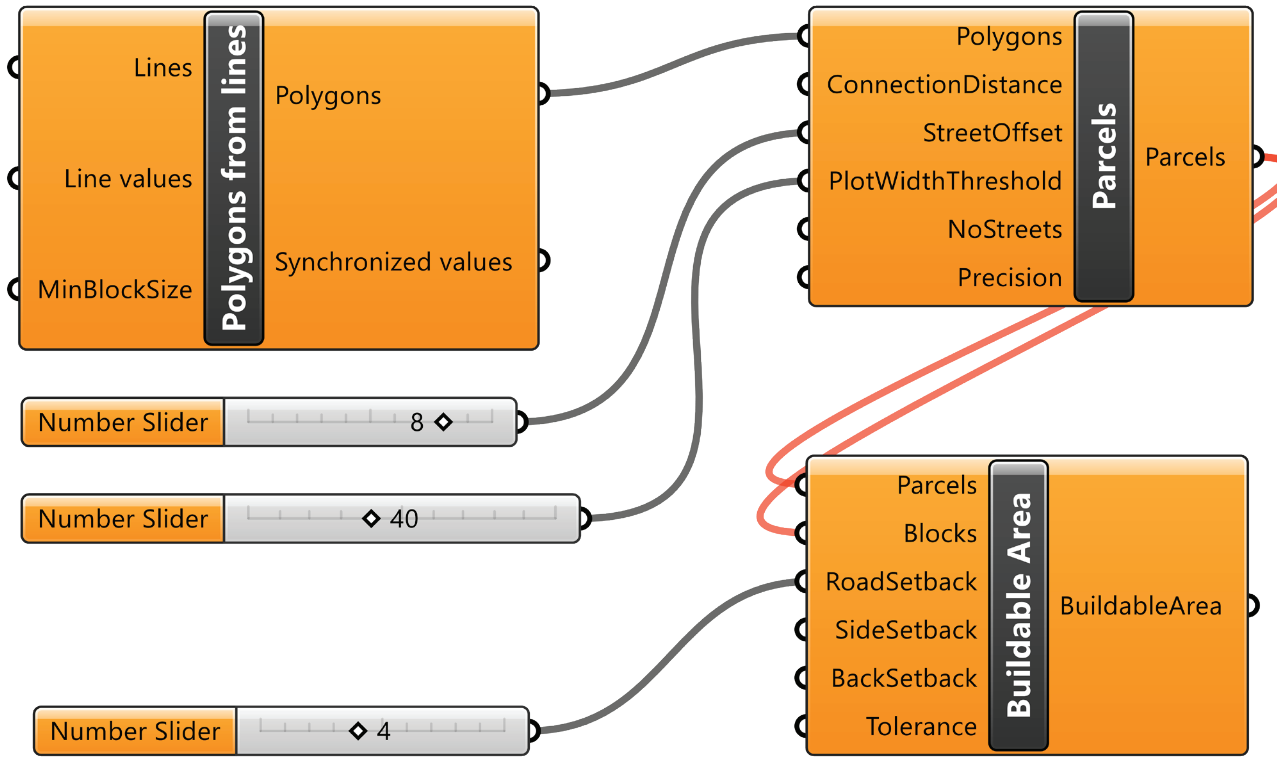


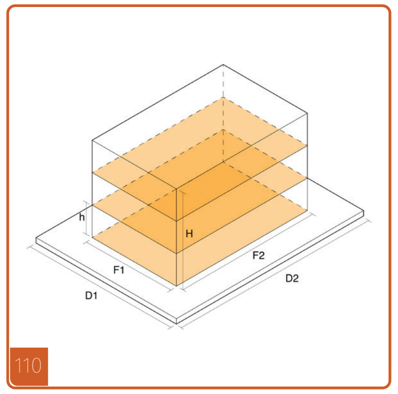
Fig 66. *Parcel Generator component in DeCodingSpaces toolkit. Source: Author.*

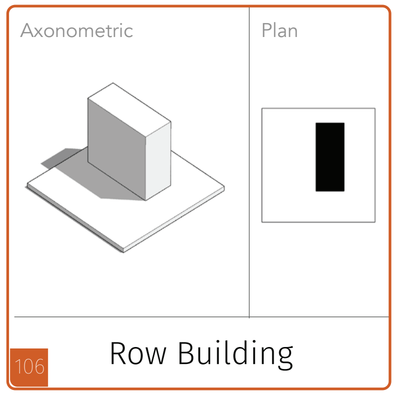
> After defining the parcels, the next step is to plan the building footprints and their heights. The DeCodingSpaces toolkit in Grasshopper provides a component that allows us to input key parameters—derived from both our analytical findings and the core design principles—to generate building volumes. This component also supports typology variations, enabling us to explore different development scenarios while maintaining consistent design logic.

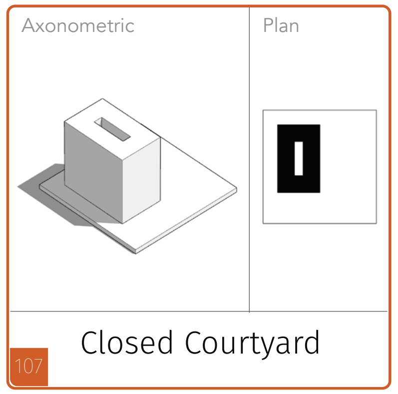
> A crucial parameter is **building depth**, which defines how far the building extends inward from the façade facing the street. Access to natural light significantly influences this measure. If the building receives light from both sides, a depth of 20 meters is considered acceptable—an approach also validated by the analysis of Turin's urban fabric. The building length can also be defined, though it varies depending on the block typology and can be adjusted to optimize spatial configuration.

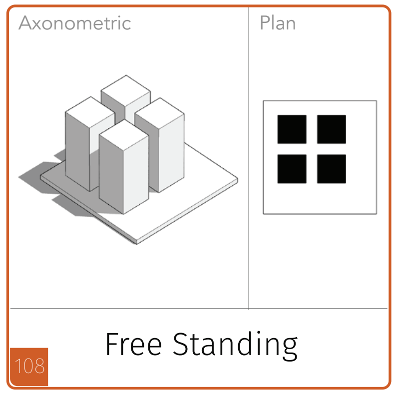
> Through the urban analysis, three main **block typologies** were identified: Freestanding, Row buildings, Closed courtyards. These options are available within the DeCodingSpaces component, allowing us to select the appropriate typology for each parcel. The building orientation and placement within parcels are also adjustable, but since the blocks are already well-oriented and the component automatically aligns buildings with the nearest street segment, the default settings are generally sufficient.

> Based on the analysis, the target **FAR** is around 1.0 for residential and 1.5 for commercial developments. Given the total required Gross Floor Area (**GFA**) of 160,000 m², we adopt an average FAR of 1.0, assuming a floor height of 4, meters to estimate the number of floors required per parcel.

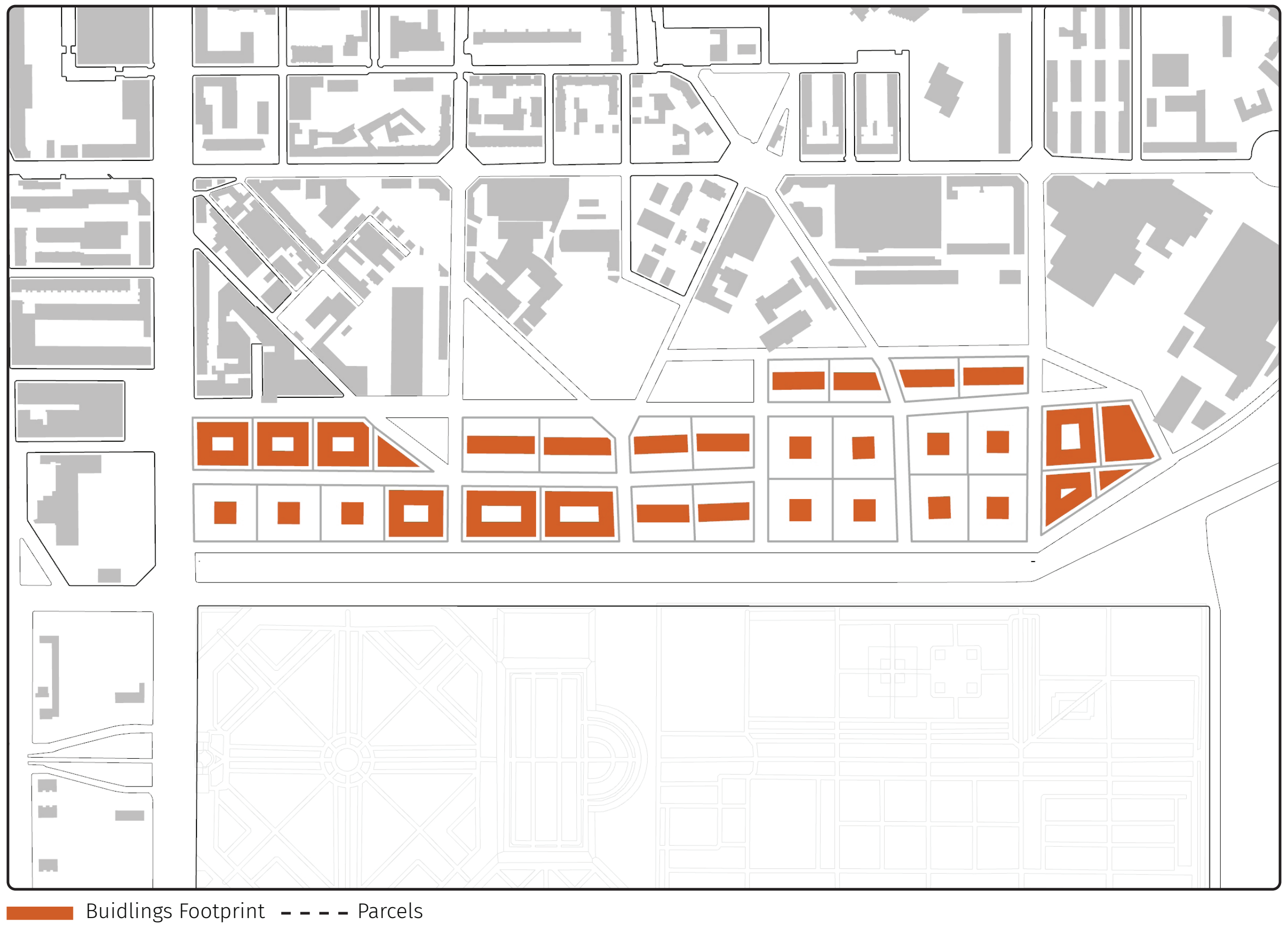








Generation Example



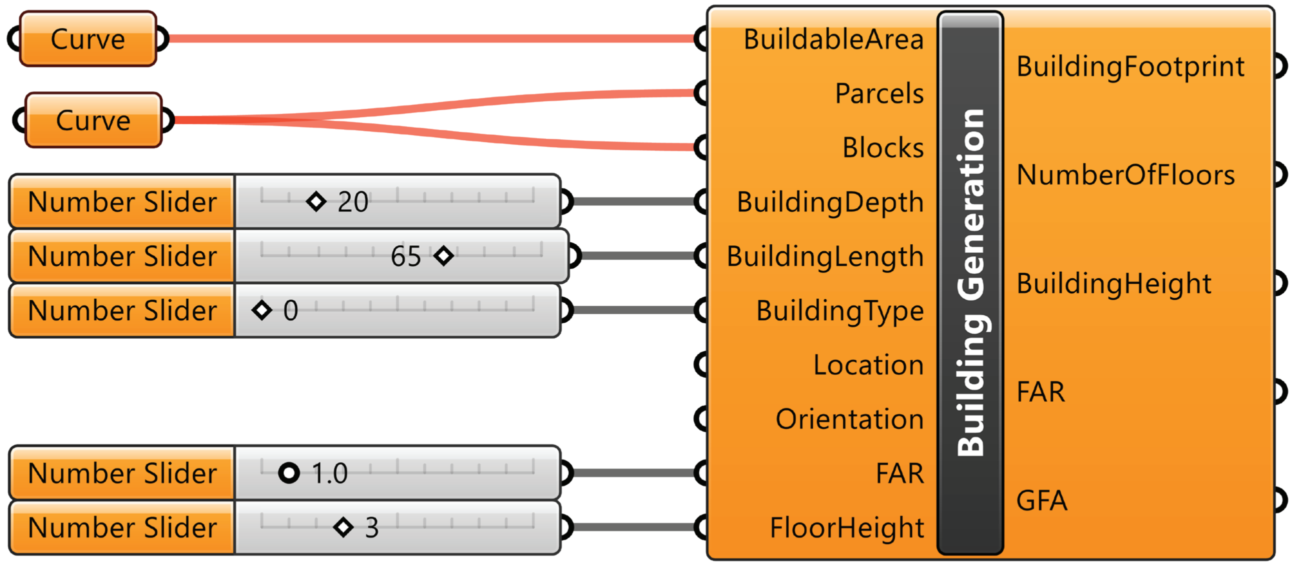
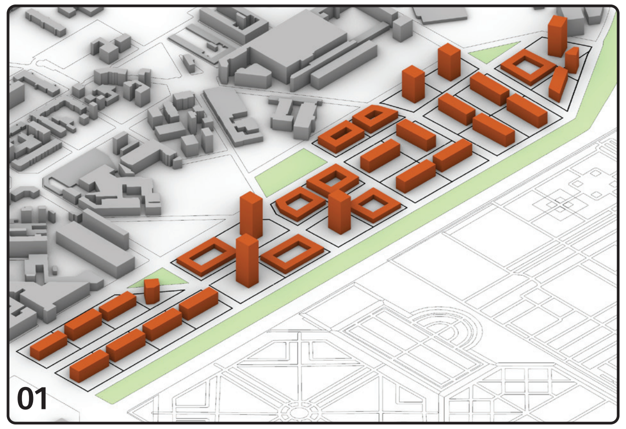


Fig 67. *Building Generator component in DeCodingSpaces toolkit. Source: Author.*

Abacus of iteration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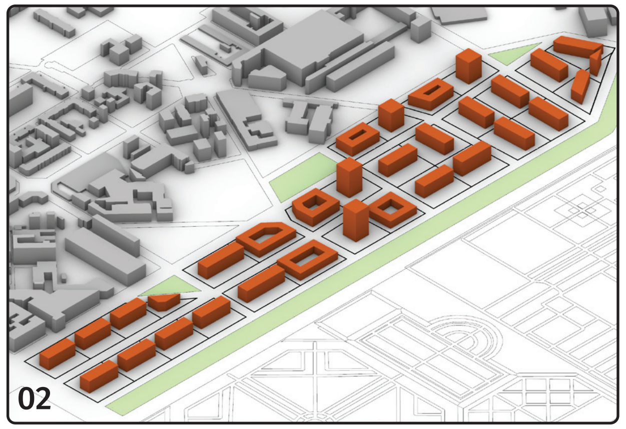
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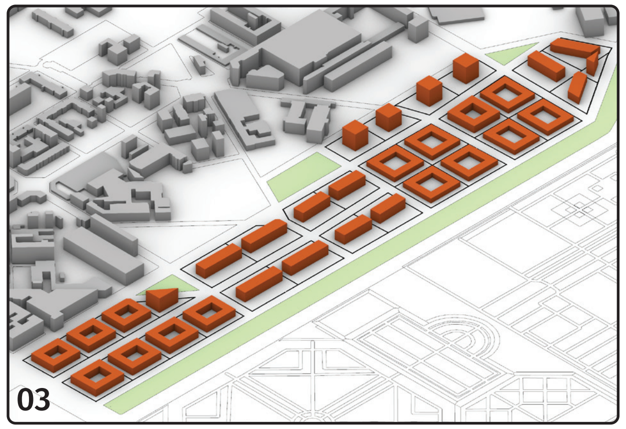
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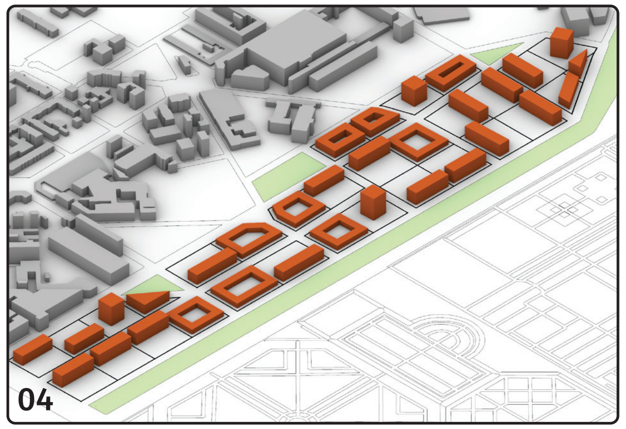
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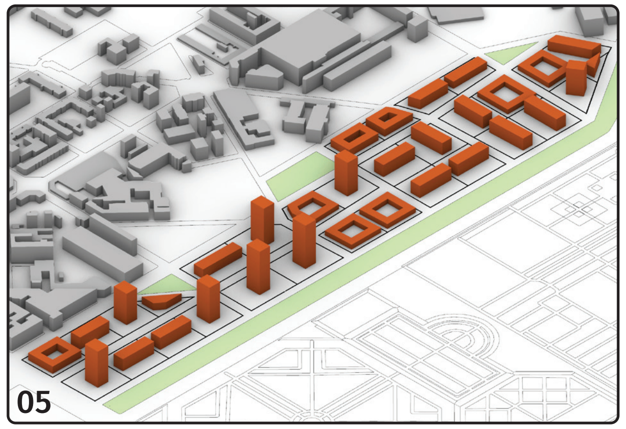
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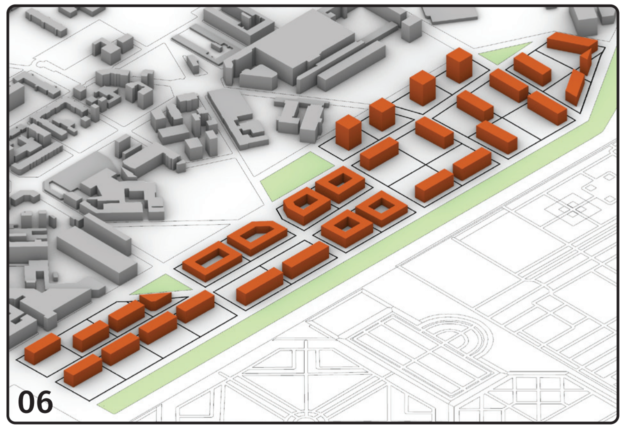
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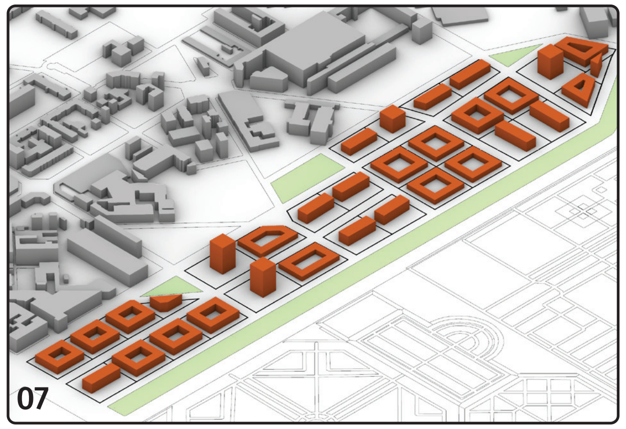
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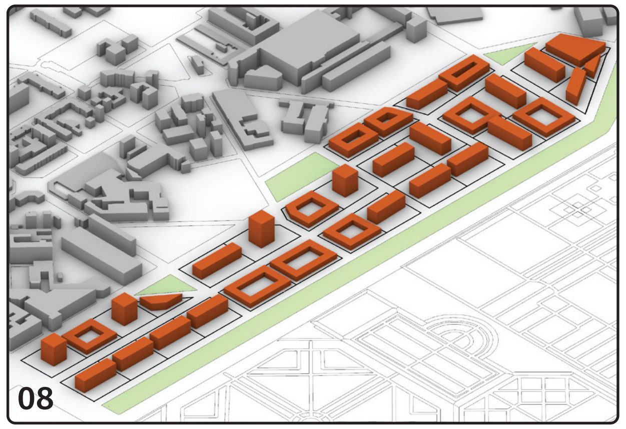
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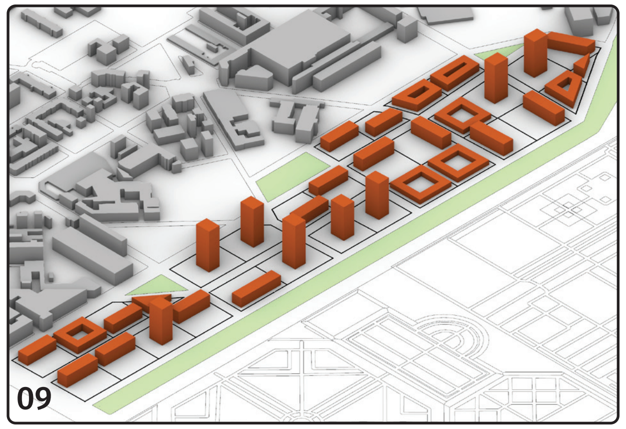
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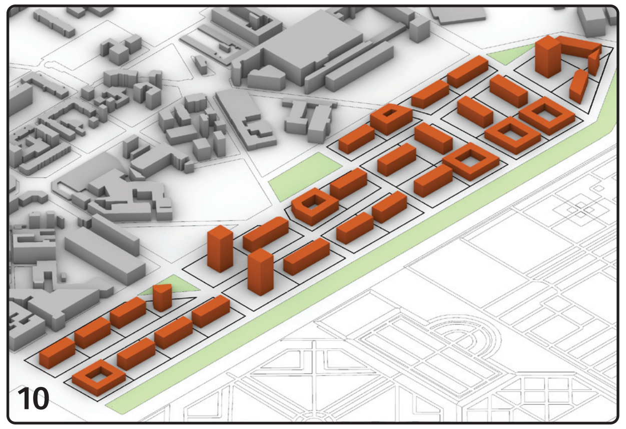
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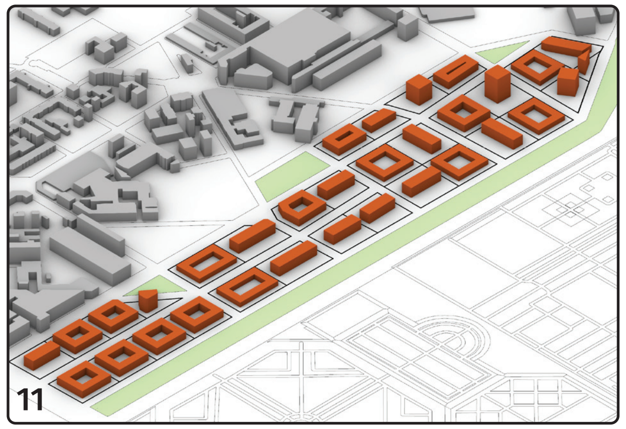
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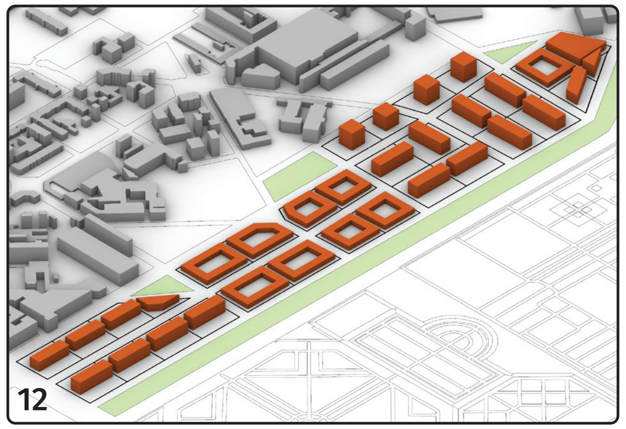
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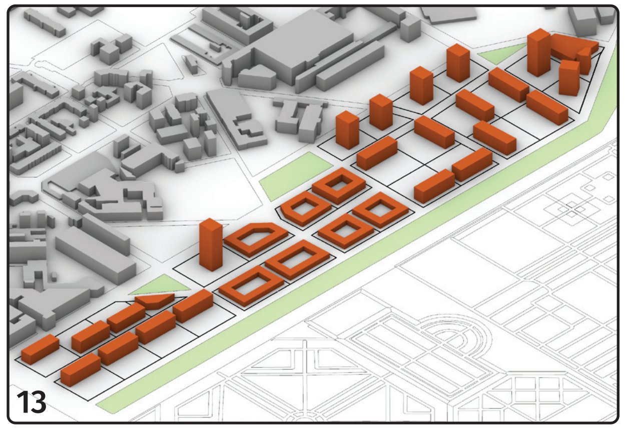
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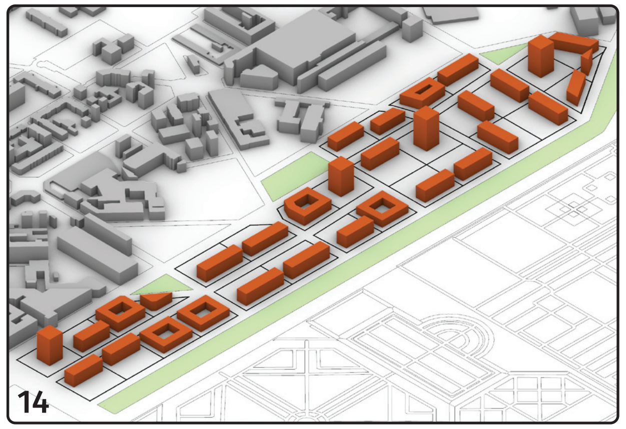
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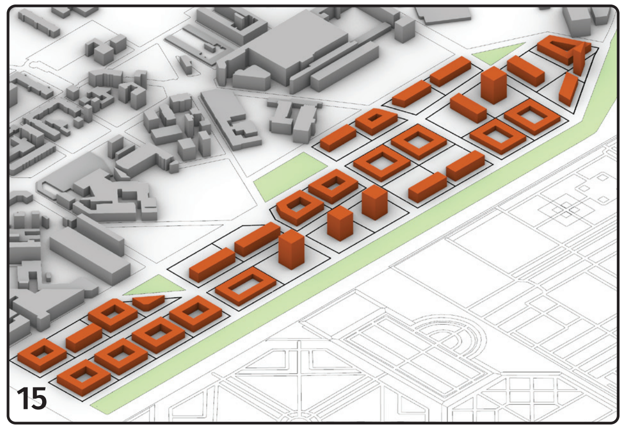
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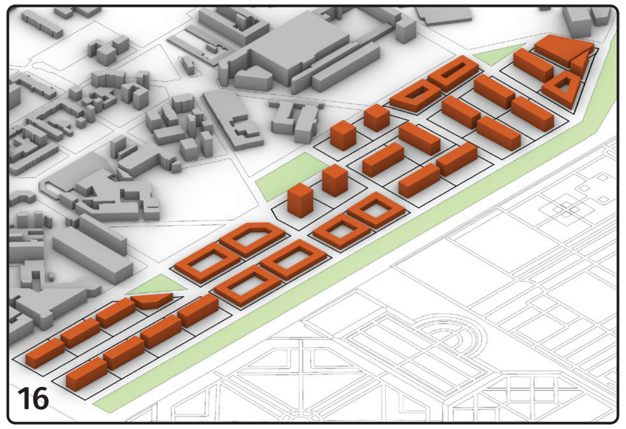
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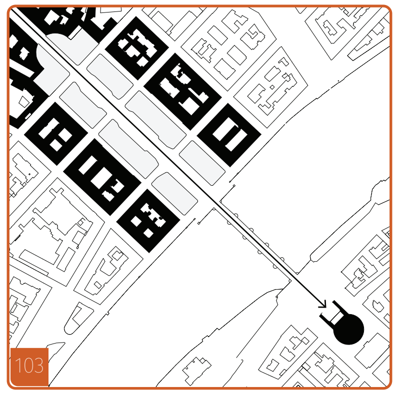
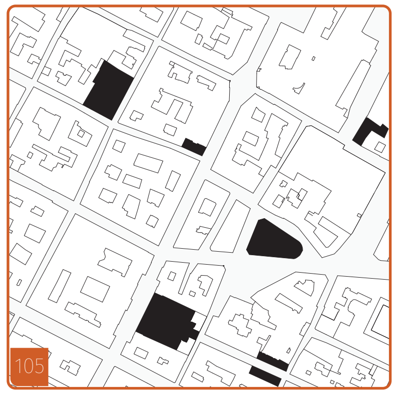
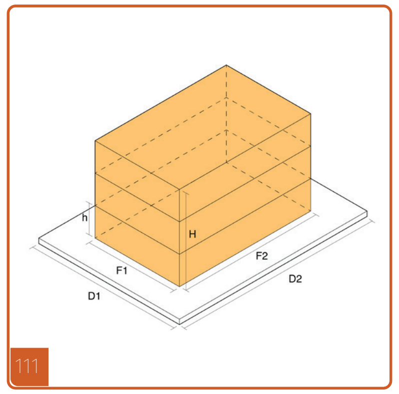
Short listed scenarios

