SUSTAINABLE NEIGHBORHOOD GENERATION IN THE NEW BOULEVARD OF TIRANA

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BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
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IN
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Approval sheet of the Thesis

This is to certify that we have read this thesis entitled "Sustainable Neighborhood Generation in the New Boulevard of Tirana" and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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ABSTRACT

SUSTAINABLE NEIGHBORHOOD GENERATION IN THE NEW BOULEVARD OF TIRANA

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In recent decades, the scale of urbanization has grown significantly, resulting in most of the globe's people living in urban regions. Because of these rapid expansions, the cities are now facing new urban challenges, such as traffic congestion, resource depletion, infrastructure strain, and environmental degradation. Such is the case of Tirana, the capital of Albania, as it is the densest city of the country, and according to statistics, one of the most polluted ones in Europe with a very low quality of life index. To solve these issues created by rapid urbanization, architects and designers need to simultaneously address and take into consideration multiple design factors that require energy, time, money, and experience. Generative Design can serve as a tool to help urban designers and architects navigate different design options while instantaneously considering a multitude of planning aspects such as walkability, accessibility to public spaces, carbon emissions, solar gain, green areas, etc. This study focused on the New Boulevard of Tirana which is currently being developed according to the Grimshaw Masterplan. This research intended to explore the generative design framework by applying it to the selected area to see the applicability of this process in the Albanian context. The urban analyses were conducted by using ArcGIS. Three scenarios were generated using Autodesk Forma and then were compared to the Grimshaw proposal in terms of area metrics, daylight potential, microclimate conditions, and solar energy potential. The proposed framework aims to assist urban designers and architects in making better design decisions.

Keywords: *Urban design, Sustainable neighborhoods, generative design*

ABSTRAKT

GJENERIMI I LAGJEVE ME PERFORMANCË MË TË MIRË NË KONTEKSTIN E TIRANËS

Hoxhallari, Klea

Master Shkencor, Departamenti i Arkitekturës

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Bashkë-udhëheqësi: Asoc. Prof. Dr. Fabio Naselli

Tendencat e urbanizimit janë rritur në mënyrë të konsiderueshme përgjatë viteve të fundit, me një shumicë të popullsisë globale që tashmë banon në zonat urbane. Kjo rritje e shpejtë urbane paraqet sfida të reja për qytetin si bllokimi i trafikut, pakësimi i burimeve dhe lëndëve të para dhe degradimi i mjedisit. I tillë është dhe rasti i Tiranës, kryeqytetit të Shqipërisë, pasi është qyteti me popullsinë më të dendur të vendit, dhe sipas statistikave, një nga më të ndoturit në Europë me një indeks shumë të ulët të cilësisë së jetës. Për të zgjidhur këto çështje të krijuara nga urbanizimi i shpejtë, arkitektët dhe projektuesit duhet të trajtojnë dhe marrin parasysh njëkohësisht faktorë të shumtë të projektimit gjë e cila kërkon energji, kohë, para dhe përvojë. Dizajni Gjenerativ mund të shërbejë si një mjet për të ndihmuar projektuesit dhe arkitektët urbanë të marrin parasysh opsione të ndryshme të projektimit duke konsideruar njëherazi një mori aspektesh planifikimi si ecja, aksesi në hapësirat publike, emetimet e karbonit, përfitimi diellor, zonat e gjelbra, etj. Ky studim pati në fokus Bulevardin e Ri të Tiranës i cili aktualisht po zhvillohet sipas Masterplanit të Grimshaw. Ky kërkim synoni të eksploronte projektimin gjenerues duke e aplikuar atë në zonën e përzgjedhur për të parë zbatueshmërinë e këtij procesi në kontekstin shqiptar. Analizat urbane u kryen duke përdorur ArcGis. U gjeneruan tre skenarë duke përdorur Autodesk Forma, dhe më pas u krahasuan me propozimin e Grimshaw për sa i përket metrikës së zonës, potencialit të dritës së diellit, kushteve të mikroklimës dhe potencialit të energjisë diellore. Strategjia e propozuar synon të ndihmojë projektuesit dhe arkitektët urbanë në marrjen e vendimeve më të mira të projektimit.

Fjalët kyçe: *Dizajn urban, Lagje të qëndrueshme, dizajn gjenerues*

To my family and my friends, I couldn't have done it without you

ACKNOWLEDGEMENTS

I would like to sincerely thank my supervisor Assoc. Prof. Dr. Odeta Manahasa and my co-supervisor Assoc. Prof. Dr. Fabio Naselli, for their invaluable assistance in helping me finish my master's thesis. I am grateful for their time and commitment to my academic development, as their knowledge and helpful criticism were crucial to the success of my research.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