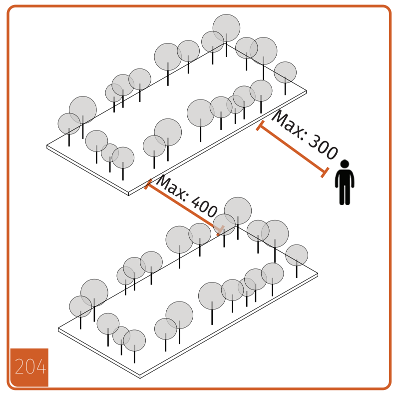
With the help of parametric tools and after running the DecodingSpaces plugin—once the code and data are embedded—it generates multiple urban form scenarios. These scenarios differ primarily in the c**onfiguration and spatial layout** of the blocks within the designated parcels, as well as in **building heights** and **typological diversity**. For example, while some scenarios feature a higher number of closed perimeter blocks, others present a looser configuration with open blocks or mixed-use arrangements. Each variation reflects a different approach to density, form, and function, allowing us to explore a wide range of possibilities before narrowing down the most suitable directions for the masterplan.

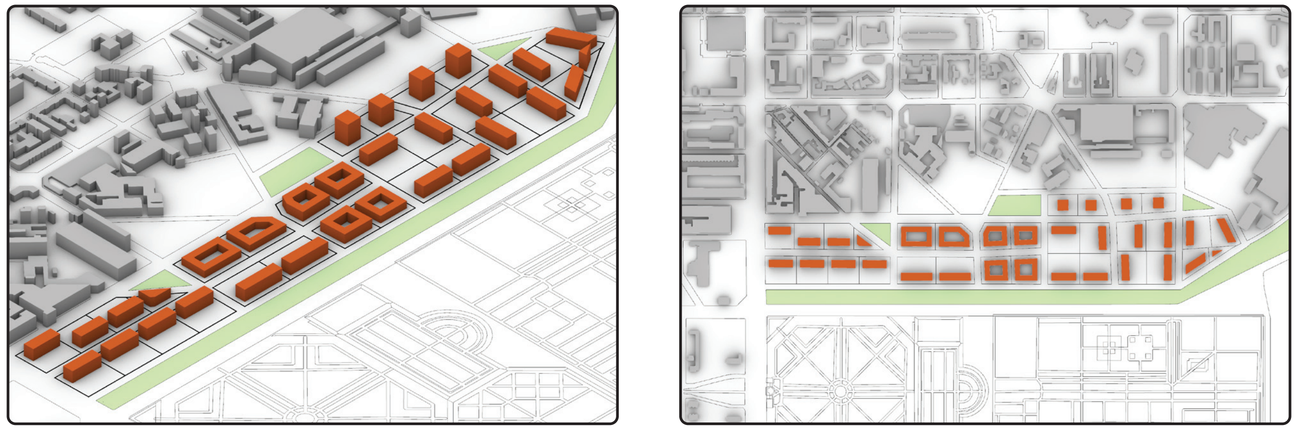
After analyzing the full abacus of 16 generated scenarios, we decided to proceed with a focused examination of four shortlisted options: Scenarios 6, 10, 14, and 15.These were selected based on their **visual compatibility** with the urban design **principles** and **spatial codes** previously defined. For instance, Code 103 highlights an existing successful urban configuration, an open **piazza** framed by buildings and oriented toward a focal point such as a monument. Scenarios that resonate with this typology were given priority, as they reflect both **contextual continuity** and spatial quality. These shortlisted scenarios demonstrate a balanced density and a geometry that aligns with the existing city fabric and surrounding typologies. Moving forward, we will evaluate them based on environmental criteria, such as solar access, ventilation, and microclimatic performance, to select the most appropriate scenario for further development of the masterplan.



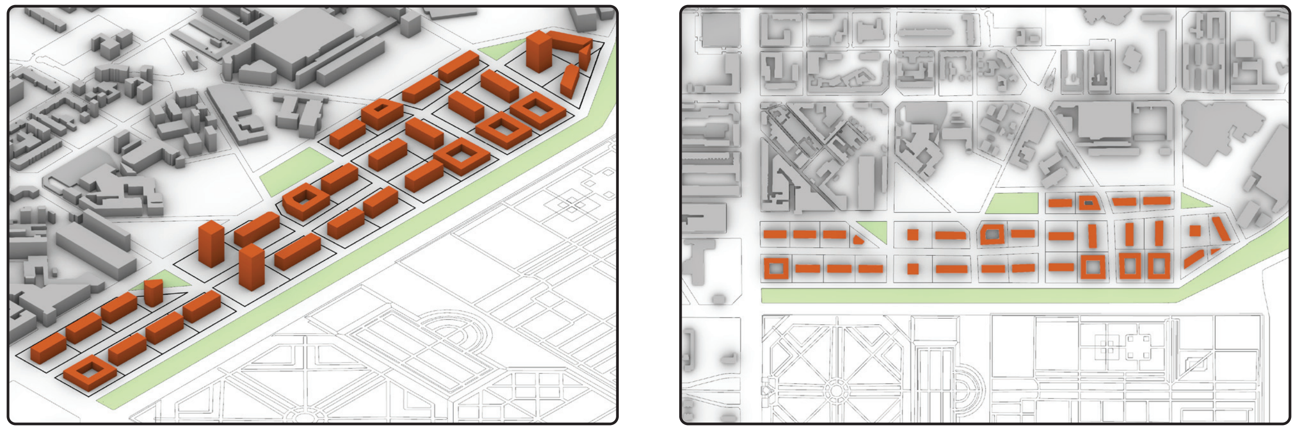




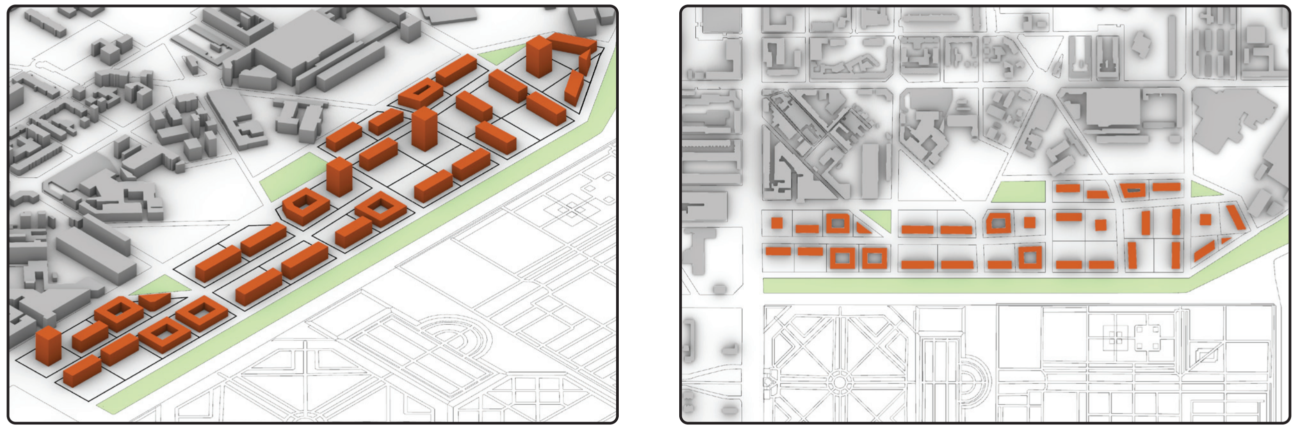




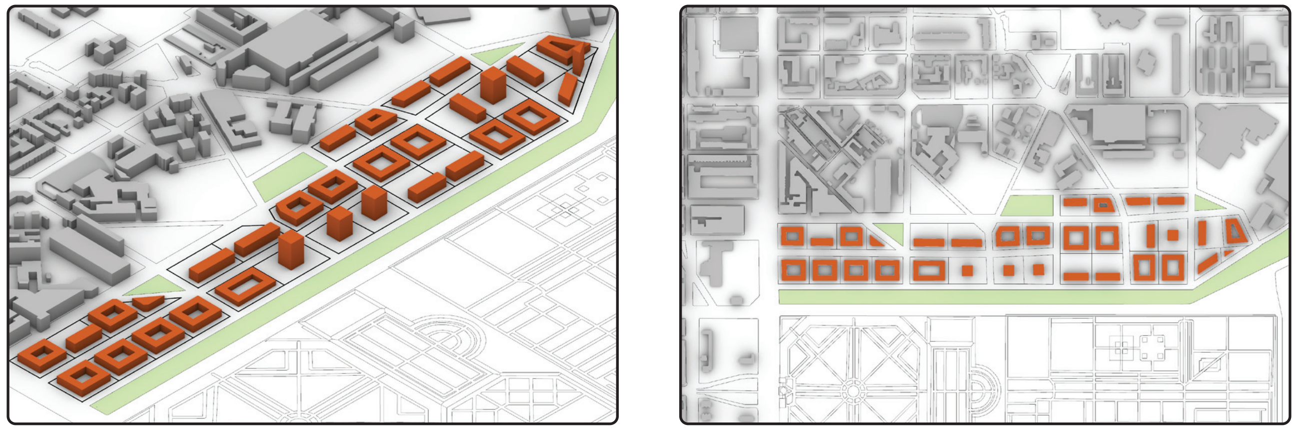
6. Building blocks with heights ranging from 12 to 36 m and a total GFA of 195,412 m².



10. Building blocks with heights ranging from 12 to 56 m and a total GFA of 194,769 m².



14. Building blocks with heights ranging from 12 to 52 m and a total GFA of 192,081 m².



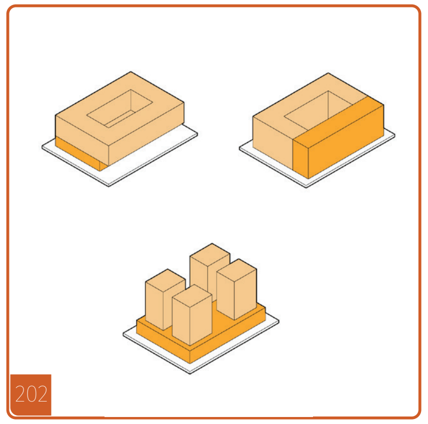
15. Building blocks with heights ranging from 8 to 40 m and a total GFA of 195,203 m².

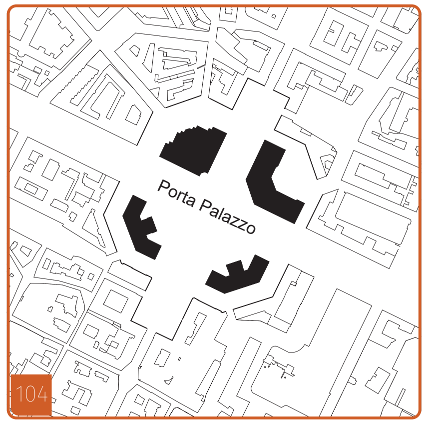
Assessment

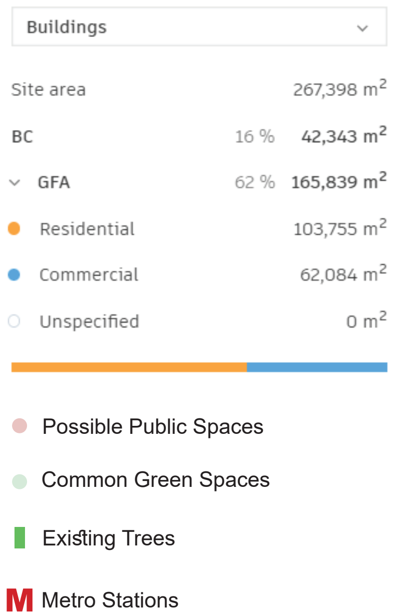
To evaluate the shortlisted urban masterplans, each scenario was imported into **Autodesk Forma**, a professional urban design tool that allows integration of proposals into their real-world context. This platform provides access to environmental data, building volumes, and **OpenStreetMap** layers, enabling a detailed assessment of how functions, geometries, and public spaces align with one another.

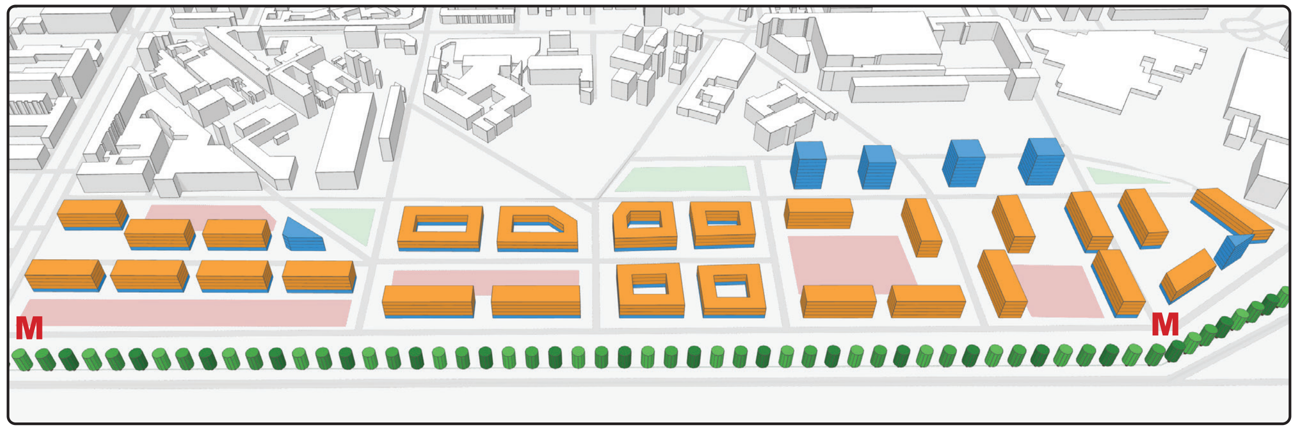
> Function alignment : As per municipal guidelines, 40% of the total area must be allocated to **commercial** use, with the remaining 60% dedicated to **residential** functions. This requires a thoughtful balance that ensures functionality, synergy between uses, and visual coherence in the urban fabric. While all four scenarios meet the required area for each function, their internal configurations and layouts reflect distinct urban strategies. In some cases, commercial activities are concentrated along **ground floors**, creating vibrant streetscapes, whereas in others, only selected sections are designated for such use. The placement of **commercial high-rises** also varies some group them into central hubs to encourage economic activity, while others distribute them more evenly to ensure accessibility. Additionally, the presence of two metro stations and the arrangement of open and public spaces are critical factors. **Metro** stations often benefit from adjacent plazas or require separation from residential blocks, while the distribution of green and public areas must support both residential quality of life and commercial vitality.

By considering these spatial relationships and functional alignments, each scenario can be **qualitatively** assessed and **ranked**. This analysis will play an essential role in guiding the final selection of the most context-responsive and balanced masterplan.