Globally, the majority of people live in urban regions, making up about 55% of the total population as of 2018. Compared to 1950, when just 30% of the population lived in cities, this is a substantial growth. According to projections, 68% of the population will be living in cities by the year 2050 (United Nations, 2019). Many causes, including a greater number of births than deaths in urban regions, migration from the countryside and foreign places, and the transformation of formerly rural zones into urban settings, are predicted to contribute to the expansion of the urban population and the size of cities in many locations (Lerch, 2017). Urbanization is crucial for sustainable development in economic, societal, and environmental aspects. Well-managed urbanization, considering long-term population trends, can enhance the benefits of dense cities while reducing environmental harm, particularly in low-income or lower-middle-income countries experiencing swift urbanization. However, unplanned urban expansion and unsustainable practices can lead to problems like pollution and environmental degradation, putting sustainability at risk. (United Nations, 2019). The aforementioned issues are difficult to resolve through a traditional design process, as they rely on the designer's experience and intuition which can limit the potential for new and more sustainable solutions. Generative Design can serve as a tool to help urban designers and architects navigate different design options while simultaneously considering a multitude of planning aspects such as walkability, accessibility to public spaces, carbon emissions, solar gain, green areas, etc. Such technologies, however, are recent and not widely used.

1.2 Problem Statement

Tirana, the capital of Albania, stands as the most extensively urbanized region in the country. The city's territory spans a 25 km radius, but the majority of developed zones are concentrated within 10 km of the city center. Tirana exhibits a notably compact structure, with most administrative subunits situated within a mere 3 km radius. Excluding the Grand Park of Tirana and its artificial lake, the central administrative region is entirely urbanized. Over the past decade, the core of Tirana has seen a 10% increase in population, rising from 611,877 residents in 2009 to 680,043 in 2018. The overall municipality has witnessed a growth rate of 13.3%, escalating from 718,058 inhabitants in 2009 to 828,403 in 2018. Recent projections by the National Statistics Institute (INSTAT) indicate a continued upward trend in population over the next decade. (Bosetti, Chiffi, Pechin, & Uccelli, 2020)

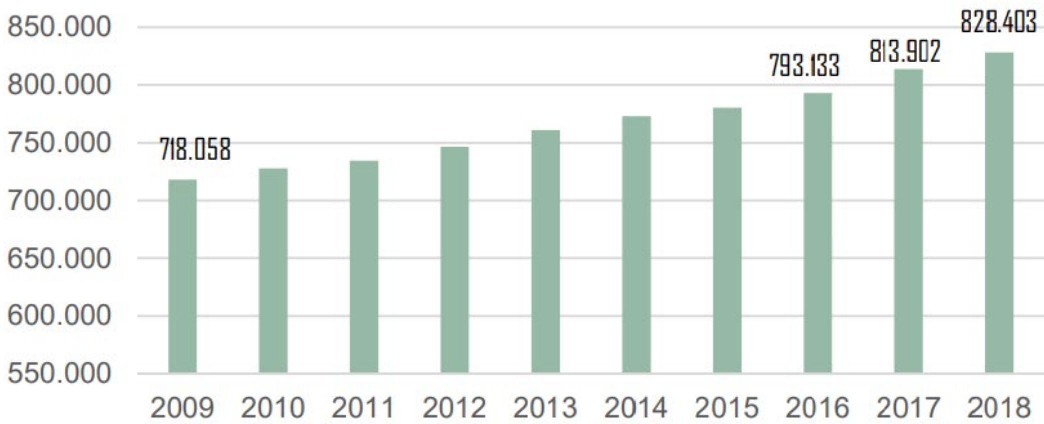


Figure 1 Demographic evolution of Tirana Municipality (Bosetti, Chiffi, Pechin, & Uccelli, 2020)

Beyond only material considerations, quality of life consist of all aspects that impact what people find valuable in their lives. It is influenced by subjective sentiments and views about one's standard of life, the state of society, and the environment surrounding them, in addition to objective, quantifiable elements like income and education. (European Comission, 2023) Housing expenses, clean air, cultural amenities, transportation, employment prospects, and dangers are just a few of the factors that are dependent on a person's location and hence have an influence on their quality of life. (Marans, 2015) According to recent studies, strategies that can enhance a city's safety, inclusivity and facilities are also expected to raise the satisfaction of its citizens with their place of residence. (Castelli, 2023)

With these being said, according to the Report on the quality of life in European cities (European Comission, 2023), Tirana ranks among the cities with the lowest quality of life in Europe.

Top 10 (highest score first)		Bottom 10 (lowest score first)	
City	Score	City	Score
Zürich (CH)	97 %	Palermo (IT)	62 %
Copenhagen (DK)	96 %	Athens (EL)	65 %
Groningen (NL)	96 %	Istanbul (TR)	65 %
Gdańsk (PL)	95 %	Tirana (AL)	66 %
Leipzig (DE)	95 %	Naples (IT)	66 %
Stockholm (SE)	95 %	Belgrade (RS)	69 %
Geneva (CH)	95 %	Rome (IT)	71 %
Rostock (DE)	94 %	Skopje (MK)	72 %
Cluj-Napoca (RO)	94 %	Miskolc (HU)	74 %
Braga (PT)	94 %	Podgorica (ME)	77 %

Table 1 Individuals content to be living in their city, 10 highest and lowest scores (European Comission, 2023)