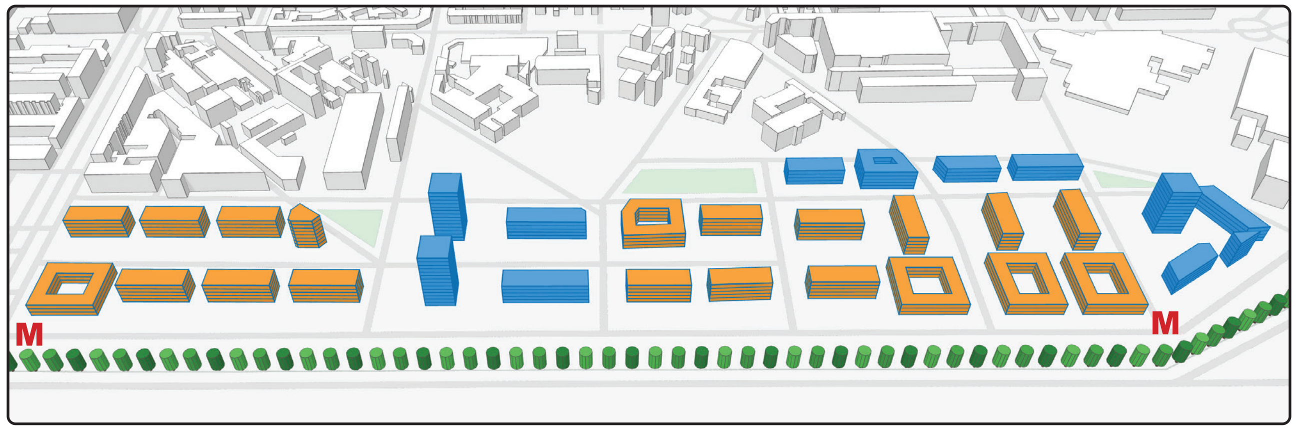




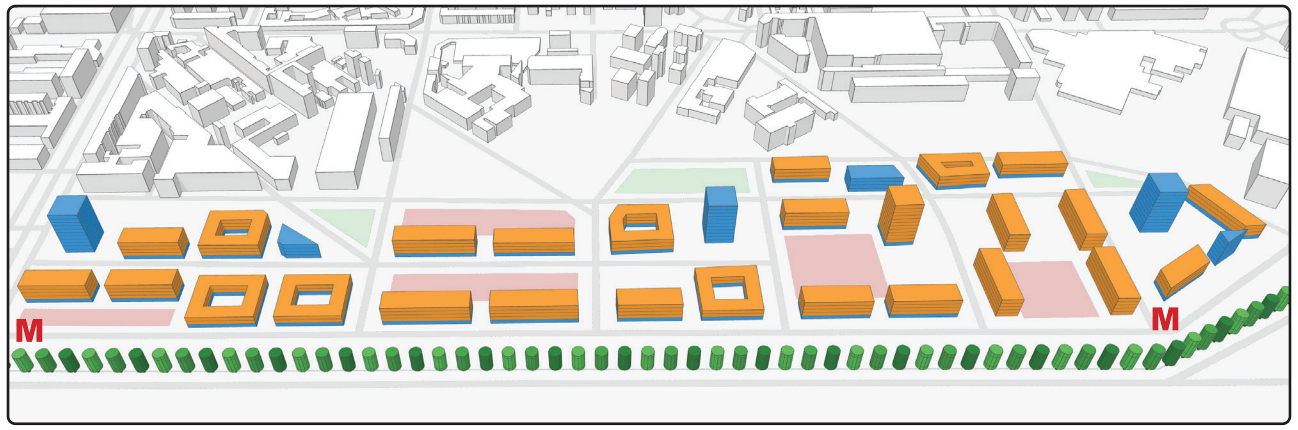




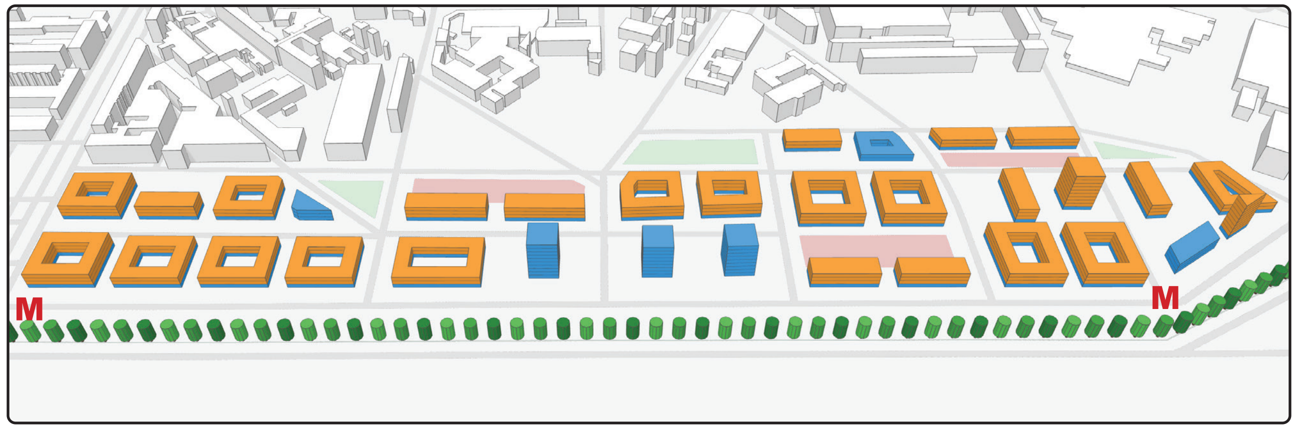
6. Ground floor stores, office hub in highrises, 30,440 m² possible green/public space. **Ranked: 1**



10. Commercial hubs in the blocks and fully residential blocks. 7,247 m² possible green/public space. **Ranked: 4**



14. Ground floor stores, office hub in highrises distributed all over the site, 29,066 m² possible green/public space. **Ranked: 2**

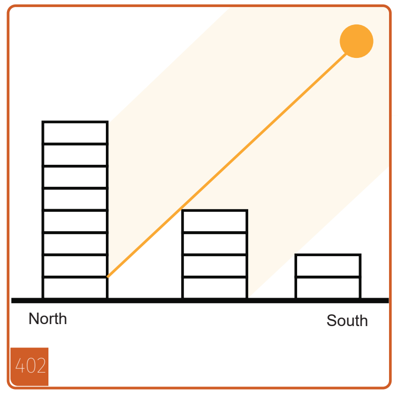


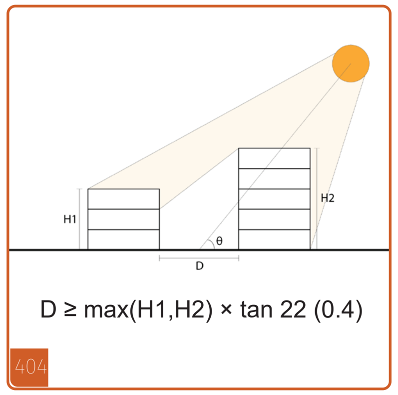
15. Ground floor stores, office hub in highrises, 7,247 m² possible green/public space. **Ranked: 3**

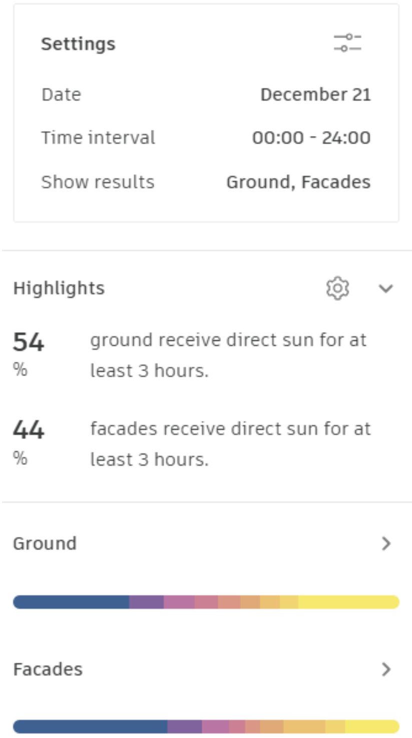
Assessment

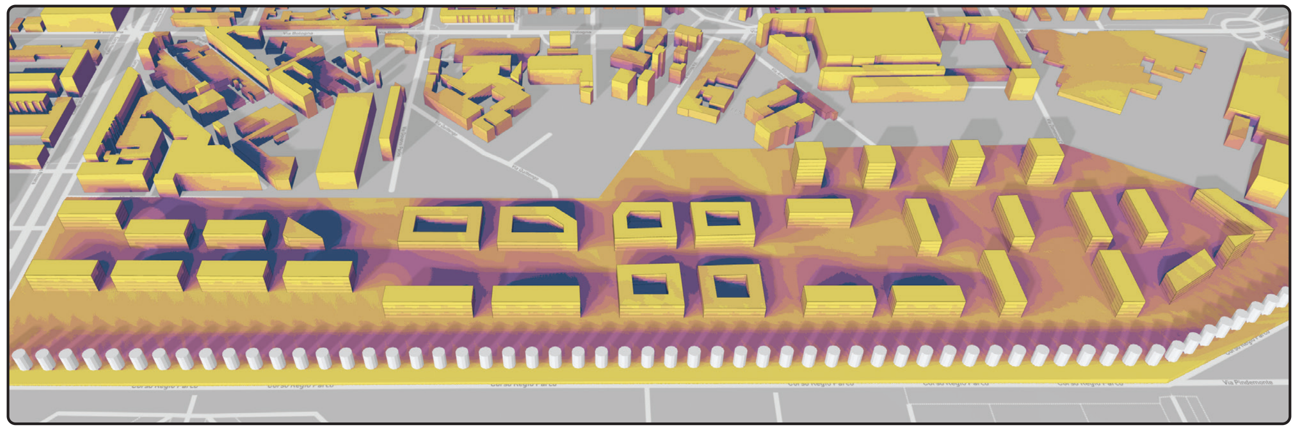
> Sunlight Access : To evaluate light access across different urban design proposals, we utilized **Autodesk Forma**, which allows for seamless integration of multiple design scenarios. In this study, four distinct urban configurations were imported into Forma, each representing a unique design strategy. The platform effectively interprets key architectural and urban metrics—including building heights, floor counts, and footprints—and positions them accurately within the real-world context. This geolocation feature ensures that the simulations account for the site's actual climatic conditions, surrounding buildings, and solar orientation, providing a reliable basis for environmental analysis.

Building upon the theoretical framework established earlier regarding the importance of daylight in urban environments, we applied Forma's dedicated Sun Hours Analysis tool to assess solar exposure. This tool calculates the number of hours each part of the site—both ground surfaces and building facades—is exposed to direct sunlight over the course of a day. For this analysis, **December 21** was selected as the reference date, representing the winter solstice, when solar exposure is at its minimum in the northern hemisphere. This worst-case scenario enables a conservative assessment of light access. For each scenario, the tool generates two key metrics: the percentage of the ground surface and the building facades receiving sunlight on that specific day. These simulations were run across all eight design proposals, and the resulting percentages were recorded to enable a quantitative comparison of light access performance across the different schemes.

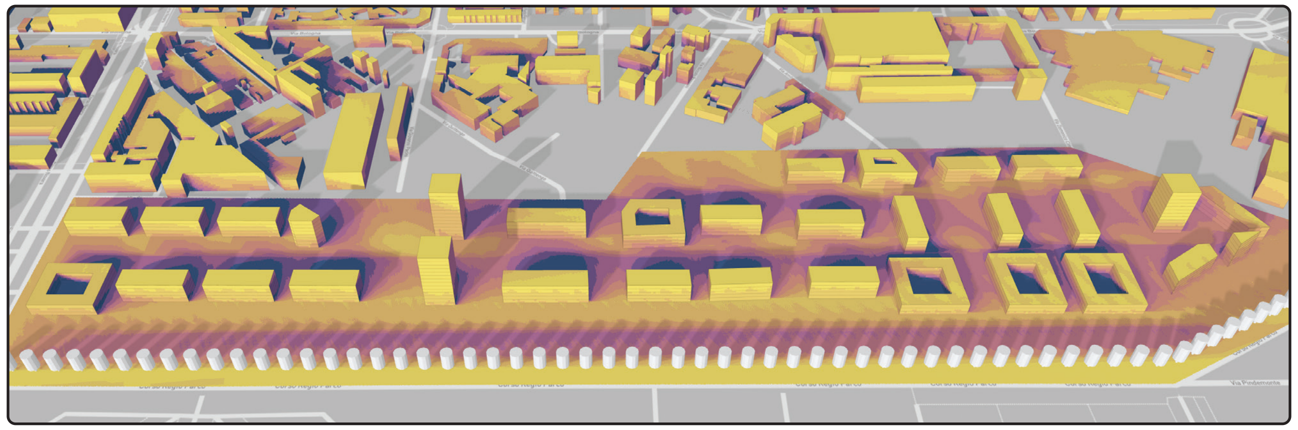




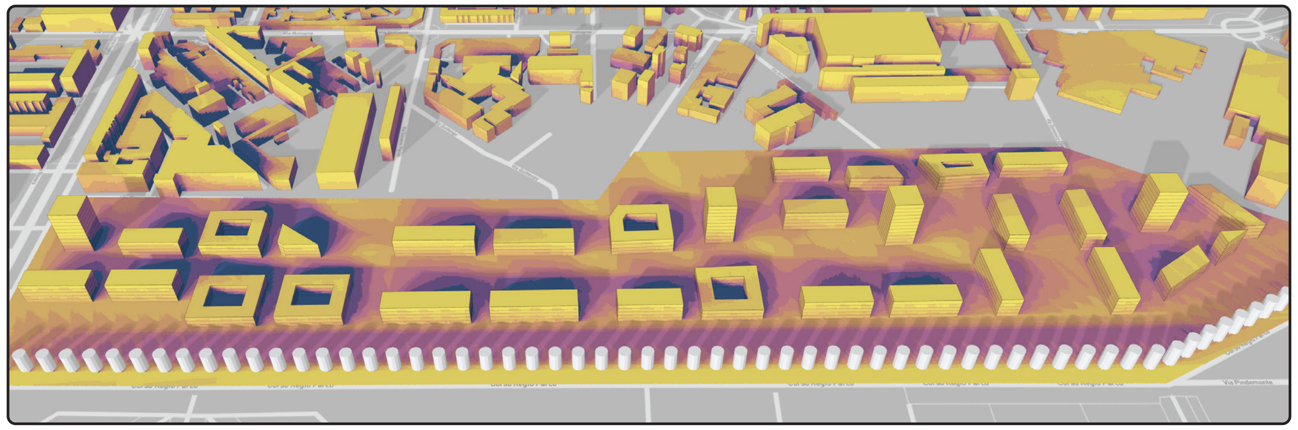




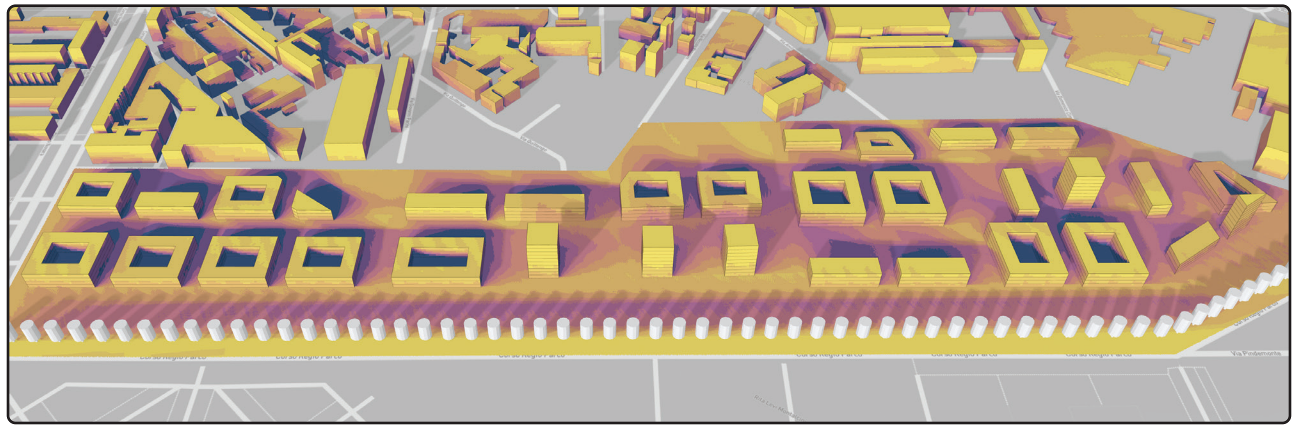
6. **63%** ground and **47%** facades receive direct sun for at least 3 hours.



10. **60%** ground and **48%** facades receive direct sun for at least 3 hours.



14. **55%** ground and **47%** facades receive direct sun for at least 3 hours.space.

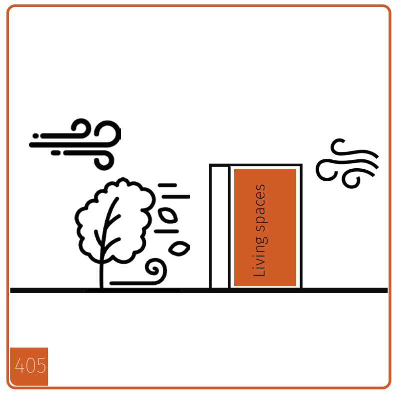


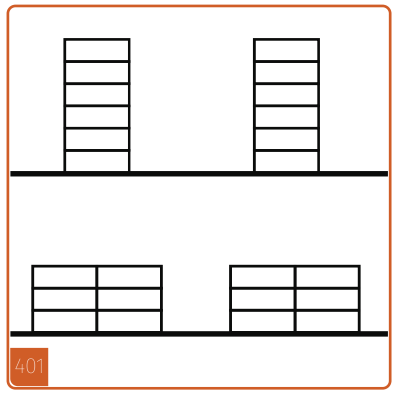
15. **56%** ground and **43%** facades receive direct sun for at least 3 hours.

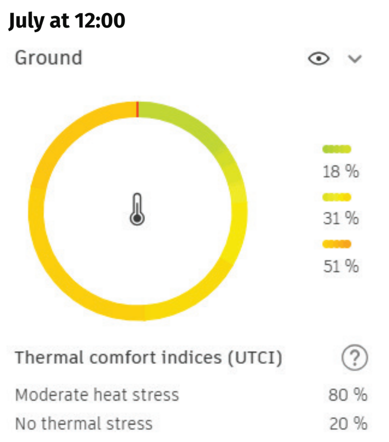
Assessment

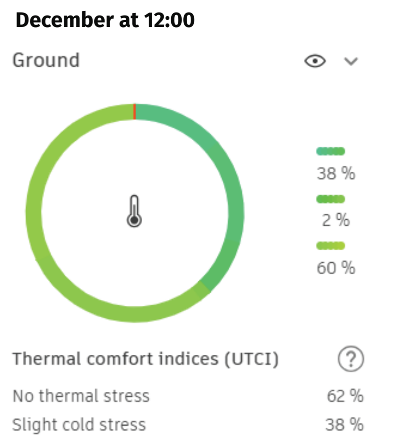
> Microclimate: To evaluate outdoor thermal comfort across seasons, we used Autodesk Forma's Microclimate Analysis tool, which simulates key environmental factors such as **air temperature, surface temperature, wind conditions, and solar radiation** based on real-world geolocation and **climatic data**. The same eight urban scenarios were analyzed to maintain consistency. For the summer assessment, we selected a typical day in **June** and focused on midday, when solar exposure and ambient temperatures peak. In this phase, areas with temperatures up to 30°C were considered within the thermal comfort range. In parallel, a winter analysis was conducted using a typical day in **December**, also at midday, to capture the highest daily temperatures in cold conditions. For this season, temperatures above 15°C were considered thermally comfortable.

These simulations assess how spatial configuration and building placement affect thermal performance in open spaces throughout the year. The analysis identifies temperature variations across each site and calculates the percentage of public or open areas that fall within the defined **comfort zones** for both summer and winter. Factors such as shading, solar access, wind exposure, and building enclosure were considered. The results were recorded for each scenario and provide valuable insights into heat mitigation, seasonal resilience, and year-round outdoor usability. Finally, the scenarios were evaluated and compared based on the percentage of open space falling within these thermal comfort zones, allowing a more comprehensive understanding of their microclimatic performance.

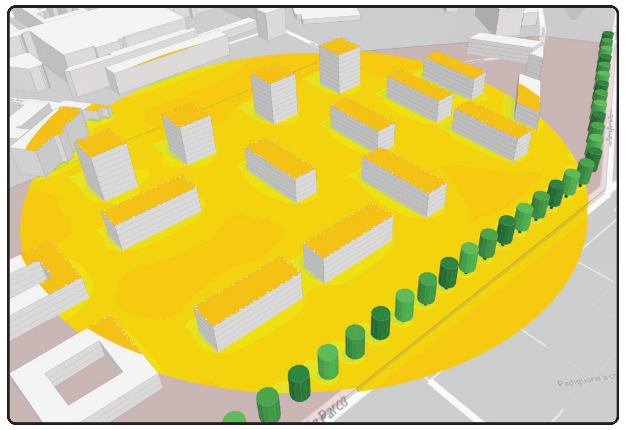


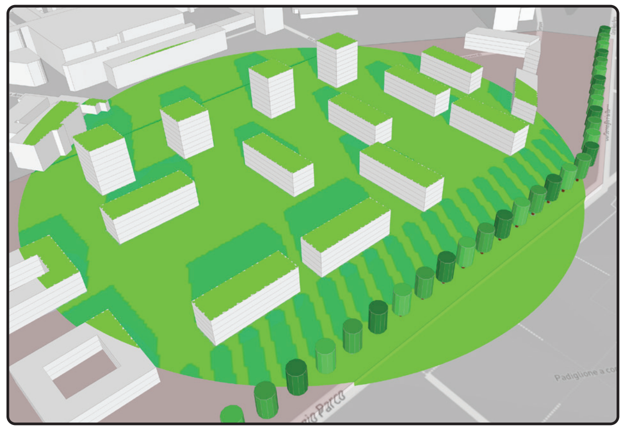


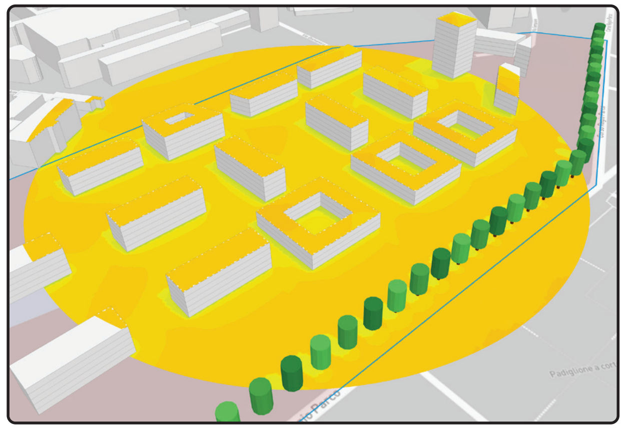




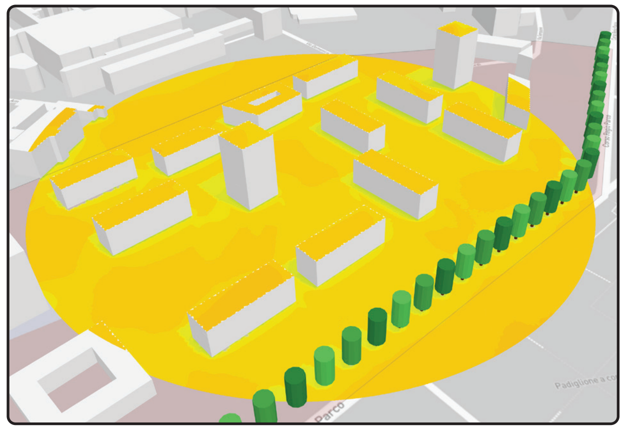
Summer | **Winter**

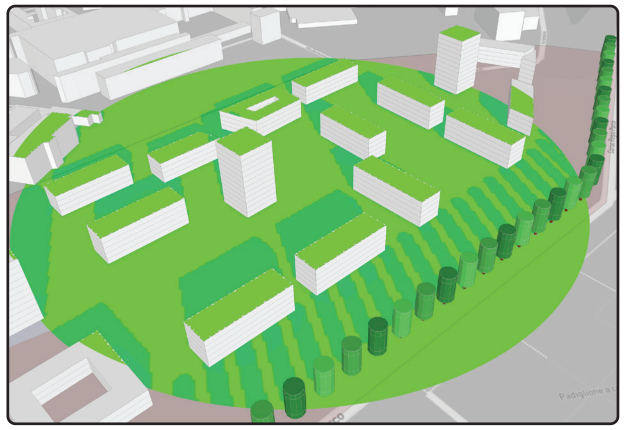

6. Summer Thermal comfort: 57%

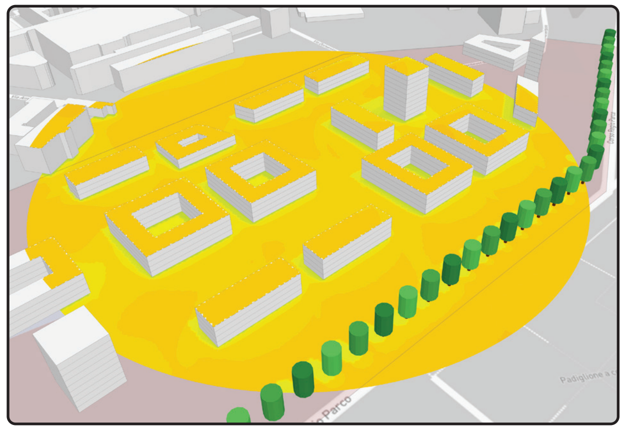

Winter Thermal comfort: 56%

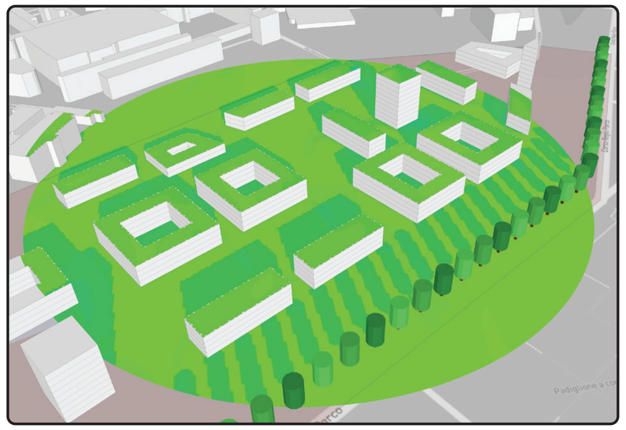

10. Summer Thermal comfort: 63%


Winter Thermal comfort: 49%


14. Summer Thermal comfort: 68%


Winter Thermal comfort: 50%


15. Summer Thermal comfort: 65%


Winter Thermal comfort: 48%

Evaluation

> Comparison methodology: To objectively compare and select the most suitable block layout scenario, we apply a **multi-criteria** assessment method based on five key metrics that reflect both functional and environmental performance. These metrics include function alignment, sun access on ground and facades, and microclimate comfort based on thermal performance during summer and winter conditions. Each metric is assigned a specific **weight** according to its relative importance in achieving high-quality urban form: function alignment (0.3), sun access on ground (0.2), sun access on facades (0.2), summer comfort (0.15), and winter comfort (0.15).

The evaluation process begins by collecting quantitative or ranked data for each metric across all four shortlisted block scenarios. Where data are expressed in percentages (e.g., sun access), values are **normalized** to ensure comparability. For ranked data (e.g., function alignment), scores are assigned based on performance order. Each metric score is then multiplied by its respective weight to obtain the weighted score. By summing the weighted scores across all metrics, we produce a **final score** for each scenario. This allows us to make an evidence-based comparison and identify the scenario that best aligns with the planning goals and site-specific conditions.

> Function alignment: This factor is qualitative and assessed through visual analysis by the designer. Each scenario was evaluated based on how well the proposed block functions align with their surrounding urban context, the shape and orientation of the blocks, their proximity to **public spaces**, and accessibility to **metro stations**. The goal was to identify which block layout fits best within the existing functional structure of the area and supports coherent urban development. After comparing the scenarios, a rank was assigned to each, with the best-performing receiving the highest rank. These ranks were then converted into scores and weighted using the function alignment weight of **0.20**. The final score for each scenario was calculated on a scale from 0 to 10.

Normalized Score = (Max Rank−Rank)/(Max Rank−1)
Weighted Score = Normalized Score × 0.30 × 10

Scenario	Rank	Normalized Score (0-1)	Weighted Score (0-10)
2	1	1	2
10	4	0	0
14	2	0.67	1.33
15	3	00.33	0.67

Table 6. *Function alignment scores. Source: Author.*

> Sunlight access:

Sun access is an important factor in evaluating urban blocks, affecting outdoor usability and indoor comfort. We assessed two parameters: the percentage of ground and building facades receiving **at least 3 hours of sunlight daily**. Higher percentages mean better sun exposure, which improves thermal comfort and daylight. Using solar radiation simulations, we normalized these values and calculated weighted scores, each with a weight of **0.20**. Final scores range from 0 to 10, showing each scenario's solar access performance. ***Normalized Score = (Xmax - X) / (Xmax - Xmin) & Weighted Score = Normalized Score × Weight***

Scenario	Ground (%)	Façade (%)	Norm. Ground	Norm. Façade	Weighted Ground (0-10)	Weighted Façade (0-10)
6	63	47	1.00	0.80	2	1.60
10	60	48	0.71	1.00	1.42	2
14	55	47	0.14	0.80	0.28	1.60
15	56	43	0.28	0.00	0.56	0

Table 7. *Sunlight access scores. Source: Author.*

> Microclimate:

This metric evaluates outdoor **thermal comfort** by analyzing microclimate simulations for both summer and winter conditions. In summer, we measure the percentage of area with temperatures under 30°C, and in winter, the percentage of area with temperatures above 15°C during the day. These thresholds indicate comfortable conditions for outdoor use. Higher percentages reflect better performance. The values are normalized and weighted individually (each with a weight of **0.2**) and then scaled to 0–10 for final scoring and comparison. ***Normalized Score = (Xmax - X) / (Xmax - Xmin) & Weighted Score = Normalized Score × Weight***

Scenario	Summer (%)	Winter (%)	Norm. Summer	Norm. Winter	Weighted Summer (0-10)	Weighted Winter (0-10)
6	57	56	0.00	1.00	0.00	2
10	63	49	0.55	0.13	1.11	0.27
14	68	50	1.00	0.25	2.0	0.51
15	65	48	0.73	0.00	1.47	0

Table 8. *Microclimate and thermal comfort scores. Source: Author.*

Selection

> Optimum Scenario: To select the most suitable block scenario, we analyzed, normalized, and weighted five key parameters; function alignment, sun access to ground and facade, and microclimate comfort in summer and winter. This approach allowed us to fairly compare the four shortlisted block layouts across environmental and functional criteria. This environmental data is derived from Autodesk Forma, a tool that evaluates each scenario under consistent conditions, providing reliable quantitative insights. Alongside these quantitative results, qualitative assessment of the function distribution and block layout is essential; this is performed by designers who apply their understanding of urban principles and codes. Together, these complementary analyses ensure that the selected block configuration not only meets measurable environmental criteria but also aligns with the intended urban design vision and functionality.

Scenario 6 achieved the highest final score, demonstrating a **well-balanced performance** in terms of both usability and environmental quality. Given these results, Scenario 6 is identified as the optimum block configuration and should be prioritized for further development within the masterplan.

Scenario	Function	Sun Ground	Sun Facade	Summer Microclimate	Winter Microclimate	Final Score (0-10)
6	2.0	2.0	1.6	0	2.0	7.6
10	0	1.42	2.0	1.11	0.27	4.8
14	1.33	0.28	1.6	2.0	0.51	5.72
15	0.67	0.56	0	1.47	0	2.7

Table 9. *Final weighted scores accordign to 5 parameters. Source: Author.*

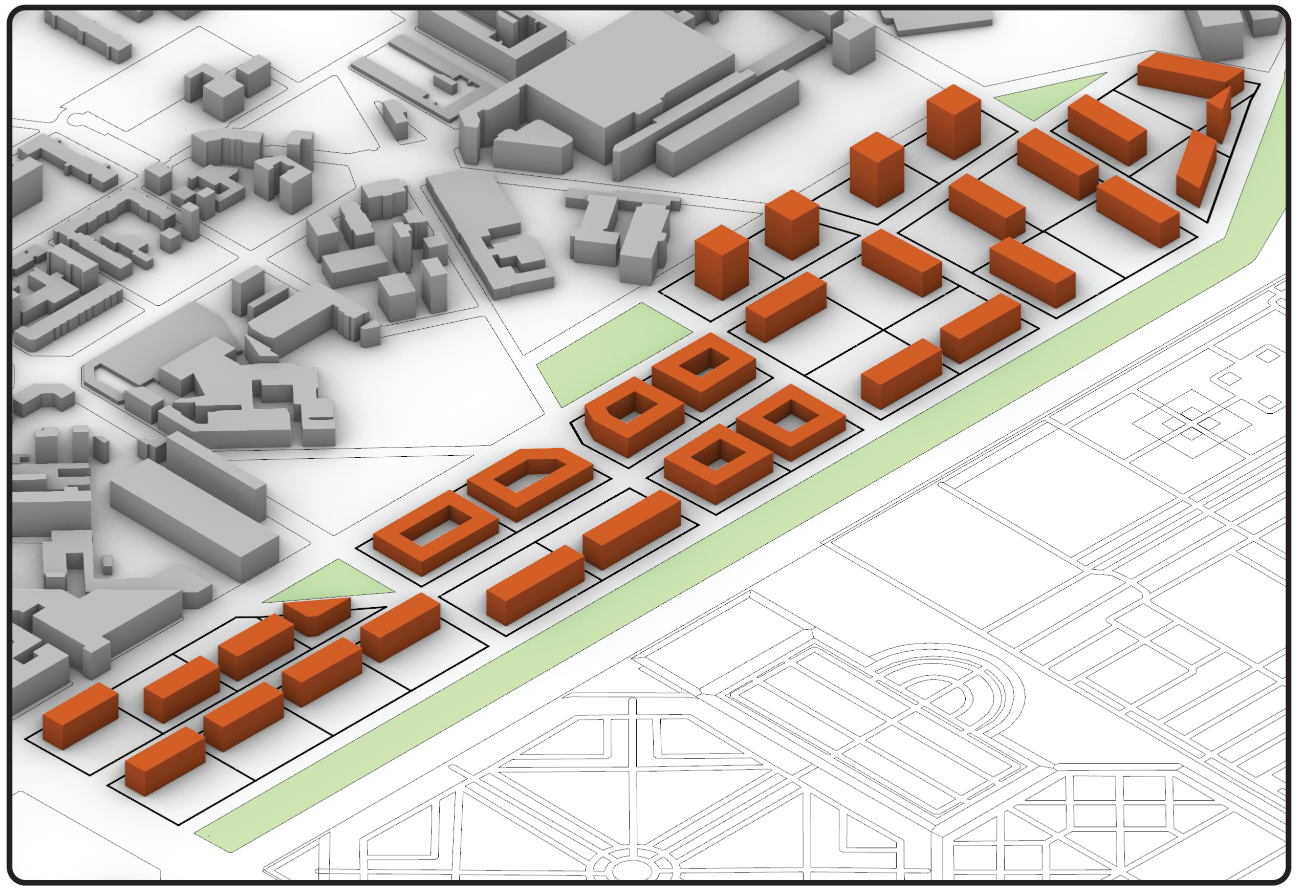


Fig 68. *Selected Block Axonometry (scenario 6) . Source: Author.*

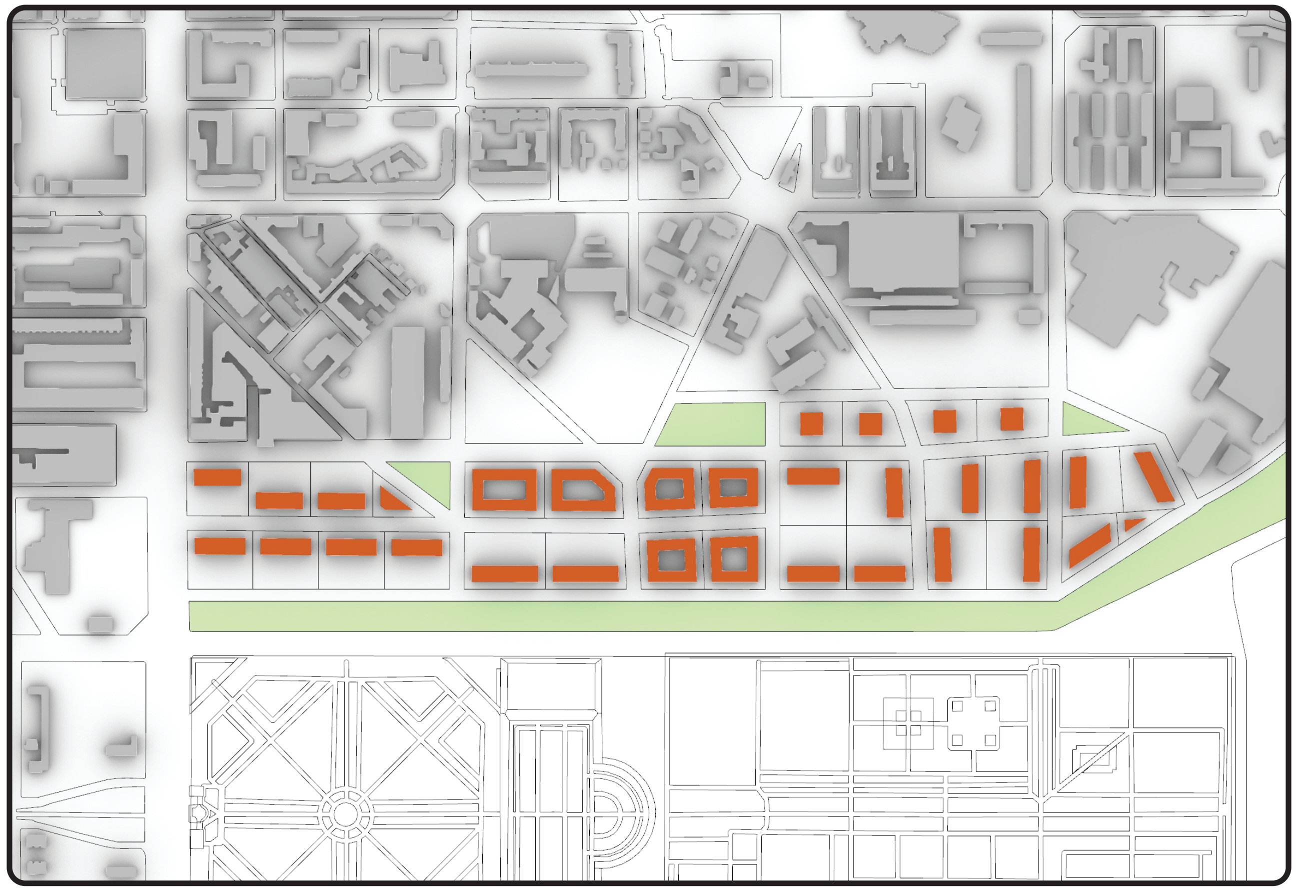


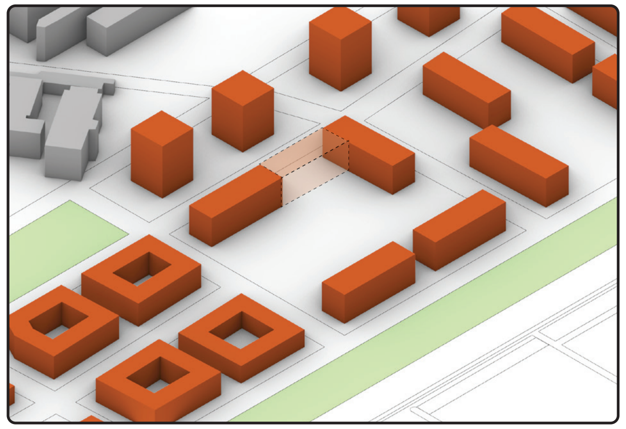
Fig 69. *Selected Block Masterplan (scenario 6) . Source: Author.*

Insights

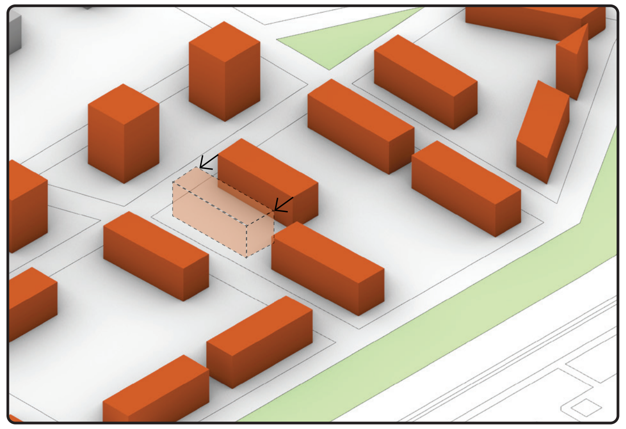
> Geometry Enhancment: The selected scenario represents the most optimal block layout among the generated options, but this does not imply that it is a flawless or definitive solution. As the shortlisted scenarios were assessed, it became evident that each presented certain limitations. The chosen configuration simply performed better relative to the others based on the established criteria.

This suggests that further refinement; such as modifying block geometries or repositioning elements could enhance the overall quality and functionality of the master plan. As discussed in the network generation section, the parametric framework allows for **adjustments** based on **designer preferences**. Similarly, in this stage, it is possible to select a different scenario or alter the weight of certain evaluation parameters depending on the specific design objectives.

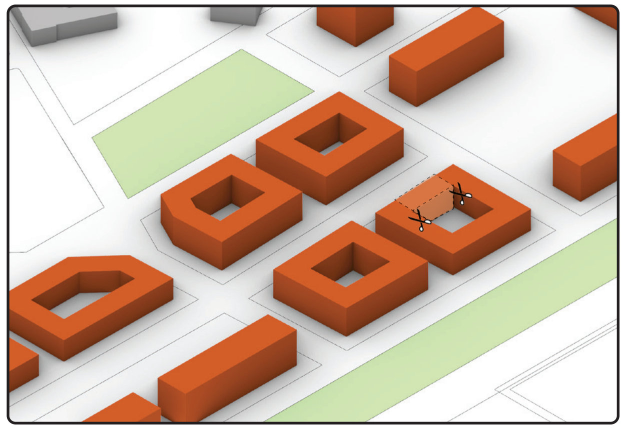
Although such refinements are both logical and, in many cases, necessary, this thesis **intentionally avoids manual** or traditional design interventions. The focus remains on evaluating the capacity of parametric3 and computational processes to guide and shape urban form. The following diagrams illustrate potential enhancements through block modifications within the constraints of the parametric system.



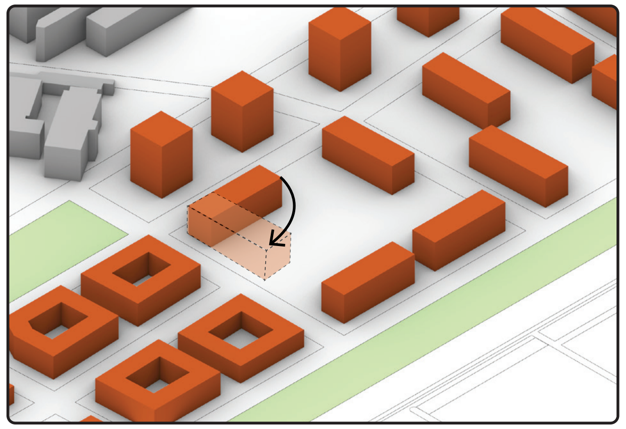
Block Extension/Filling gaps



Moving the existing shape



Cutting/Reducing



Rotating/ Aligning

> Climatic Responsiveness: The assessment of various scenarios serves not only to compare alternatives and identify an optimal solution, but also to address climatic factors and **enhance sustainability** in the design process. For instance, in the solar analysis, data is presented on the percentage of ground surfaces and facades that receive at least three hours of sunlight per day. This information can be further explored to identify strategies for improving the environmental performance of urban blocks or to provide design guidelines for subsequent phases.

As an example, if a building facade receives excessive sunlight throughout the day, especially during summer months, additional shading solutions may be necessary to reduce heat gain and improve comfort. While such remarks are important and should ideally inform **future design stages**, this thesis focuses strictly on the preliminary phases of urban design. Therefore, the outputs of the parametric tools are presented in their original form, without manual interventions, in order to evaluate the independent capability of the computational process.