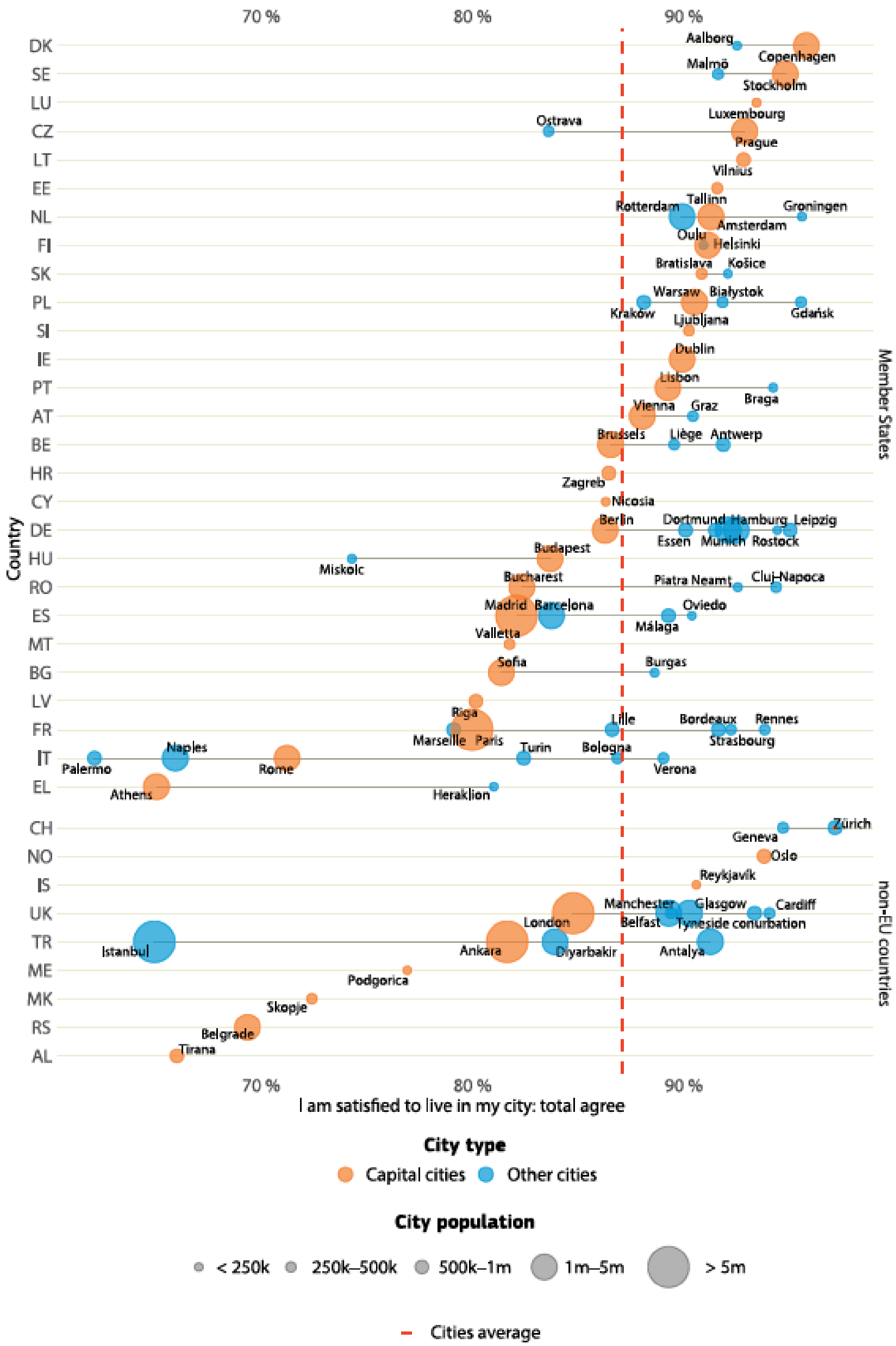


Figure 2 Individuals content to be living in their city, (European Comission, 2023)

Figure 3 individuals content to be living in their city versus the city is a good place to live for individuals in general (European Comission, 2023)

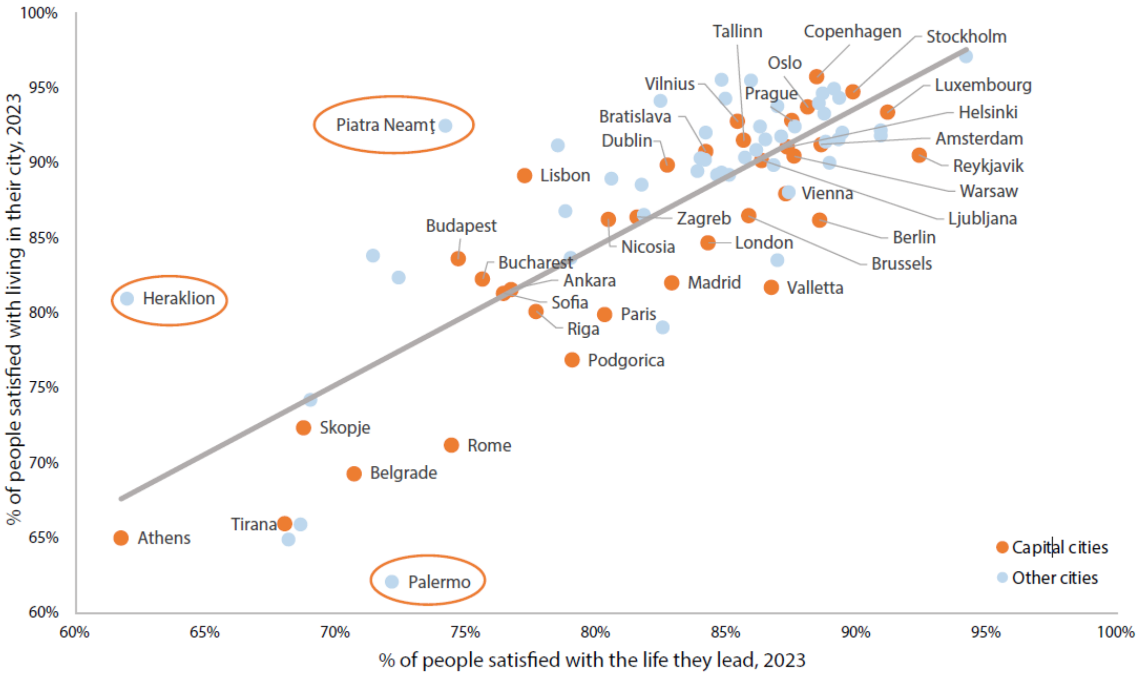


Figure 4 Individuals content to be living in their city versus individuals content with the life they have (European Comission, 2023)

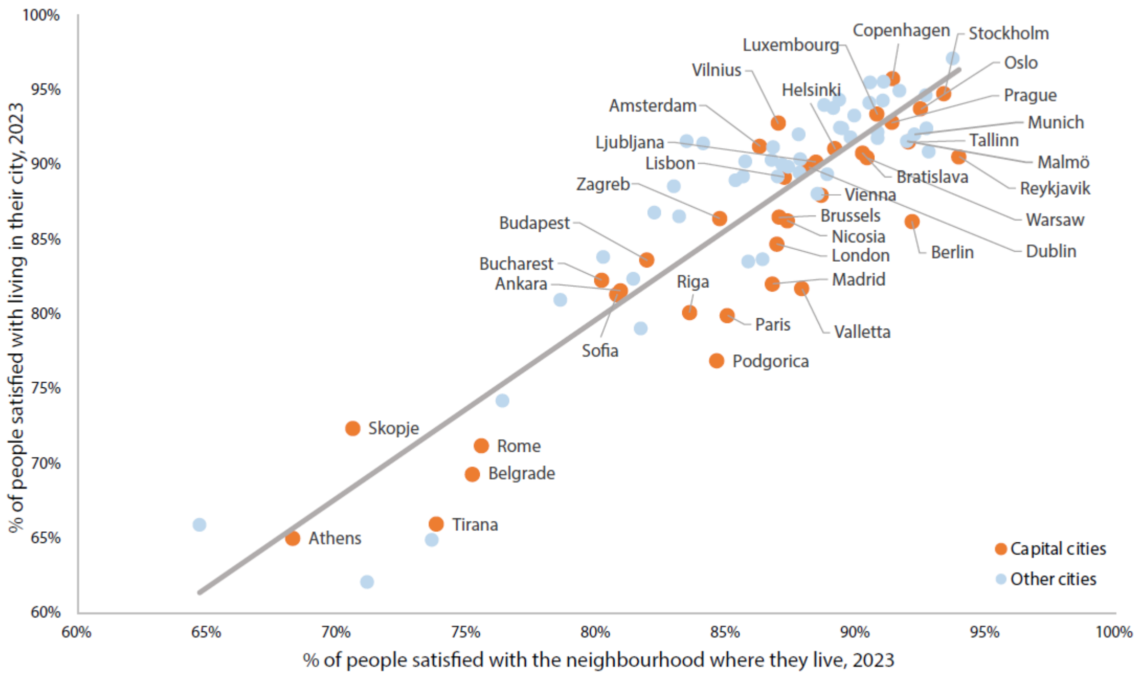


Figure 5 Individuals content to be living in their city versus individuals content to be living in their neighborhood (European Comission, 2023)

Top 10 (highest score first)		Bottom 10 (lowest score first)	
City	**Score**	**City**	**Score**
Geneva (CH)	94 %	Naples (IT)	31 %
Malmö (SE)	92 %	Heraklion (EL)	32 %
Oslo (NO)	91 %	Palermo (IT)	34 %
Munich (DE)	91 %	Skopje (MK)	36 %
Helsinki (FI)	90 %	Athens (EL)	37 %
Groningen (NL)	90 %	Tirana (AL)	38 %
Hamburg (DE)	89 %	Valletta (MT)	43 %
Copenhagen (DK)	89 %	Istanbul (TR)	53 %
Cardiff (UK)	89 %	Podgorica (ME)	55 %
Rennes (FR)	89 %	Nicosia (CY)	56 %

Table 2 Overall satisfaction with green spaces in the city, 10 highest to lowest scores (European Comission, 2023)