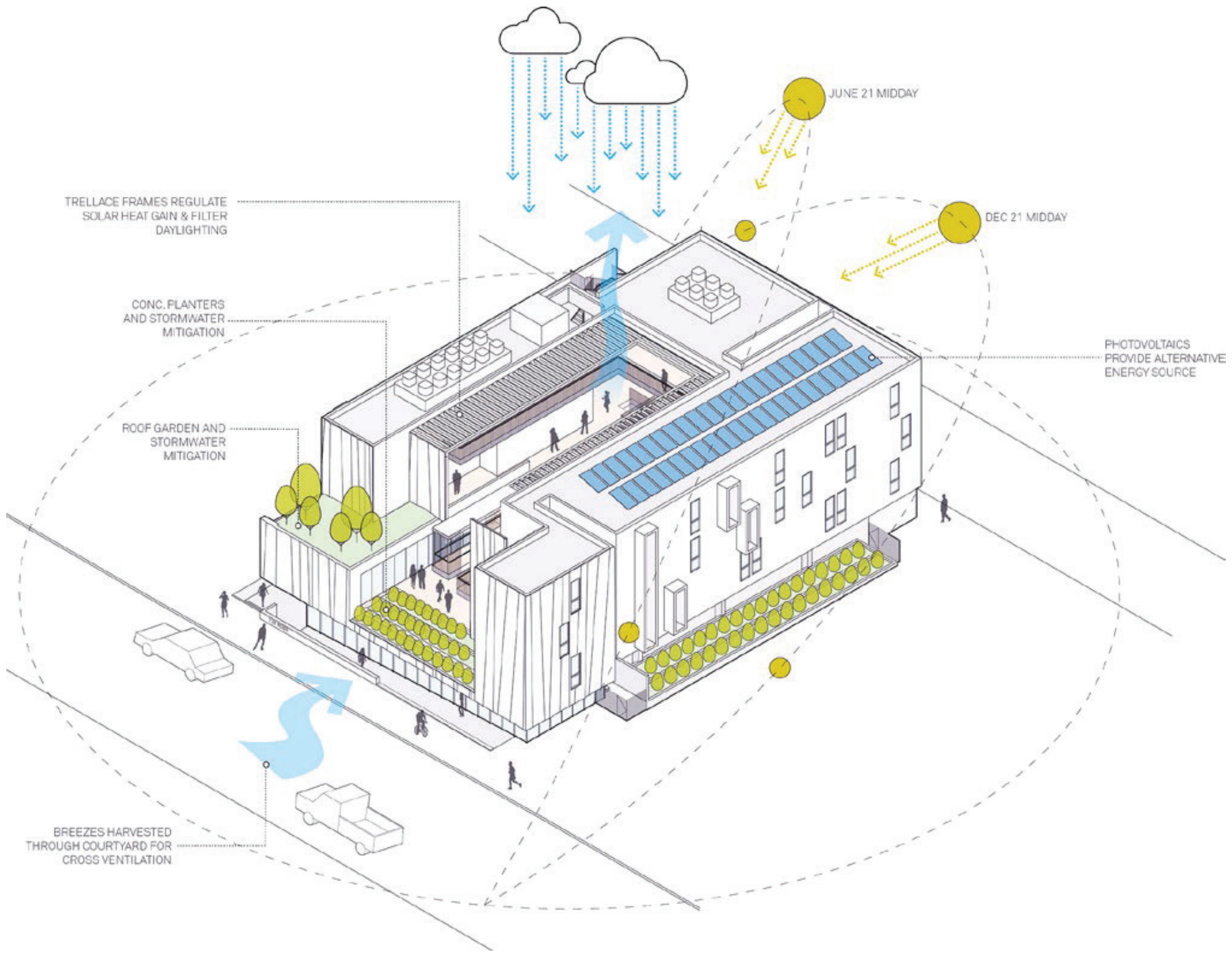


Fig 70. *Possible responses to the climate to improve efficiency and sustainability. Source: Brooks + Scarpa Architects, Inc.*

4.2.3. Unit Configuration

Following the selection of the optimum scenario for the masterplan, a total of **32 building blocks** were defined, representing three different typological forms. These blocks were generated based on spatial and urban design principles; however, their geometries remain conceptual at this stage. As such, it is essential to assess their feasibility for accommodating the intended functions, particularly residential uses. While detailed architectural design is beyond the scope of this thesis, the **configuration of units** and distribution of functions at the block level are critical to ensuring the success and livability of the overall masterplan.

This phase focuses on evaluating whether the generated blocks can support **high-quality, livable residential spaces**. The internal subdivision into units will also help assess whether the block forms are adaptable and whether minor geometric refinements are required to improve usability and spatial logic. Moreover, the unit configuration process serves as a test of how well the proposed block geometries align with the urban morphology and typological logic of the surrounding city context.

To achieve more precise control over key variables such as unit layout, typology distribution, circulation, and floor efficiency, a **zoomed-in** area of the masterplan was selected for detailed study. This selected portion includes two key residential block types—closed courtyard blocks and row blocks—which are typologically more flexible and context-responsive compared to, for instance, high-rise commercial towers. The latter typically follow fixed core and floor plate designs, limiting the potential for variation across scenarios.

The main objective of this localized study is to explore and compare multiple unit configuration scenarios. The analysis focuses on identifying the configurations that:

- Maximize the use of **Gross Floor Area** (GFA) by reducing circulation spaces such as corridors and vertical cores;
- Provide the **highest number** of high-quality, well-proportioned living units;
- Ensure a **balanced distribution** of unit sizes (e.g., studios, one-bedroom, two-bedroom);
- Support the integration of **functional diversity** where applicable.

Insights gained from this focused study inform the applicability of unit layouts across the larger site and provide evidence for the adaptability and performance of the generated urban forms.

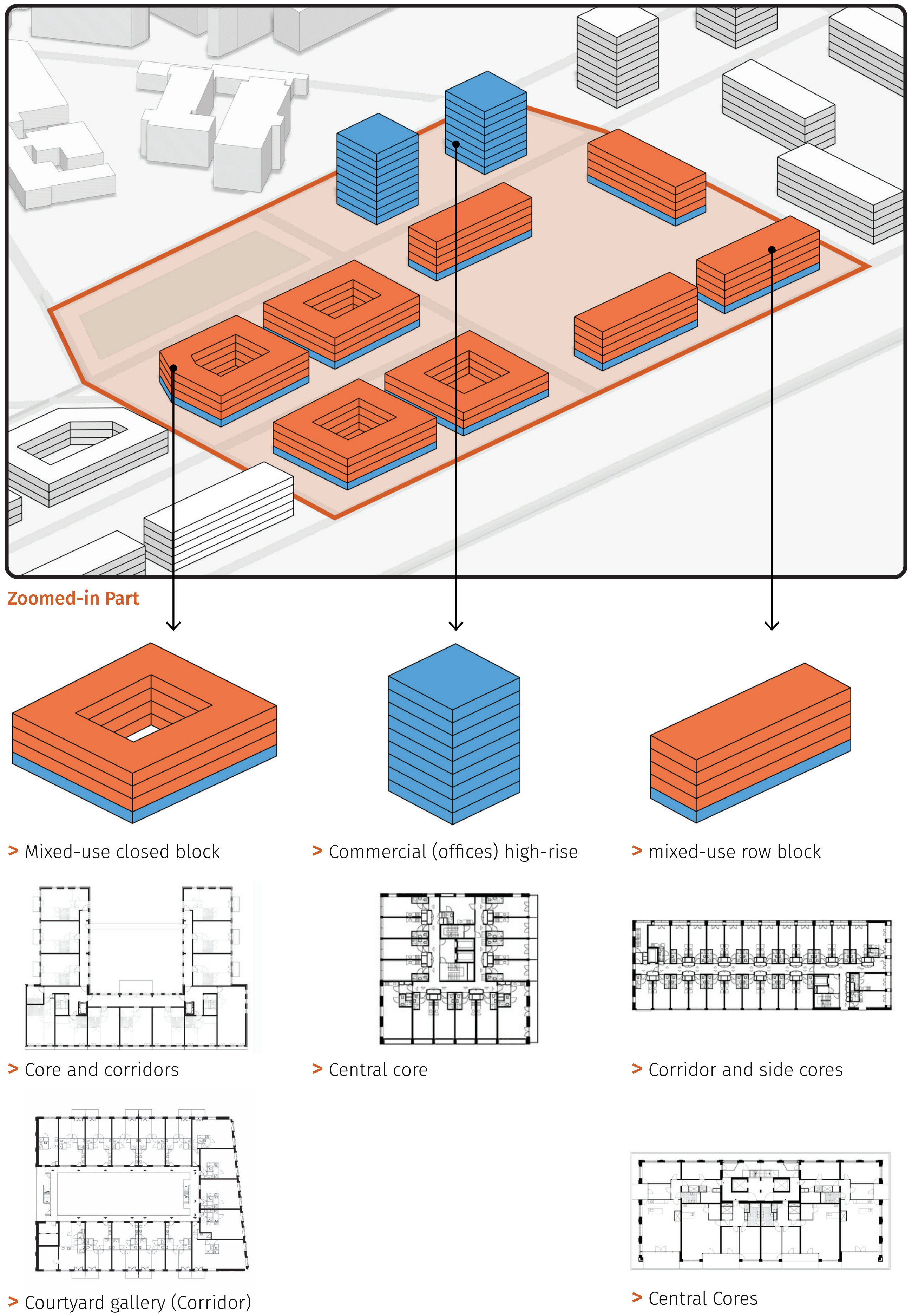


Fig 71. *Case studies of possible floor plan's units and circulation. Source: Kenk Architecten (Internship office)*

Parametric Tool Application

To carry out the unit configuration process, the generated building blocks were imported into **Autodesk Forma**, a powerful tool for early-stage urban and architectural design. Forma was selected for its ability to handle volumetric models while enabling interactive testing of unit layouts, circulation strategies, and functional distributions. Moreover, since the 3D model had already been imported into Forma for climatic analysis in previous steps, continuing the design development within the same environment allowed for an efficient and integrated workflow.

At this stage, Forma enables a range of editable parameters that are crucial for unit planning such as Assigning **specific functions** to each floor (e.g., residential, commercial, or service) and Modifying **building metrics**, such as floor-to-floor height or number of levels, across multiple blocks simultaneously. In addition, Creating **custom floorplans** that can be easily duplicated and assigned across buildings with similar geometry.

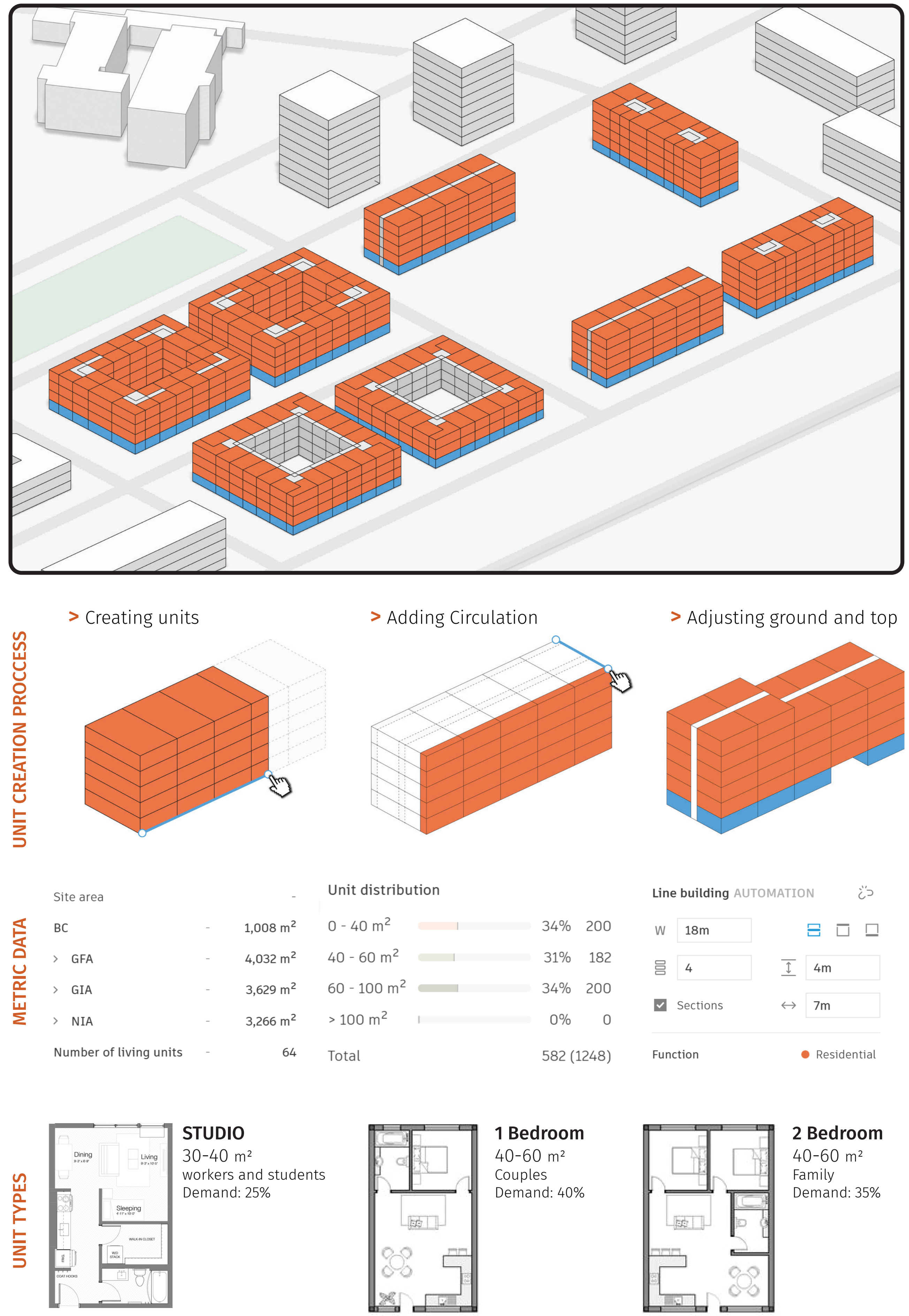
One of Forma's key advantages lies in its ability to generate and replicate floor layouts efficiently. Users can define a layout with various unit sizes and arrangements—including vertical cores, horizontal corridors, or atrium configurations—and apply it across multiple floors or buildings. This allows for rapid testing of different organizational models.

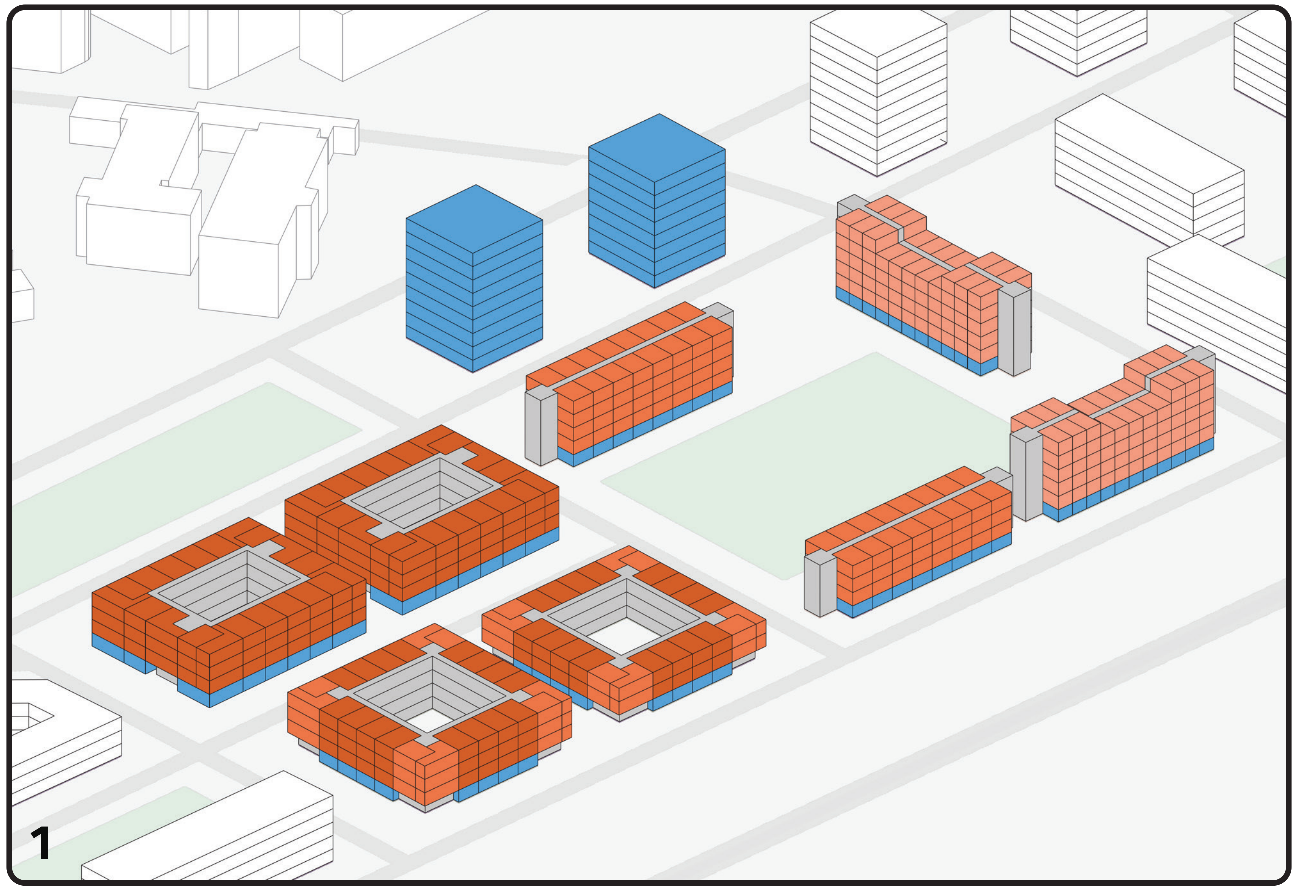
Once the circulation and unit divisions are assigned, Forma automatically generates a wide range of quantitative data, including:

- **Number of units** per typology;
- Total **Gross Floor Area** (GFA) and Net Living Area;
- Proportion of different **unit sizes**;

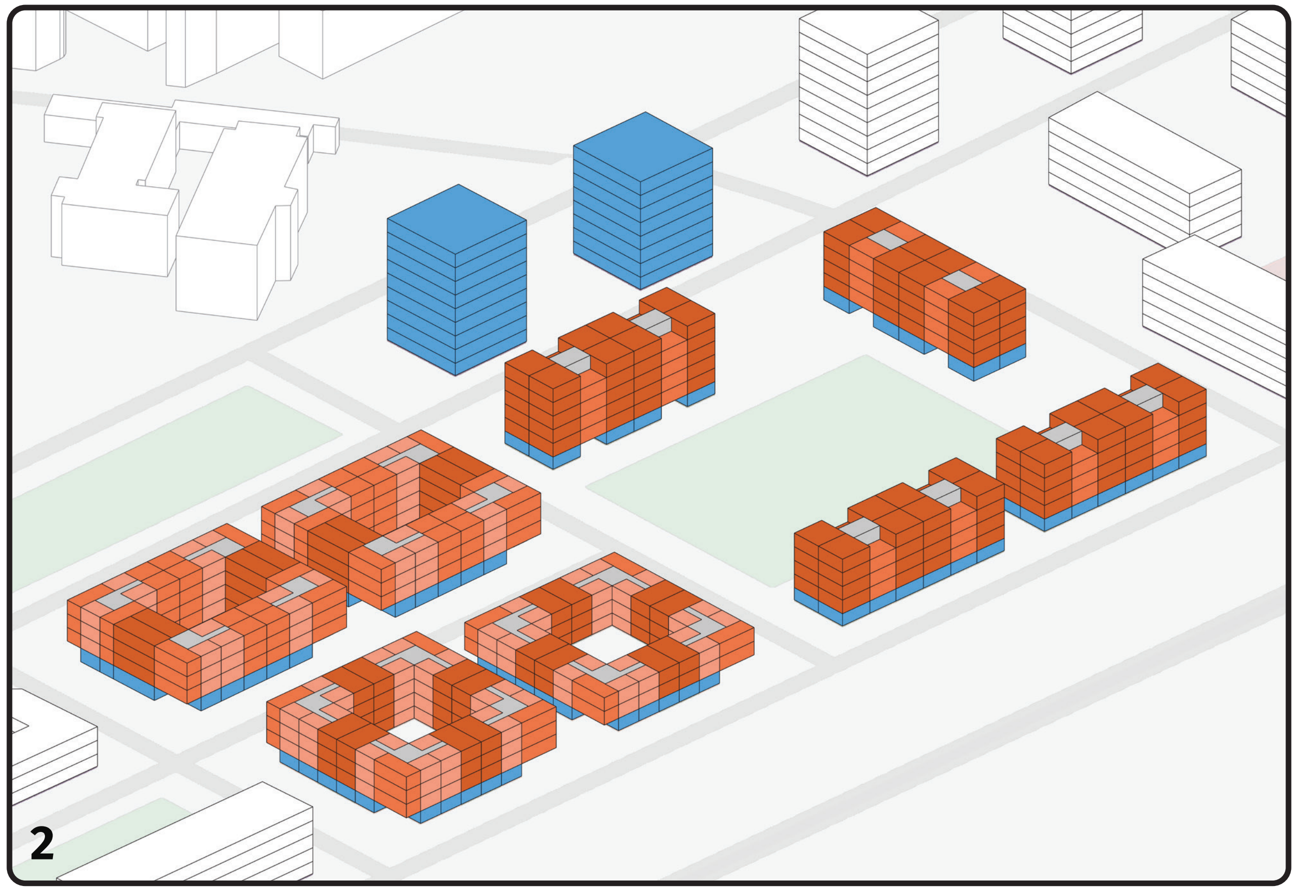
This data is essential for comparing different layout options and identifying the most balanced solution, particularly the one that achieves a higher GFA utilization with minimum circulation space and an optimal mix of unit sizes. For this analysis, three unit types were defined: **Studio** (30–40 m²), **One-bedroom** (40–60 m²), **Two-bedroom** (60–100 m²).

The unit configuration process was carried out within the zoomed-in portion of the masterplan, **focusing on mixed-use blocks** with predominantly residential functions. This localized analysis allowed greater control over layout strategies, circulation, and typological variation. These blocks offered the flexibility to test different unit arrangements based on their geometry and functional potential. As commercial and office spaces typically follow fixed floorplates with limited variability, the study concentrated on **residential units**, where layout choices significantly influence livability, spatial efficiency, and design quality. The results from this phase serve as the basis for comparing residential layout scenarios in the next step.