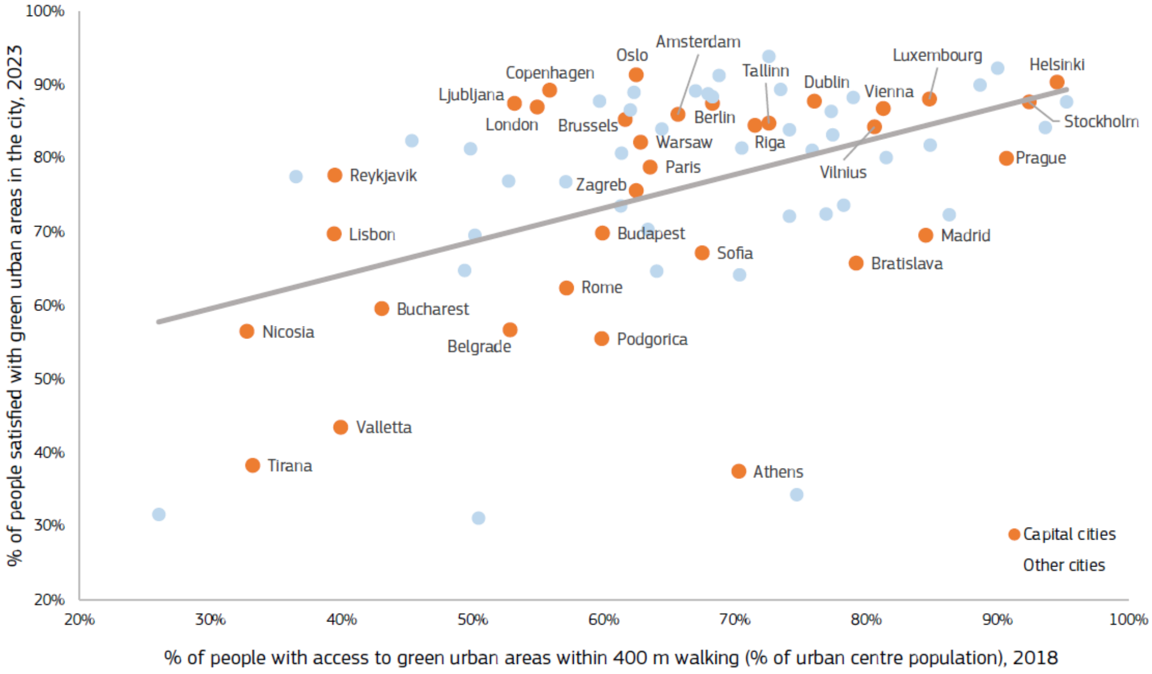


Figure 6 Satisfaction with green spaces versus access to green areas (European Comission, 2023)

Top 10 (highest score first)		Bottom 10 (lowest score first)	
City	Score	City	Score
Luxembourg (LU)	92 %	Athens (EL)	39 %
Groningen (NL)	90 %	Naples (IT)	45 %
Geneva (CH)	90 %	Valletta (MT)	45 %
Strasbourg (FR)	89 %	Palermo (IT)	46 %
Zürich (CH)	88 %	Heraklion (EL)	49 %
Oviedo (ES)	88 %	Tirana (AL)	51 %
Rennes (FR)	88 %	Skopje (MK)	53 %
Malmö (SE)	88 %	Istanbul (TR)	55 %
Rotterdam (NL)	88 %	Bucharest (RO)	56 %
Munich (DE)	87 %	Rome (IT)	56 %

Table 3 Individuals content with public spaces in the city, highest and lowest scores (European Comission, 2023)