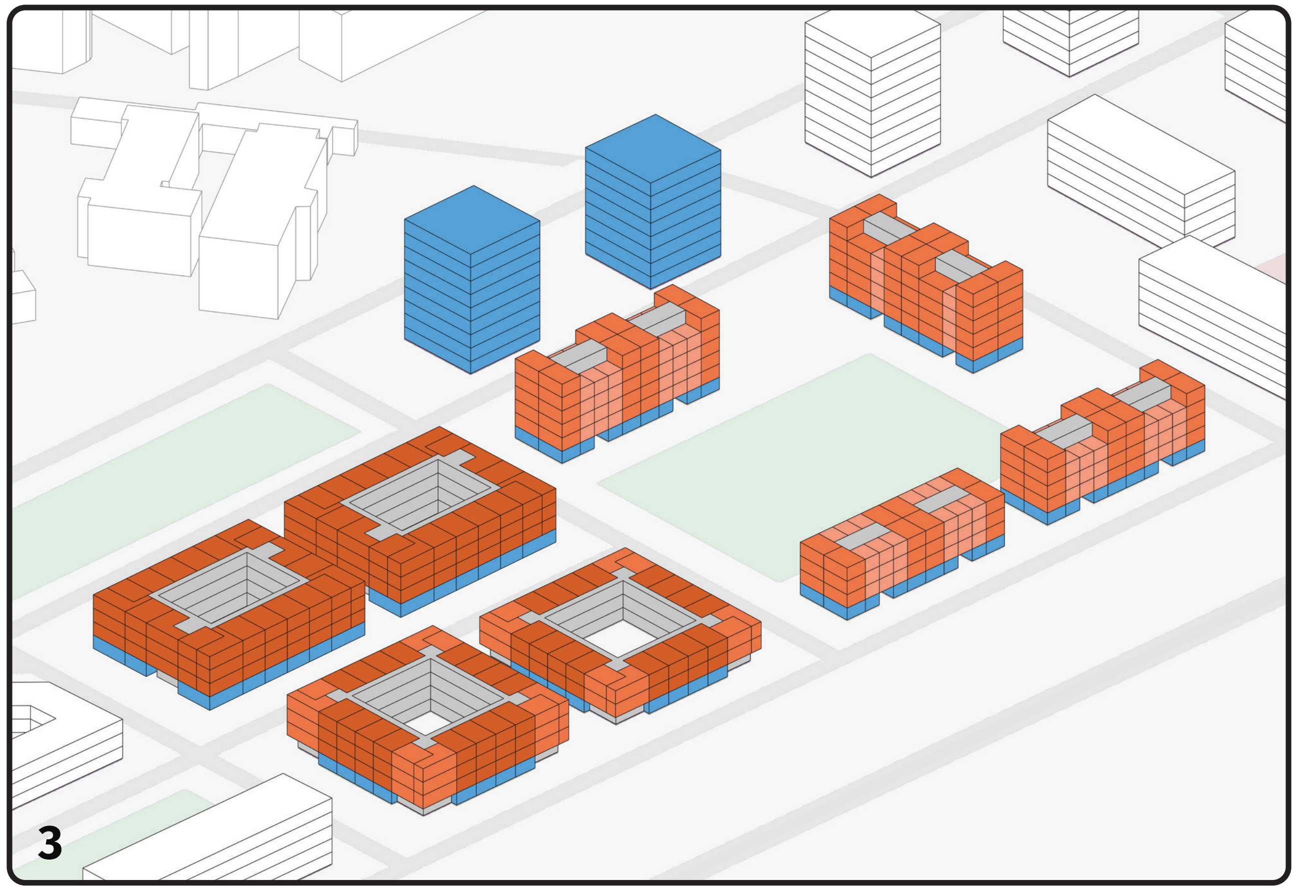




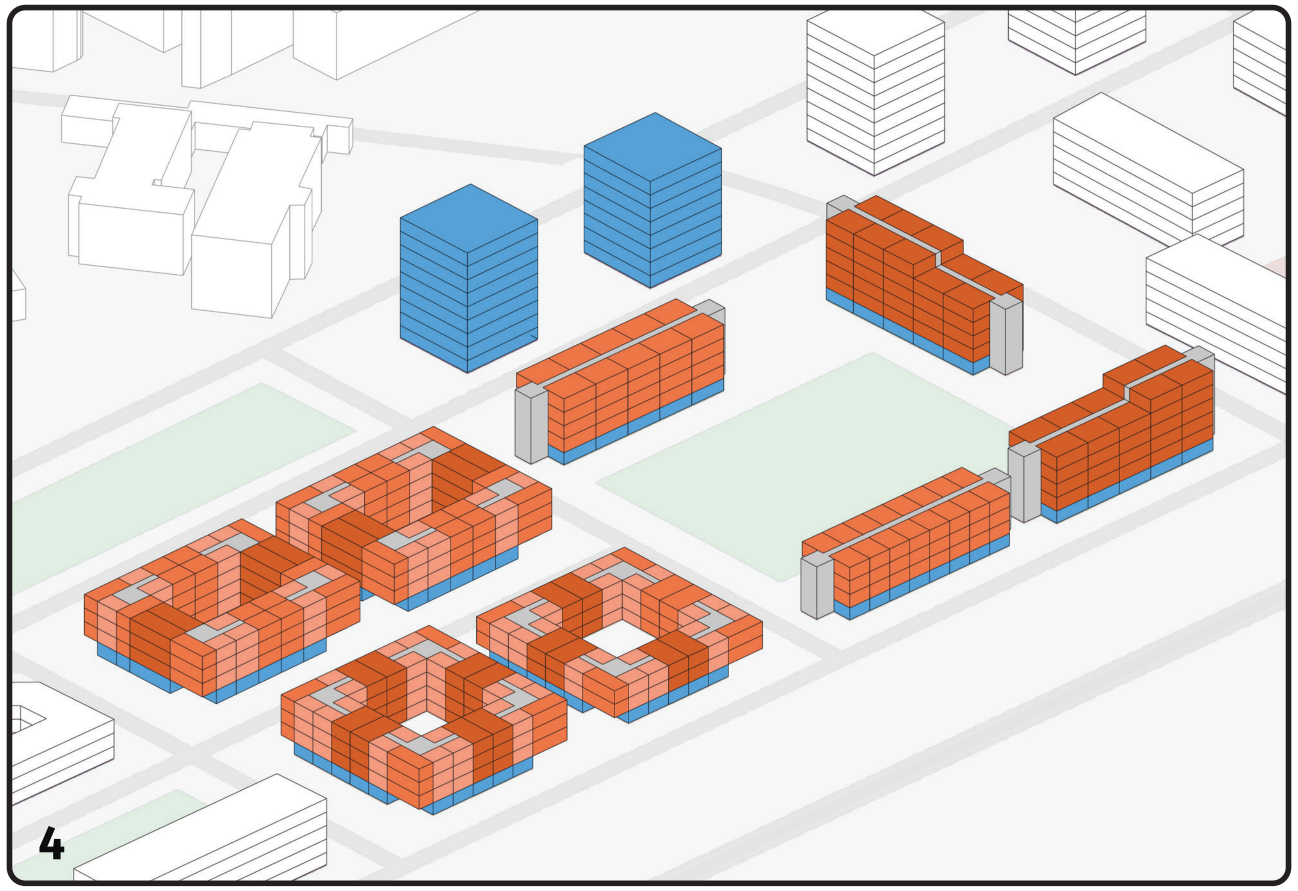
Studio (34%) 1-Bedroom (32%) 2-Bedroom (34%) Commercial Circulation Total GFA: 36318 m²



Studio (25%) 1-Bedroom (35%) 2-Bedroom (38%) Commercial Circulation Total GFA: 39646 m²



Studio (27%) 1-Bedroom (38%) 2-Bedroom (34%) Commercial Circulation Total GFA: 37345 m²



Studio (28%) 1-Bedroom (35%) 2-Bedroom (37%) Commercial Circulation Total GFA: 38247 m²

Final Form

To select the optimal unit configuration, both a **higher Gross Floor Area** (GFA) and a **balanced proportion** of different unit sizes were considered. Among the four scenarios, **Scenario 2** is the most desirable, while the others are acceptable and function well. In this scenario, circulation cores are placed at the center of the blocks, and the resulting geometries are visually coherent and efficient.

To obtain the final **metric data** and apply the unit configuration to the remainder of the site, the same process was repeated, as illustrated in the following image. In this approach, the scenario and the existing block shapes and sizes were maintained, while the forms were adjusted to create a more appealing urban environment.

Metric Data

Site area		267,398 m^2
BC	13 %	**35,031 m^2**
GFA	62 %	**166,584 m^2**
Residential		100,488 m^2
Commercial		66,096 m^2
Unspecified		0 m^2

Unit distribution 1

0 - 40 m^2	30%	584
40 - 61 m^2	38%	757
61 - 100 m^2	32%	629

1 x 584
2 x 757
3 x 629

Total Unit Numbers: 1970
Total Residents: 3985

Fig 72. *Axonometry of the site area with units distribution. Source: Author*

4.3. VISUALIZATION WITH AI

In the previous section, the urban planning of Ex Scalo Vanchiglia was developed through three main stages: network generation, block generation, and unit configuration. At each step, the range of scenarios generated by parametric tools was gradually narrowed down through analysis and evaluation, aiming to identify the most optimal solution. These evaluations were based on urban principles, regulations, and quantitative metrics. However, beyond analytical assessments, it is essential to verify whether the proposed design aligns with **real-world** expectations and functions as intended in a tangible urban context.

To achieve this, a higher level of **visual detail** and documentation is required in order to better interpret and communicate the spatial quality of the design. While the scope of this thesis is focused on the foundational aspects of urban planning rather than detailed architectural or landscape design, AI generative tools provide a powerful means to bridge this gap. These tools allow for the rapid creation of realistic visualizations and enriched design documents based on existing parametric models.

In this section, **3D models** and associated data are exported from parametric platforms such as Grasshopper and Autodesk Forma. These are then processed using AI-based tools to generate more realistic and contextually rich images. It is important to emphasize that the use of AI tools requires careful and intentional prompting to ensure that outputs remain consistent with the core design criteria and desired visual perspectives established during the planning process.

AI Generative Tools

AI generative tools have emerged as valuable assets in the fields of architecture and urbanism, offering new possibilities for visualization, design ideation, and communication. These tools typically rely on machine learning models, especially **generative adversarial networks** (GANs) and diffusion models, to create images from either textual **prompts** or **base visual** inputs. By interpreting descriptive language or reference images, they generate coherent visuals that can depict everything from architectural details to large-scale urban forms.

AI tools can generally be categorized into **text-to-image** and **image-to-image** platforms. Some are designed for conceptual exploration with an artistic focus, while others provide better control over spatial composition, scale, and materiality, making them more relevant to architecture and urban design. Their **effectiveness** varies based on factors such as prompt precision, architectural awareness, level of realism, and ability to convey context For architects and urban designers, these tools are not intended to replace technical design or regulatory processes but rather to enhance early-stage ideation, presentation quality, and spatial storytelling. They are particularly useful in generating quick **visual alternatives**, envisioning atmospheres, or testing urban patterns and building typologies.

Overview of Selected Tools

MNML
Focused on architectural and urban form generation, MNML emphasizes minimal, clean compositions. It is especially useful in early design stages to explore building massing, urban blocks, and spatial qualities with a restrained, conceptual style.

PromeAI
PromeAI supports both sketch enhancement and material/style transformation. It is useful for refining building facades, adding realistic textures, and turning abstract urban diagrams into polished visuals—bridging the gap between schematic design and visualization.

LookX
LookX provides flexible tools for both architecture and urban imagery, with strength in generating creative perspectives and styled views. It is well-suited for producing mood boards, conceptual sections, and stylized neighborhood or streetscape views.

Urban Masterplan

The masterplan is a key drawing for understanding and communicating an urban design proposal. In this study, the initial masterplan was exported from Autodesk Forma and tested across various AI generative tools to evaluate which platform produced the most visually compatible and effective result.

In addition to the base image, a well-crafted prompt was essential. Some AI tools also support reference image input, allowing the generated output to follow a specific style or composition. This enables designers to explore diverse visual interpretations of the same plan. On the following page, the original masterplan is presented for comparison.

Prompt

The base image shows the urban masterplan, with the specified site area marked by a red boundary. The designed buildings are in white, and the existing buildings are in dark gray. Focus on the site boundary to design the landscape with greenery and public spaces. Add more detail to the streets and the rooftops.

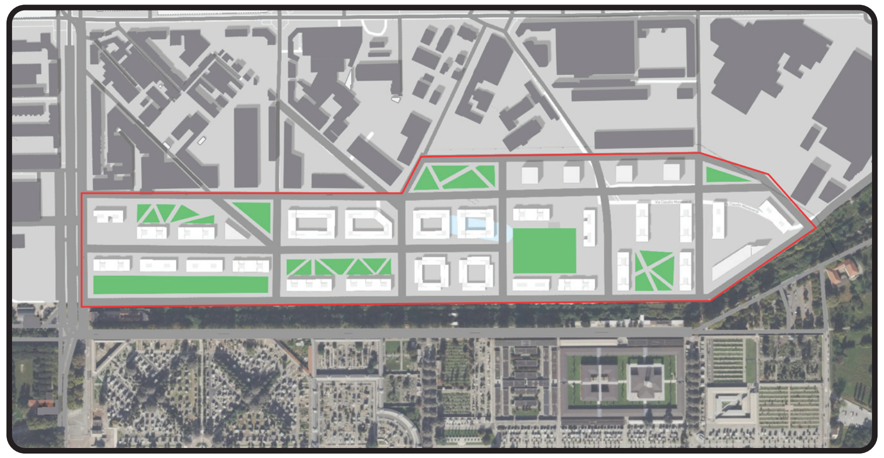


Fig 73. *Orignial urban masterplan exported from Autodeks Froma. Source: Author*

Fig 74. *AI generated urban masterplan. Source: mnml.ai*

View 1

To generate detailed and realistic visualizations, we use the platform Lookx.ai, which creates high-quality architectural renders. This tool requires two input images: the first is a base image exported from Autodesk Forma, showing the 3D model view of the design. The second is a reference image taken from Google Street View, used to define the desired style of the render. This helps align the result with the architectural atmosphere of Turin. Additionally, writing a clear and precise prompt is essential to guide the AI in producing accurate and context-aware visuals.

In the selected view, a combination of different functions is examined: a commercial building on the right, functioning as office space, and residential blocks located along the same street. The ground floor, with a slight setback, is designed to accommodate retail stores, which is a common urban typology in Turin, as reflected in the reference image.

Prompt

Transform the base image into a realistic render. Omit the blue and yellow colors—they indicate function only. Reflect commercial (blue) and residential (yellow) buildings through distinct facade design and materials. Use dark blue rectangles to guide modern window placement. Apply asphalt to dark gray areas and pedestrian surfaces to light gray ones. Follow the reference image for mood, materials, and a clean, modern style.

Key Map

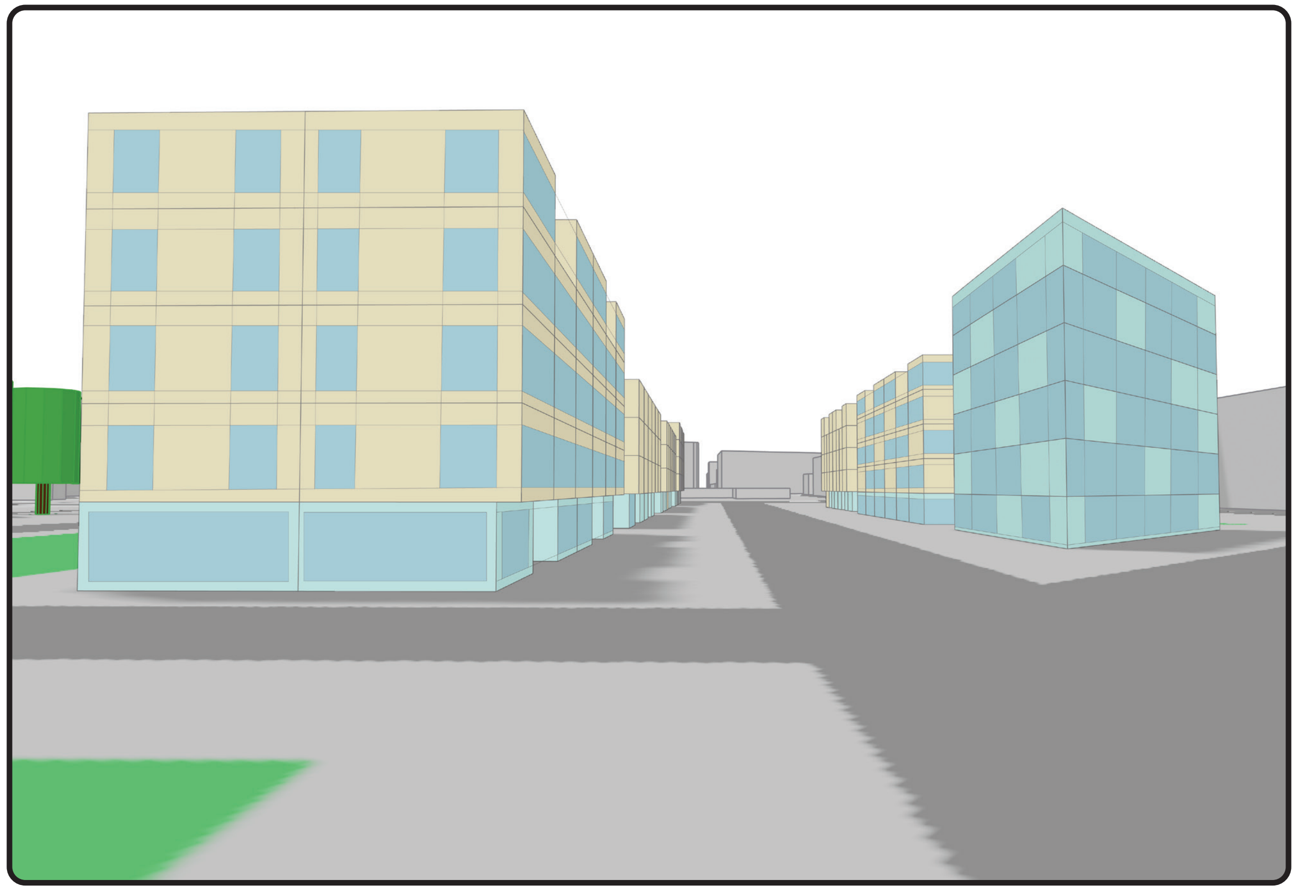


Fig 75. *Base drawing exported from Autodesk Forma. Source: Author*

Fig 76. *City reference located in near piazza Castello, Via Pietro Micca, Turin, Italy. Source: Google Street view*

Fig 77. *AI generated render of the selected view showing the mixed-use area. Source: lookx.ai*

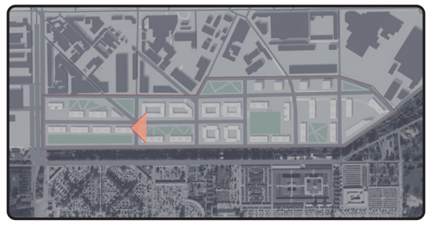
View 2

Since Lookx.ai produces high-quality renders, we continue using this platform to generate visualizations by providing the three essential inputs: the base photo exported from Autodesk Forma, a reference style photo from Google Street View, and a carefully written prompt.

In this specific view, the sunlight access to both the streets and building facades is analyzed. Additionally, the ground floors are occupied by commercial units, while the presence of green spaces contributes to creating a vibrant, safe, and livable environment for the residents of these blocks.

Prompt

Convert the base drawing into a realistic render by showing the ground floor as commercial/store spaces and the upper floors as residential units, using the blue areas as window positions. Add bushes and landscape elements in the green areas. Reflect the difference between darker gray streets and lighter pedestrian zones with appropriate paving. Follow the rhythm and atmosphere of the reference image, while keeping a modern architectural style.



Key Map

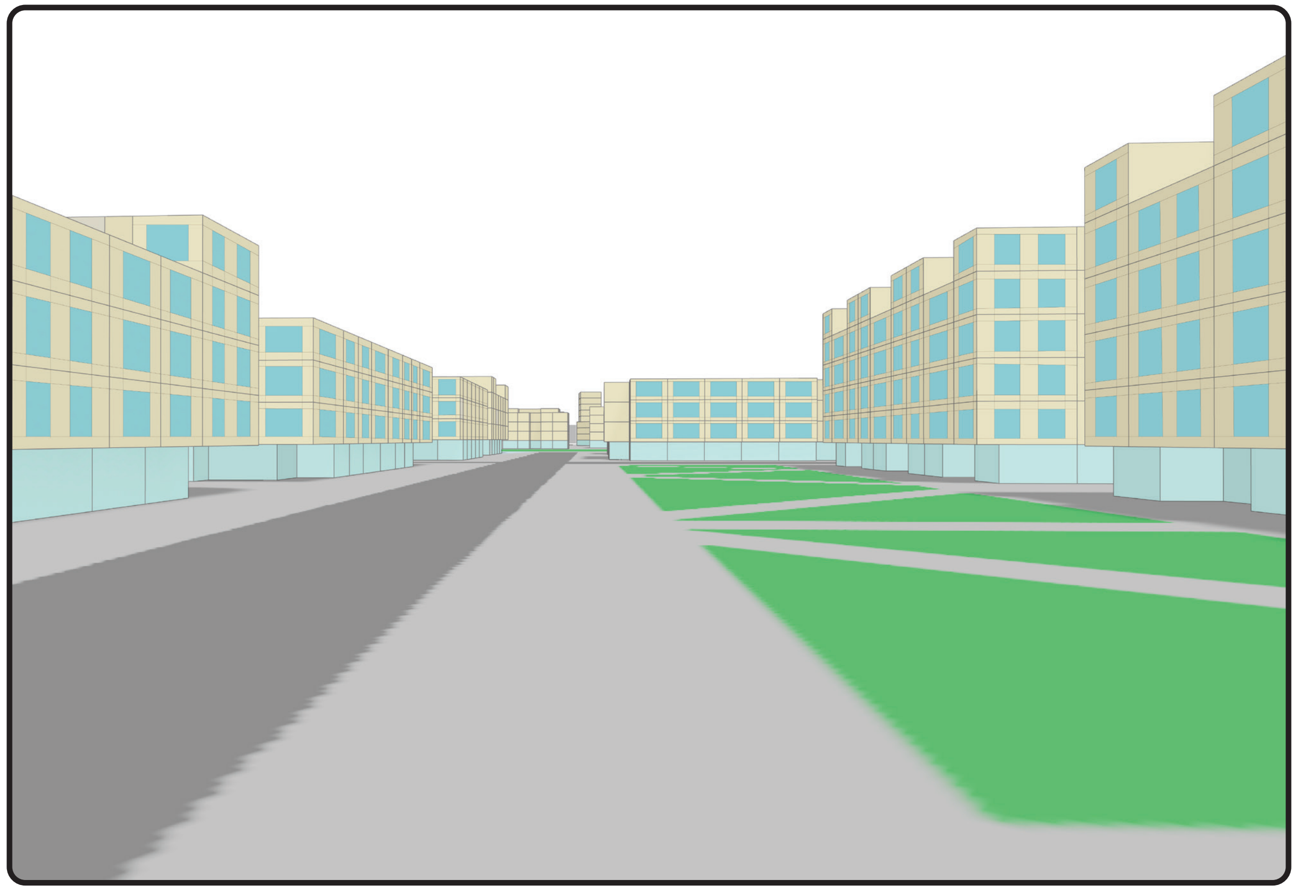


Fig 78. *Base drawing exported from Autodesk Forma. Source: Author*

Fig 79. *City reference located in Piazza Madama Christina, Turin, Italy. Source: Google Street view*

Fig 80. *AI generated render of the selected view showing the liveable and safe spaces. Source: lookx.ai*

View 3

In this view, the focus is on capturing an urban plaza situated at the center of residential blocks, offering a vibrant, safe, and permeable public space. This open area not only serves the residents but also provides a pleasant visual and recreational amenity for the nearby high-rise commercial buildings and their office users.

Such open spaces within urban blocks are a common feature in the city of Turin, especially in the historic center, where they serve multiple purposes including cafés and restaurants, public events, greenery, and social interaction.

Prompt

Transfer the base drawing into a realistic render, focusing on the green area, which functions as an urban plaza. Add benches, people, and greenery to create a lively and welcoming atmosphere. The yellow blocks represent residential buildings with large windows, while the blue building is an office block with a fully glazed facade. Take inspiration from the reference style image to guide the mood and composition, while maintaining a modern architectural style.

Key Map

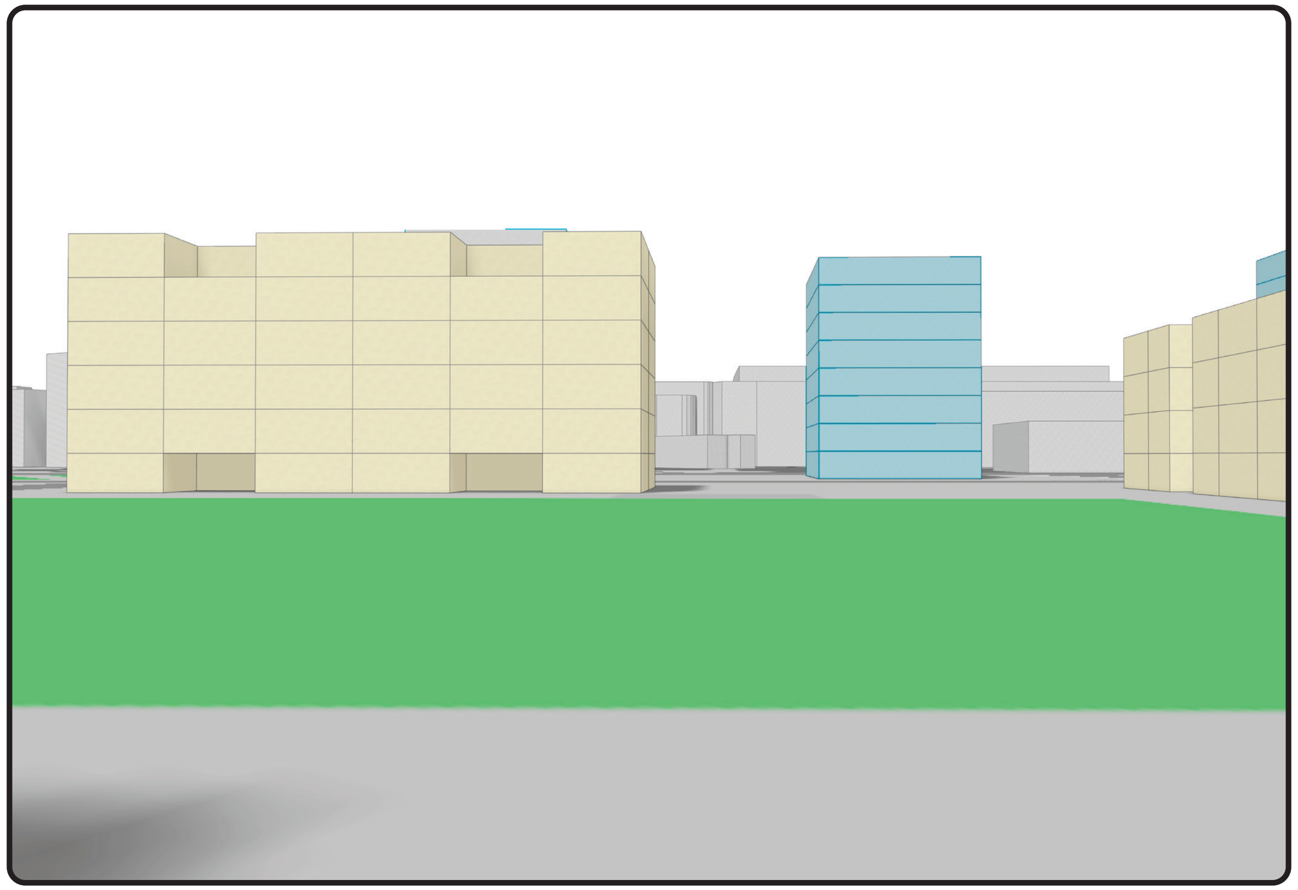


Fig 81. *Base drawing exported from Autodesk Forma. Source: Author*

Fig 82. *City reference located in Piazza Solferino, Turin, Italy. Source: Google Street view*

Fig 83. *AI generated render of the selected view showing the vibrant and lively urban plaza. Source: lookx.ai*

View 4

This perspective shows the vicinity of two urban blocks, which are repeated throughout the site. Each block is located in the middle of its parcel, with a 5-meter setback on all sides, creating a 10-meter distance between buildings. These parcel divisions serve exclusively as pedestrian pathways, not for vehicle access or streets. Therefore, to activate these spaces and make them more lively, introducing some commercial activities is necessary. The building entrances are located at the corners, enhancing accessibility. In Turin, many pedestrian-only streets thrive when integrated with shops, cafés, or restaurants, contributing to a vibrant urban life.

Prompt

Convert the base drawing into a realistic render by representing the ground floor as commercial/ storefront spaces and the upper floors as residential units, using the indicated blue areas to guide the window placement. The gray areas represent paved surfaces with high-quality finishes and integrated landscape elements. The ground floor should appear vibrant and visually active, reflecting commercial use. Use the reference style image as a guide for the window rhythm and architectural style.

Key Map

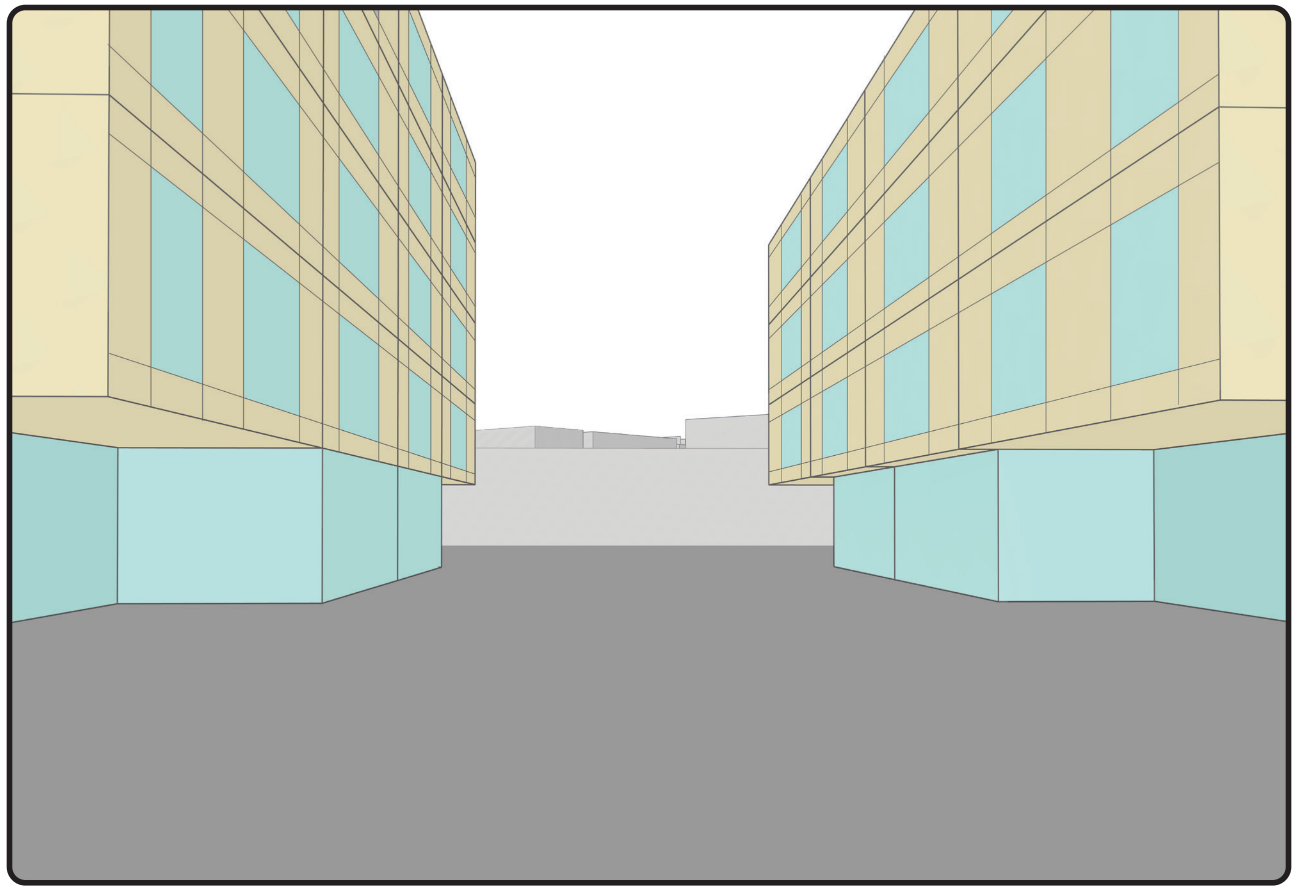


Fig 84. *Base drawing exported from Autodesk Forma. Source: Author*

Fig 85. *City reference located in Piazza Don Franco Delpiano, Turin, Italy. Source: Google Street view.*

Fig 86. *AI generated render of the selected view showing pedestrian-only street between two blocks . Source: lookx.ai*

Insights

> First impression: The use of generative AI tools aims to provide a preliminary visualization of the urban design and master plan, assisting the designer in identifying strengths and weaknesses. Elements such as building volumes, spatial atmosphere, permeability, vibrancy, liveliness, block distances, materials, and more can be evaluated. Additionally, these tools allow designers to present an early-stage design to stakeholders, accompanied by metric data and information generated through parametric tools. This facilitates communication of the initial design intent and its responses to stakeholder or municipal requirements. If these initial requirements lead to potential weaknesses in the proposal, the designer is able to justify necessary changes.

For example, if the municipality requests a total Gross Floor Area (GFA) of 160,000 m² for the site, the preliminary design may fulfill this requirement. However, upon evaluation, it may become evident that the proposed density does not align well with the surrounding urban context. The current building heights and the abundance of open spaces could indicate that additional GFA can be accommodated. In such cases, the designer can argue for an increase in the GFA requirement to achieve a better fit with the site's potential and context

> Adjustments: Another advantage of generating rapid previews using AI tools is the ability to make quick visual edits. Upon first review, a designer may identify the need to adjust elements such as building volumes, typologies, architectural styles, materials, and more. These modifications can be made in two efficient ways. First, if major changes are required, the parameterized model can be updated directly by modifying the input parameters—an approach that is significantly faster than manual adjustments. Second, AI image-generation tools can be used to visually modify the outputs through prompt-based editing, offering designers a fast and intuitive method to explore alternatives.

Once the changes are implemented, both designers and stakeholders can review and compare the revised outcomes to inform further development and decision-making. On the following page, updated renders are presented to demonstrate this process. The new visualizations respond to issues identified in the initial outputs and were edited using AI tools. In this case, ChatGPT combined with DALL·E technology proved particularly effective, allowing specific elements in the render to be altered simply by providing a short prompt. For instance, in the original masterplan, open areas were shown exclusively as green spaces. However, recognizing the potential for more diverse urban functions—such as plazas or mixed-use public spaces—the AI was prompted to regenerate the image accordingly, resulting in a more contextually appropriate and functionally diverse outcome.

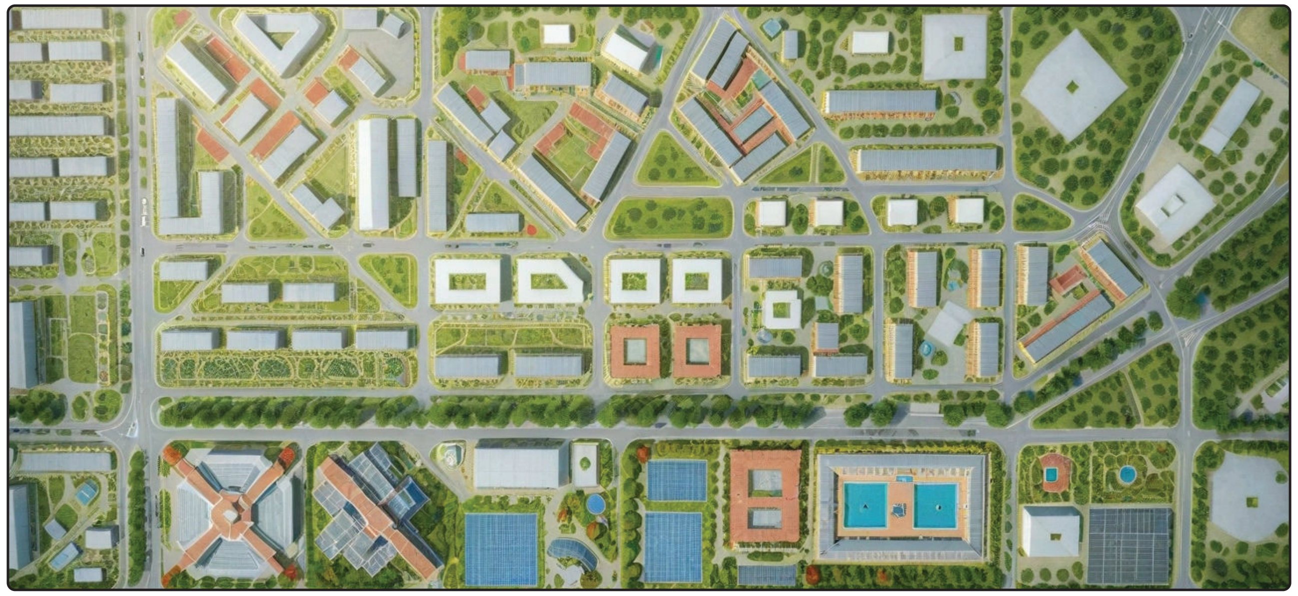


Fig 87. *Adjusted masterplan (fig 74) adding ubran activies and details on the open areas. Source: Myarchitectai.com*

Fig 88. *Adjested view 1 (fig 77) changing the office building envelope with more accuracy. Source: Dall-E 3*

Fig 89. *Adjested view 2 (fig 80) changing the green area to urban public space with restuarants. Source: Dall-E 3*

Fig 90. *Adjested view 3 (fig 83) transforming the green space to a vibrant park with some facillities. Source: Dall-E*

Fig 91. *Adjested view 4 (fig 86) modifying the architecture style to more classic Italian. Source: Myarchitectai.com*

PART 5

CONCLUSION

After conducting an in-depth investigation into the background of the topic, including its history, urban planning principles, and the parametric approach, and applying this knowledge to a real-world case study, this thesis can now address its central question:

To what extent can parametric design, through its tools and techniques, contribute to preliminary urban planning?

5-1. SUMMARY OF KEY FINDINGS

Throughout the design process, the background knowledge proved essential in showing the feasibility and benefits of integrating parametric design in urban planning. The research and design findings confirm that parametric urban design is **adaptive**, **responsive**, **innovative**, and **sustainable**, capable of addressing complex and dynamic urban challenges.

1 Parametricism: Past and Present

While rooted in history such as the geometric forms of the Pantheon, parametric thinking's application to urbanism is recent and evolving. Digital parametric tools allow designers to manage multiple **dynamic** parameters and generate design alternatives throughout various planning stages. They also support **evaluation**, **analysis**, **optimization**, and **decision-making** based on variables, making them especially valuable in early, open-ended design phases.

However, effective use of these tools demands a solid understanding of urban principles, constraints, and regulations. Since these are interdependent and ever-changing, selected parameters must be precise, meaningful, and flexible enough to reflect **evolving urban contexts**.

2 Urbanism: System of Rules

To establish a robust understanding of urban principles, the second part of the thesis examined **rules**, **codes**, and **regulations**. Grand Urban Rules, a key reference, shows that regulations vary across contexts and evolve over time. Thus, a rule-based approach must consider each rule's origin, rationale, and relevance. Only then can these principles form a coherent framework for informed design.

Prioritization is crucial in building a **responsive system**. This thesis showed that even a limited set of key principles can effectively guide early and main design stages. The more principles are integrated, the more refined the design becomes. Density, geometry, and network emerged as the most influential categories, with space syntax proving especially useful in developing the network and spatial layout.

3 Network and space syntax

The **mobility network** forms the design's backbone. Its core principles, road hierarchy and multi-modal transport,must be addressed from the start. **Space syntax**, covered in detail due to its parametric relevance, enhances understanding of spatial connectivity and social interaction.

4 Density and Geometry

The thesis also showed that **density** extends beyond municipal figures, it is shaped by climate and context. In the design phase, factors like light access, microclimate, and permeability were key for comfort and sustainability. Context heavily influences both density and **geometry**: urban fabric, morphology, and typologies shape block and building forms. While function guides early-stage geometry, sustainability becomes more integrated during detailed design phases.

Once principles were identified and framed, they were translated into parameters. Since parameters are inputs for **parametric tools**, the next step involved exploring relevant tools. Of the eight introduced, four were used in the design due to their support for the intended design stages. Other tools may suit different projects or goals.

5 Tools: Generators

Tool analysis showed that while CityEngine is effective for rule-based design, it lacks flexibility. In contrast, **Grasshopper** (within Rhino) offers extensive control over geometry at multiple scales and stages. The **DecodingSpaces** plugin emerged as particularly advanced for early urban design and includes analytical features like graph-based space syntax, comparable to DepthmapX.

Evaluation and decision-making tools are also vital. Plugins like Wallacei and Opossum, part of Grasshopper, support multi-objective optimization and performance-based evaluation—ideal for advanced stages but requiring expertise. AI-based tools like **LookX** aid decision-making through realistic visual feedback. While LookX was used here, many similar tools exist to suit varying user preferences and project needs.

6 Parameterizaion

These tools function as parametric assistants, translating design principles into parameters through formulas and logic. Though the technical modeling process is beyond the thesis scope, the focus is on parametric thinking: **defining**, **structuring**, and **quantifying** urban principles. This includes converting qualitative aspects into measurable inputs for digital tools.

To examine theoretical concepts, a design project was conducted in the **Ex-Scalo Vanchiglia** area of Turin. The goal was not to produce a finalized design but to assess the effectiveness of a preliminary parametric urban planning framework. Although one scenario was presented, multiple alternatives were evaluated based on designer and stakeholder preferences.

7 Desing: An Inquiry

As stated at the beginning of the thesis, parametric tools aim to enhance **adaptability** and **sustainability** in urban planning. The design phase confirmed this is achievable when principles are clearly defined and translated into parameters. The process followed three main stages: site analysis, parameter application to generate scenarios, and evaluation to select the optimal outcome. It was iterative rather than strictly linear, with **evaluations** at each stage, for instance, assessing networks before generating blocks.

8 Data Collection

Site analysis included both **site-specific** and **general urban principles**. A comprehensive understanding of the city, site, design needs, and regulations was essential. While some principles were excluded, data collection was as complete as possible. The data was categorized and coded numerically to serve as input for parametric tools. The four analysis categories, urban context and morphology, function and land use, mobility, and environment and sustainability, form the basis of the parametric model.

9 Categorized Codes

Urban context and morphology examined city-scale typologies influencing urban fabric and structure. Block forms were studied to identify common types and density levels. **Function and land use** focused on municipal requirements, land-use distribution, boundaries, and gross floor area (GFA). Geometric patterns were analyzed for their role in supporting livability and activity. The **mobility** layer studied networks, block sizes, hierarchies, and transport connections to ensure integration with surroundings and alignment with analytical tools. **Environmental** analysis addressed climatic factors like solar access, microclimate, and permeability—crucial for comfort and sustainability. All defined parameters, or “codes,” were used as input data for parametric modeling. These enabled design principles to be translated into structured, data-driven processes.

Tool Deployment

10 Next, the codes were implemented using parametric tools, primarily Grasshopper in Rhino, due to its flexibility and design-stage control. The DecodingSpaces plugin, tailored for early urban planning, was used for **generating and analyzing networks**, plots, and blocks. These tools accepted both numerical and geometric inputs based on the earlier codes.

Network: Initial layer

The process began with importing the site and surroundings. Site **boundaries**, nearby streets, and data like street lengths were key inputs. The **network** component generated scenarios, which could be varied using a seed slider. Selected scenarios from the iterations were further analyzed. **Block sizes** were evaluated using area data, enabling comparison of configurations. **Betweenness centrality** revealed traffic distribution, while **closeness centrality** assessed connectivity—both grounded in space syntax.

11 Following quantitative analysis, qualitative evaluation considered visual integration and was translated into ranked scores. All **evaluation** metrics were normalized and weighted for fair comparison. The top-scoring scenario was selected, though others remained viable based on goals or refinements.

Plot, Parcel, Block

Once the **optimum network** was chosen, it was applied to the site. Generated plots and codes, such as setbacks and plot widths, enabled creation of building footprints. Incorporating various building types allowed for multiple **block distributions**. Adjusting type and placement created an abacus of options, from which a shortlist was selected for deeper analysis.

This analysis was performed using **Autodesk Forma**, a powerful parametric tool. Scenarios were imported and assessed for **function alignment**, verifying spatial distributions of residential and commercial areas. Forma also evaluated **sunlight** exposure and **microclimate**,

12 providing data on ground-level solar access and thermal comfort during summer and winter.

As in previous steps, results were normalized, weighted, and scored. The most efficient scenario was selected, though designers could modify parameters or weights to prioritize alternative outcomes.

Units

13 A zoomed-in part of the selected scenario was explored further to test unit **layouts** and **circulatory** systems using Forma, which provided key **metrics** like unit areas and population estimates. The layout with the highest GFA and best fit for spatial requirements was chosen as the final preliminary design.

AI Graphics

14 To evaluate the practical viability of the final proposal, AI tools were used to generate **masterplans** and **visualizations**. These required a base image, design prompt, style description, and reference image. The outputs helped identify flaws, which could be corrected by adjusting parameters showcasing the adaptability and efficiency of the parametric approach.

Conclusion

15 This thesis has demonstrated that integrating parametric design techniques into preliminary urban planning is not only feasible but essential for meeting the demands of contemporary urbanism. By converting core planning principles, such as density, geometric, and mobility, into quantifiable, adjustable parameters, designers can systematically explore and refine multiple scenarios within a single adaptive framework. These workflows heighten responsiveness to contextual variables such as climate, land use, and circulation, enabling the generation of diverse spatial solutions while markedly enhancing both the efficiency and analytical depth of early-stage planning, where rapid iteration and evidence-based decision-making are paramount.

Through hands-on applications and software experimentation, this study shows that Grasshopper and Autodesk Forma each bring unique strengths to the process, operating across layers of urban design, from circulation networks and block geometry to residential layouts and environmental performance within a cohesive methodology that balances structure and flexibility. This approach fosters more transparent, data-driven workflows and paves the way for future integration of artificial intelligence and Systematic planning strategies. Ultimately, this work calls for a shift away from rigid, top-down master plans toward iterative, dynamic systems that empower urban designers to build smarter, more resilient cities through parametric thinking.