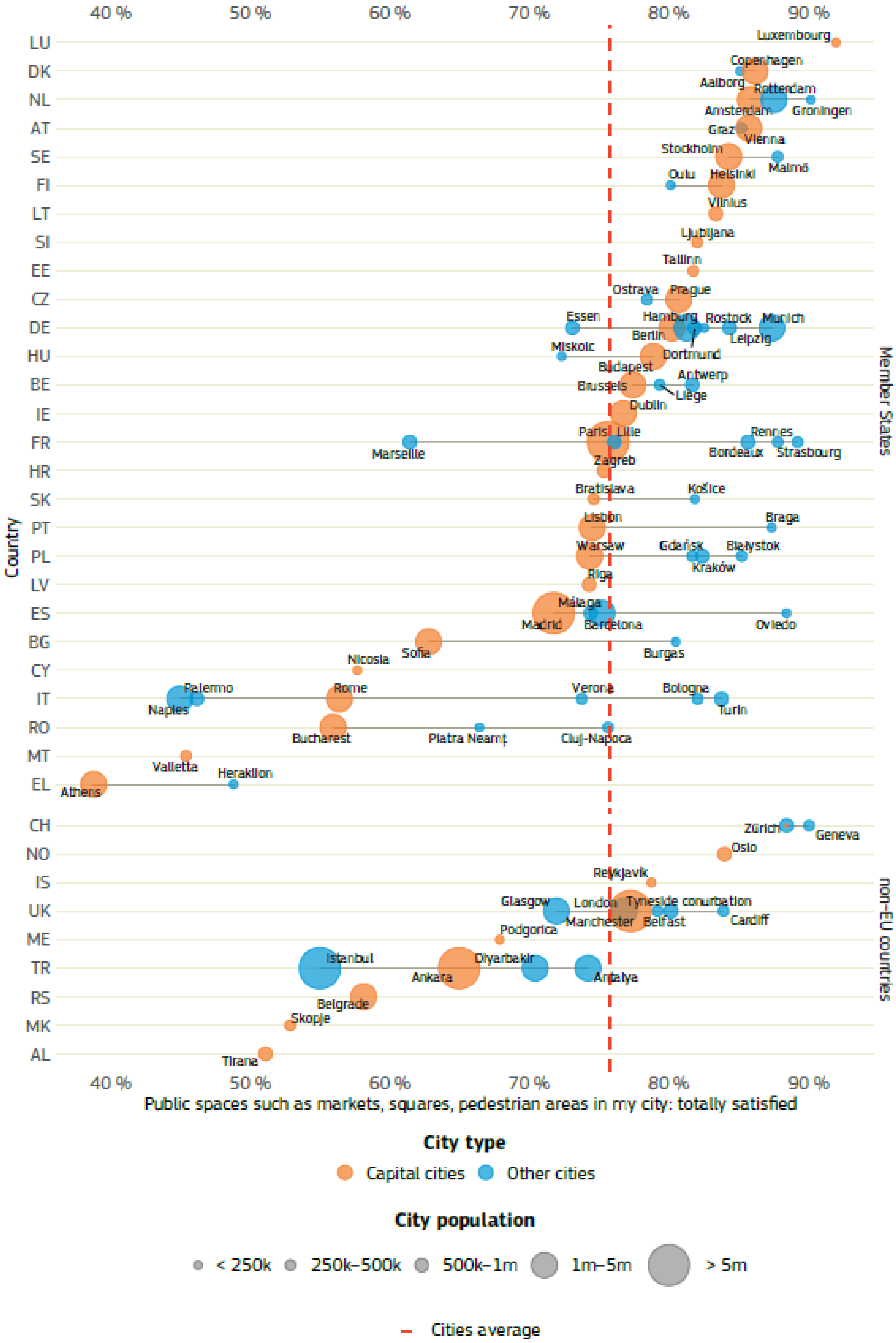


Figure 7 People content with living in public spaces, by city (European Comission, 2023)

Top 10 (highest score first)	
City	**Score**
Zürich (CH)	89 %
Helsinki (FI)	88 %
Rostock (DE)	88 %
Aalborg (DK)	87 %
Oulu (FI)	85 %
Groningen (NL)	85 %
Białystok (PL)	85 %
Reykjavik (IS)	83 %
Leipzig (DE)	83 %
Dublin (IE)	82 %

Bottom 10 (lowest score first)	
City	**Score**
Skopje (MK)	12 %
Bucharest (RO)	20 %
Kraków (PL)	22 %
Paris (FR)	26 %
Athens (EL)	28 %
Turin (IT)	29 %
Tirana (AL)	29 %
Rome (IT)	31 %
Belgrade (RS)	33 %
Ostrava (CZ)	33 %

Table 4 10 Highest and lowest scores by city for the air quality (European Comission, 2023)