5-2. GENERALIZED SYSTEM

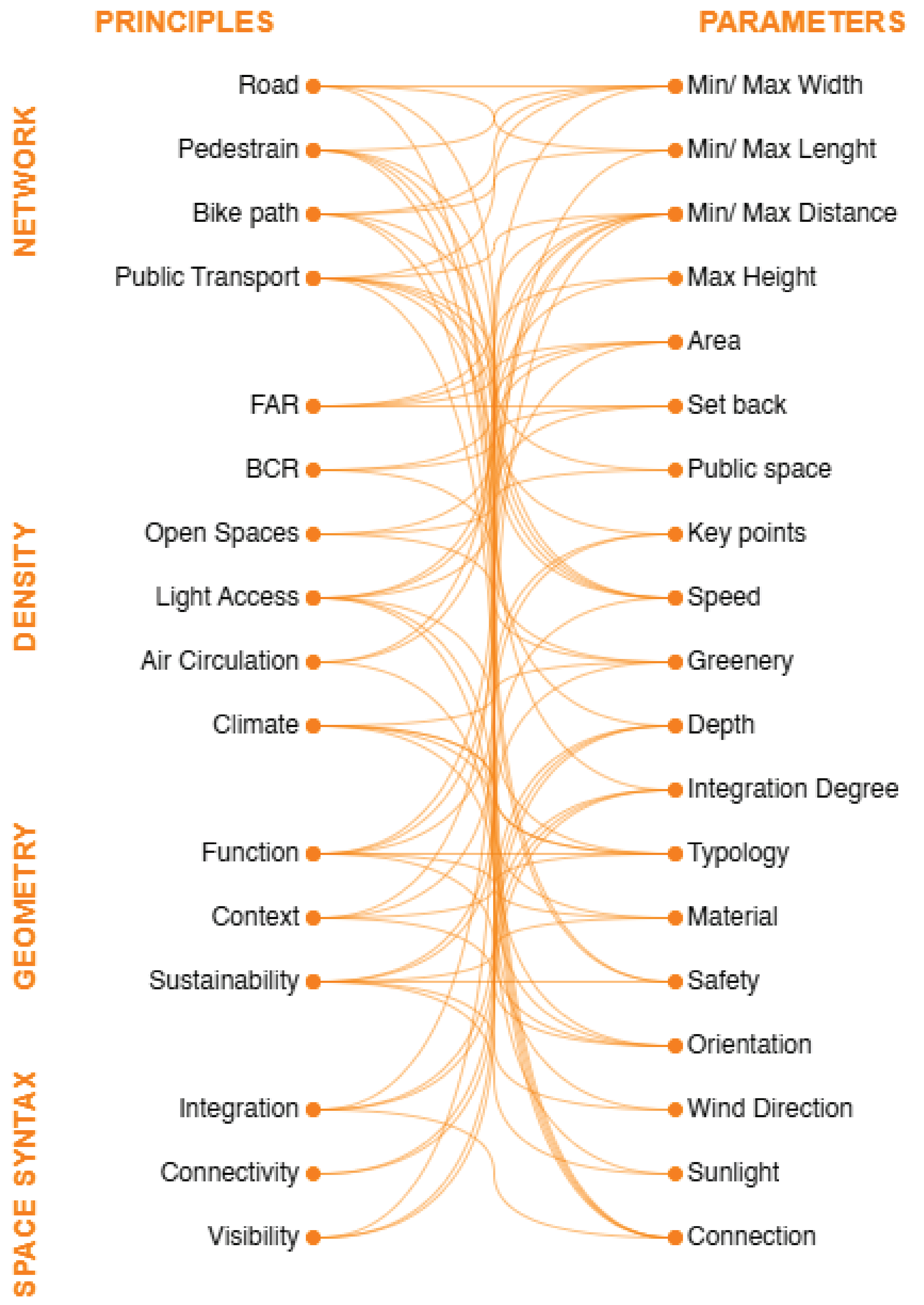
One of the core objectives of this thesis is to propose a **generalized parametric system** that can be adapted to various urban contexts and design principles. The design project presented in this study served as a test case to examine how the system performs in a real-world scenario and whether it provides meaningful support to the designer. Given the successful outcomes, this approach can be extended to other sites and tailored to different urban challenges.

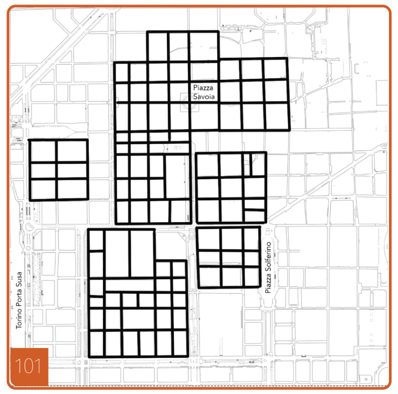
While the system's **structure and methodology** remain consistent, its inputs such as **design principles**, **parameters**, and **data** must be adapted to the specific conditions of each site. In other words, the process is transferable, but the content is context-specific. For example, urban density, block typologies, or street widths may vary significantly from one location to another, affecting the rules that govern spatial relationships. However, by adjusting the relevant parameters, designers can still apply the same system across diverse urban settings.

Additionally, the **level of complexity** and detail can be customized based on project needs. Designers have the flexibility to define how many principles and parameters are included, depending on available data, project scope, and stakeholder requirements. As mentioned earlier, this thesis focuses on a selection of fundamental urban principles to demonstrate the workflow, but the system can easily be expanded to include additional criteria such as environmental performance, historical constraints, or economic viability.

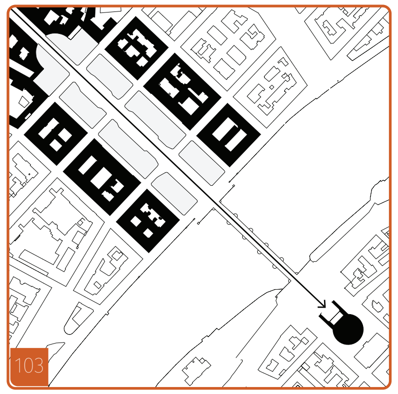
The following pages present the **main principles** examined in this thesis alongside their associated **parameter codes.** Each principle represents a category of urban information that must first be studied and analyzed to extract parameterizable data. These data points are then translated into codes that can be used in parametric modeling. Importantly, some principles may influence multiple parameters. For instance, the availability of public transportation can shape street networks, define speed hierarchies, establish connectivity thresholds, and identify key urban nodes. These relationships are not rigid rules but rather suggested logics that can be adapted or reconfigured depending on the goals of each project.

The parameter codes illustrated here demonstrate how abstract urban principles can be converted into diagrammatic representations or numerical data suitable for use in parametric tools. These examples are specific to the current design case but serve as a proof of concept for broader application. It is important to acknowledge that parametric tools may have **limitations** in addressing highly specific or nuanced needs. In such instances, manual **interventions** or **complementary tools** may be required to achieve the desired level of detail and responsiveness.

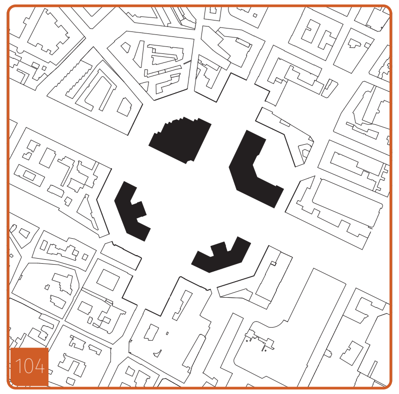




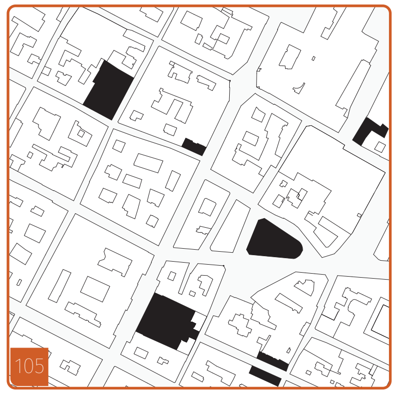
Grid



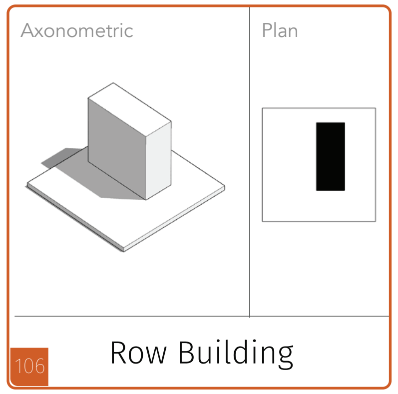
Pattern



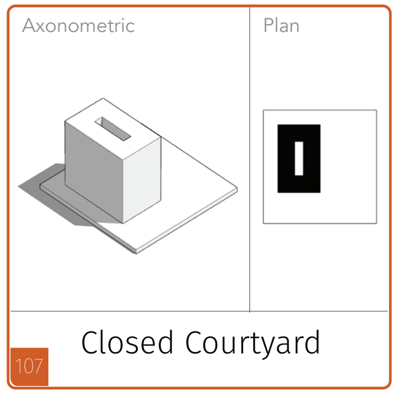
Economy



Buffers



Typology



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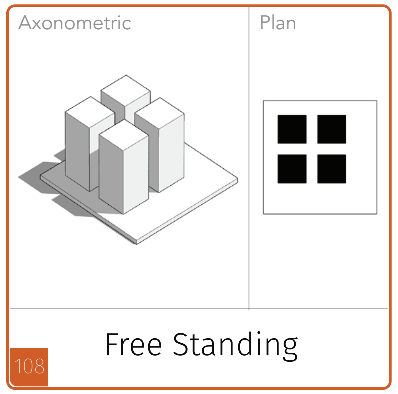
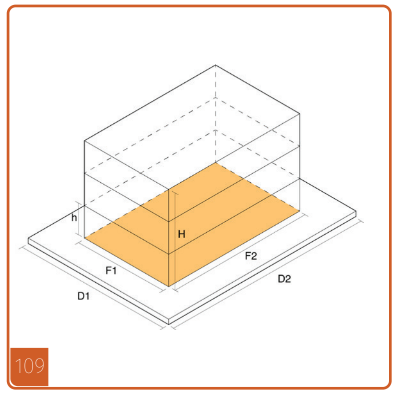
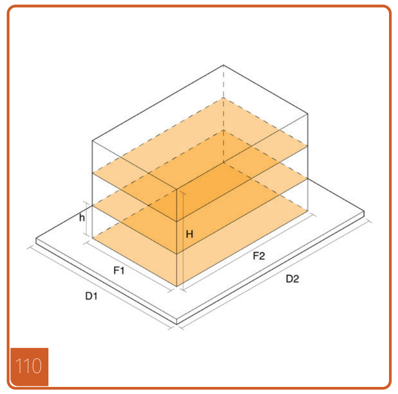


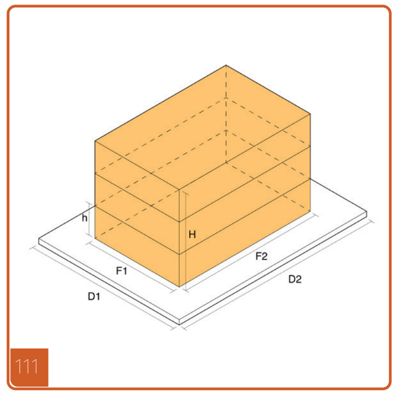
Typology



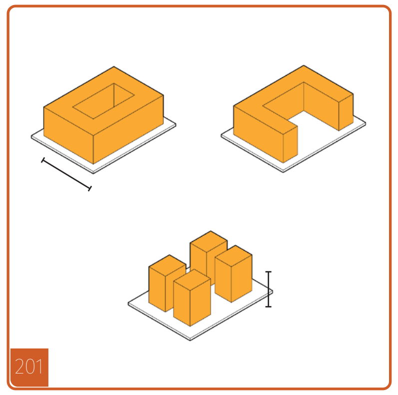
Covarage Ratio



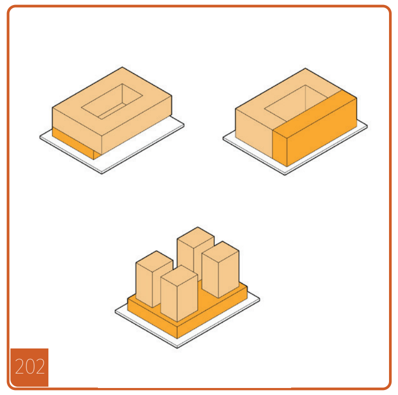
Floor Area Ratio



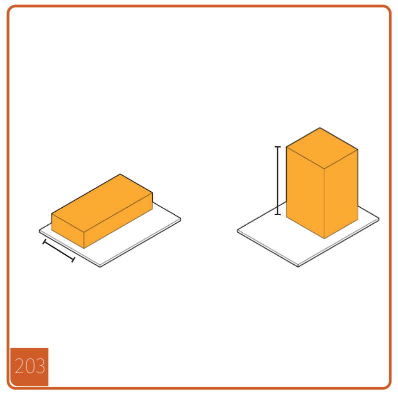
Volume/Height



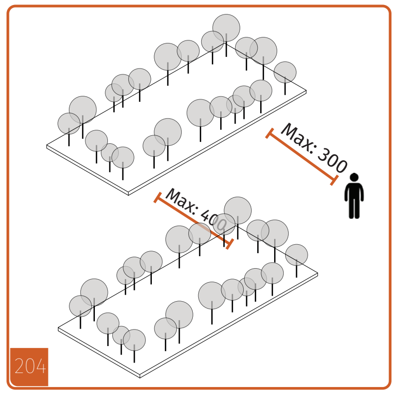
Residential



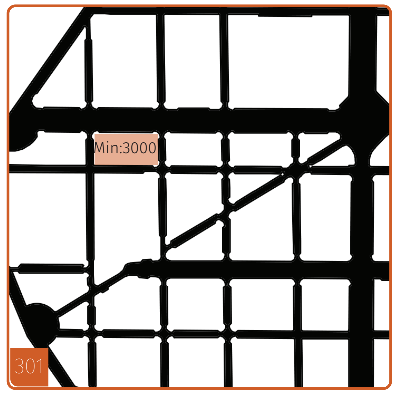
Mixed-use



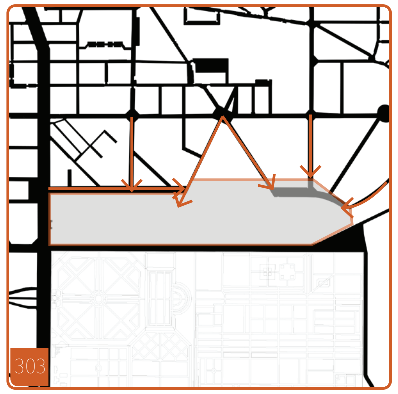
Commercial/Office



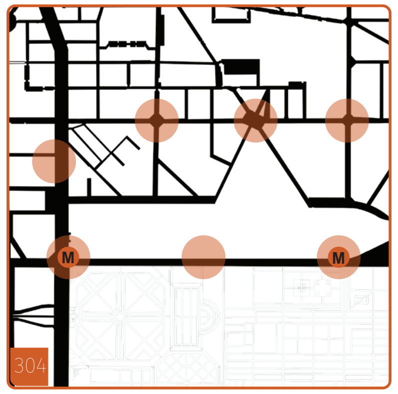
Public/Green



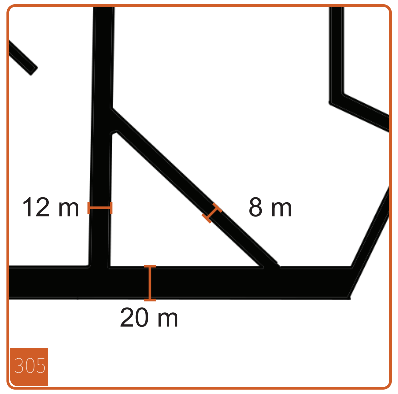
Block size



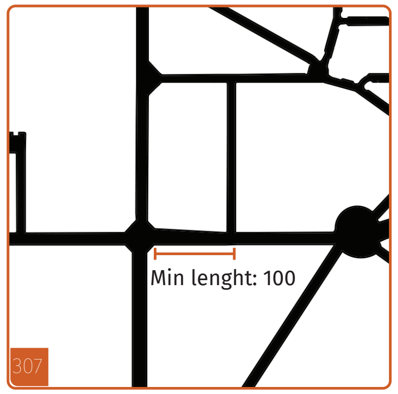
Boundary/Connections



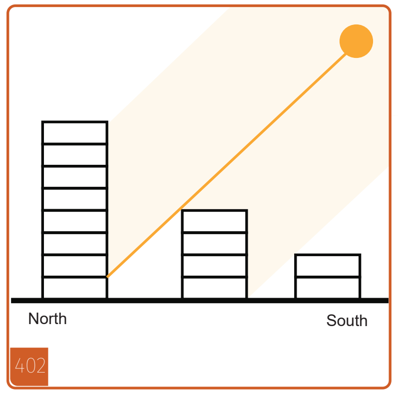
Public transtport



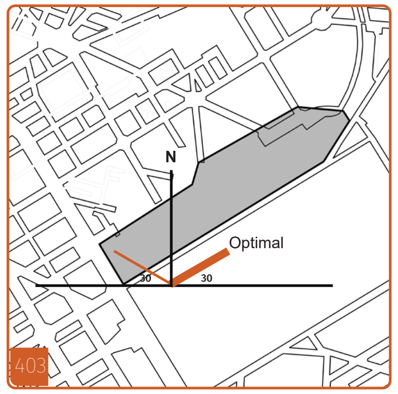
Street hierarchy



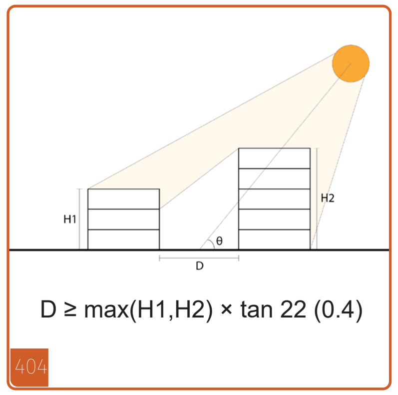
Street lenght



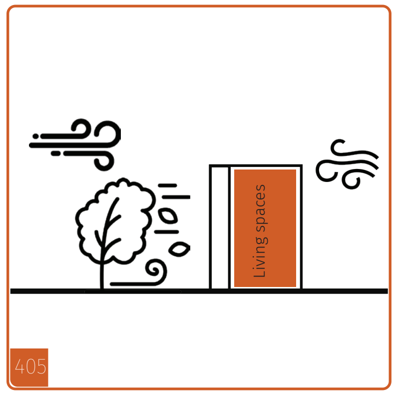
Sun Direction



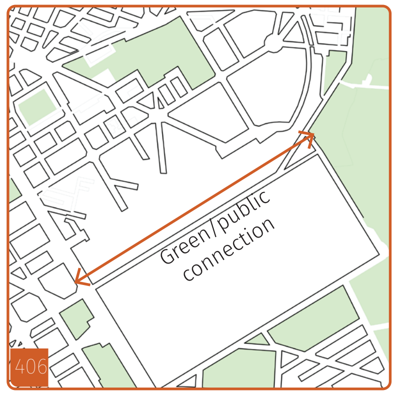
Site Orientation



Sun Access/Shading



Wind



Neighborhood Alignment

5-3. OUTCOMES AND FUTURE WORKS

> Outcomes:

Feasibility and Added Value of Parametric Design: This thesis, through both research and design practice, demonstrates the feasibility and added value of integrating parametric methods into preliminary urban design. It enables designers to rapidly arrive at basic proposals, which is crucial for efficiency in early planning stages. Additionally, the design alternatives generated within the parametric framework illustrate diverse possibilities while remaining aligned with urban planning principles. The decision-making process is also clarified through both numerical and qualitative analyses, supporting a more objective evaluation.

Development of a Generalized and Adaptable System: A key contribution of this work is the development of a generalized system that can be adapted and transferred across various urban contexts. This system considers sustainability, local regulations, contextual characteristics, and site-specific constraints. It represents one of the core outcomes of the thesis and serves as a potential foundation for future research and development.

Quantification and Parameterization of Urban Knowledge: By studying and synthesizing urban rules, principles, and planning knowledge, the thesis identifies and distills core concepts. These are analyzed in depth and summarized in schematic formats, demonstrating how various aspects of urban data can be quantified and parameterized, thus enabling a more structured and measurable planning approach.

Tool Selection and Application in Parametric Workflows: Another significant outcome is the exploration and application of parametric design tools, with eight particularly relevant tools used in the process. Identifying the capabilities and limitations of each tool helps designers select the right tools for each design stage, ensuring more effective and informed workflows.

Proposal of an Innovative Design Framework: The thesis introduces a four-stage design framework: principle establishment, generation, assessment, and selection. Each stage follows a logical and rational process rather than relying on subjective preferences, reducing bias and increasing clarity in decision-making. The use of numerical data in assessment and selection provides a strong foundation for comparison and justification of design outcomes.

Additional Contributions to Urban Planning Practice: In addition to the main findings, the thesis offers several broader contributions: it provides a strong historical and theoretical background, incorporates sustainability principles, enhances the judgment process, introduces modular typologies, and demonstrates the value of computational workflows in early-stage urban design.

> Future works:

Development of a Dedicated Application or Plugin: A key future step is the development of a specific application or plugin that consolidates the parametric urban planning workflow within a single interface. This tool could integrate geometry generation, rule-based evaluation, sustainability checks, and visualization capabilities—offering a unified environment for urban designers and planners. Such a plugin could be built on existing platforms like Grasshopper or Autodesk Forma, or as a standalone solution tailored to early-stage urban decision-making.

Extension into Architectural Design Stages: Continuing in this parametric approach, future work could focus on the next stages of the design process, particularly in architectural planning. New tools are emerging that attempt to parameterize architectural floor plans and building layouts (e.g., generative plan solvers, AI layout generators). Integrating these with urban-level parameters would enable a seamless transition from master planning to building design, maintaining data continuity and design coherence across scales.

Integration of Real-Time and Dynamic Data: While the current framework relies on static datasets, future research could incorporate real-time data feeds such as environmental sensors, mobility data, or demographic changes. This would support the development of adaptive planning models that respond dynamically to changing urban conditions, improving resilience and responsiveness in design.

Integration of Machine Learning for Urban Pattern Recognition: A promising future direction involves the use of machine learning models to extract urban patterns from large datasets. Instead of manually defining all planning principles, algorithms could learn spatial configurations, density profiles, or circulation patterns from precedent cases and apply them intelligently in new contexts. This would automate and enhance the "principle establishment" phase of the design cycle.

Parametric and AI-Based Evaluation and Optimization: As AI tools continue to evolve, future work could focus on combining parametric systems with AI-based evaluation and optimization processes. Rather than using AI tools solely for visualization (as done in this thesis with MNML, LookX, DALL·E, and MyArchitectAI), the next step would involve deploying AI as a co-designer that evaluates or generates urban forms based on specific performance metrics. These metrics could include accessibility, sunlight exposure, walkability, or functional diversity. Such integration would enable semi-automated, performance-driven design iterations, helping designers identify optimal solutions more efficiently and objectively.

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FIGURES

TABLES

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