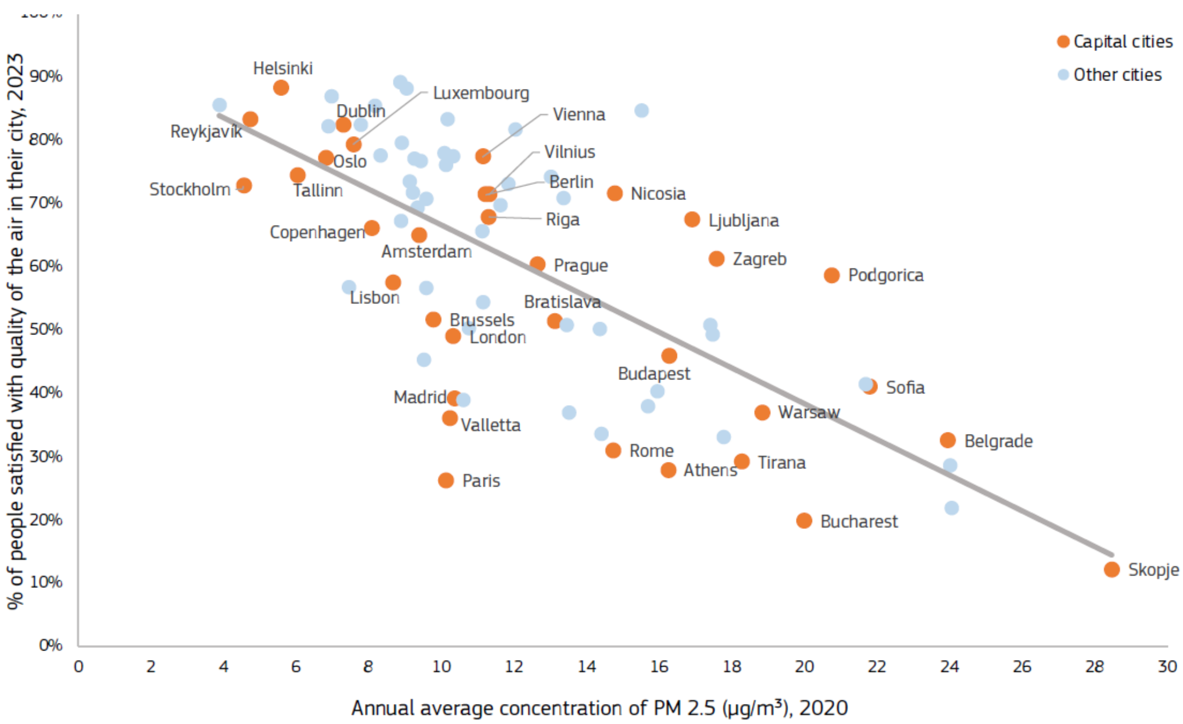


Figure 8 Satisfaction with air quality versus 2020 annual average concentration of fine particles (PM2.5) (European Comission, 2023)

Top 10 (highest score first)	
City	Score
Oulu (FI)	87 %
Dublin (IE)	82 %
Tyneside conurbation (UK)	82 %
Malmö (SE)	82 %
Aalborg (DK)	81 %
Groningen (NL)	81 %
Reykjavik (IS)	80 %
Rostock (DE)	80 %
Helsinki (FI)	80 %
Cardiff (UK)	79 %

Bottom 10 (lowest score first)	
City	Score
Bucharest (RO)	30 %
Palermo (IT)	31 %
Istanbul (TR)	33 %
Athens (EL)	36 %
Tirana (AL)	36 %
Skopje (MK)	36 %
Sofia (BG)	38 %
Naples (IT)	38 %
Paris (FR)	43 %
Rome (IT)	43 %

Table 5 Satisfaction with noise level, 10 highest to lowest scores (European Comission, 2023)

Figure 9 Satisfaction with the noise level (European Comission, 2023)

Presented with the aforesaid issues, there is an immediate need for a new way of designing in Tirana, which takes into consideration its rapid urbanization trend and addresses the associated challenges through sustainable urban development, thus contributing to a better quality of life for its residents.

1.3 Objectives

This study focuses on the New Boulevard of Tirana, located on the city's periphery. The zone is currently developing according to the Grimshaw Project, Tirana Master Plan. The first goal of this research was to use the existing material and data to comprehend the neighborhood's current state and make a thorough analysis. After analyzing the current state, the Grimshaw Project for the new Boulevard is then evaluated based on a set of parameters and constraints derived from the principles of a sustainable neighborhood. The second objective of this paper was to generate multiple scenarios in which the neighborhood can be improved following the evaluations of the Tirana Master Plan. The third objective was to evaluate the performance of the generated scenarios and then compare them with the Grimshaw Project. By constructing such a framework, urban designers and architects can select the best-performing scenario in regard to the characteristics of an optimal-performing neighborhood. Other objectives include the encouragement of generative tools and analytics use in architecture and urban design.

1.4 Thesis Organization

This thesis is structured into six chapters, organized accordingly: Chapter 1 introduces the thesis, presenting the problem statement and setting the context for the study. Chapter 2 provides a review of the relevant literature, highlighting key theories and previous research. Chapter 3 outlines the research methodology, detailing the design and data collection processes used to gather information for the analysis. Chapter 4 focuses on the Grimshaw Project, analyzing its components and developing three different scenarios based on the project analysis outcomes. Chapter 5 evaluates and compares these scenarios with the original Grimshaw Plan, assessing their feasibility and potential impacts. Finally, Chapter 6 offers a comprehensive discussion, drawing conclusions from the research findings and providing recommendations for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Cities are increasing at an exponential rate, making it difficult for them to achieve sustainability goals. In the meanwhile, the modern urban planning process is frequently perceived as a complex and disorganized workflow. Even after years of development, CAD and BIM technologies still struggle to integrate the entire design process. Therefore, employing the latest advancements, such as generative design tools, can help transition from traditional methods to a more analytical and scenario-driven approach. This literature review examines all the topics that will develop the framework of this research. It thoroughly explains the concepts of generative design, sustainable neighborhoods, and urban morphology and it also examines similar studies to better comprehend how they compare to the chosen topic of research.

2.2 Sustainable Urban Neighborhoods

The neighborhood is viewed as a crucial part of the urban fabric where sustainability ideas may be implemented to create sustainable cities and guarantee sustainable living. The word "sustainable" refers to the neighborhood's capacity to continue operating while preserving the environment. Sustainable urban neighborhoods combine a number of significant elements, including social, environmental, and economic ones. While "neighborhood" refers to the built environment as well as the social, cultural, and economic components of the region, "urban" refers to the neighborhood's location and physical layout. (Khemri, Caputo, & Melis, 2021)

Another definition of a sustainable neighborhood is a vibrant mixed-use community that prioritizes social and environmental responsibility, fosters community and neighborhood life, and seeks to improve inhabitants' quality of life by boosting employment and financial security. A very populated area that facilitates sustainable mobility through walking, bicycling, and public transportation, as well as social interaction and vibrancy by housing a variety of socioeconomic classes and offering close access to essential amenities and recreational opportunities, is referred to as a sustainable neighborhood. (Khemri, Caputo, & Melis, 2021)

Furthermore, the sustainable neighborhood continues to serve the same purpose as the conventional neighborhood—that is, to unite people around a shared social and cultural identity while also serving as a place for everyday activities. It includes a socioeconomic component, by using ecologically friendly planning, it fosters social engagement and environmental performance. A sustainable neighborhood aims to meet people's needs for housing, employment, and leisure through compact, connected, and environmentally friendly urban forms that encourage walkability and social interaction (Farr, 2008).

In order to create pleasant and efficient neighborhoods and achieve sustainable urban development, UN-Habitat (2014) outlined five basic principles (United Nations, 2014):

- Enough room for streets and an effective street network: Establish an effective street network that can accommodate many forms of transportation, giving priority to bikes and pedestrians and lowering the dependency on automobiles. At least 30% of the area should be taken up by the street network, with at least 18 km of street length per km².

- High density: Encourage the development of high-density urban areas, minimize urban sprawl, and optimize land utilization. There should be a minimum of 15,000 people per km2, or 150 people per ha or 61 persons per acre.

- Mixed land use: Make sure that the land is used effectively and create a network of connected routes that offer comfortable, safe, and effective transportation. In any neighborhood, at least 40% of the floor area should be set up for commercial purposes.

- Social mix: A neighborhood should have a mix of homes in various price ranges and tenures to serve a variety of income levels. Low-cost housing should make up 20 to 50 percent of the residential floor area, and each tenure type should not account for more than 50 percent of the total.

- Limited land-use specialization: In order to restrict single-function blocks or neighborhoods; no neighborhood should have more than 10% single-function blocks.

The Principles can be applied in the following situations:

1. Rapidly expanding cities: The Five Principles can be used to assist cities that must provide land, infrastructure, and public services for a population that is expanding quickly due to a variety of factors, including natural growth, rural immigrants looking for work, and internally displaced people escaping conflict or natural disasters.

2. New urban settlements and urban extensions: To prevent making the same mistakes twice, the Five Principles might be used in new urban areas.

3. Urban regeneration and renaissance: The Five Principles can be used by declining cities to guide programs for urban transformation and rehabilitation.

4. Urban densification: Using the Five Principles, expanding cities with

limited space for expansion can achieve a more gradual densification process. (United Nations, 2014)

2.3 Urban Morphology

The study of city shapes with an emphasis on growth and changing patterns is known as urban morphology. It looks at how urban form and space are organized, as well as how the infrastructures that support it are arranged spatially. The study of urban morphology looks at a city's land uses, street patterns, urban blocks, and how the urban shape develops over time. Urban morphology bridges the gap between geography and architecture by examining how the urban fabric might gradually produce recognizable areas. (Kim, 2020)

2.4 Urban Morphology Elements

2.4.1. Cadastral outline (Road Network)

Roads represent the public network that connect different parts of the city, enabling movement through the urban landscape between private domains like street blocks. This network includes avenues, boulevards, and other roadways. The composition of a street refers to its overall shape and includes detailed geometric information such as width, position, length, area, and orientation. (Elzeni, Emokadem, & Badawy, 2022)

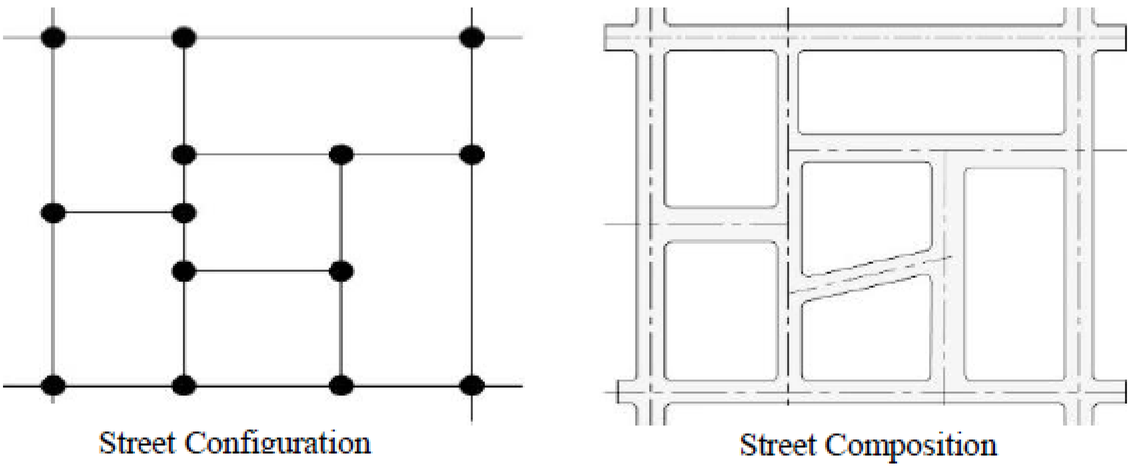


Figure 10 street configuration and street composition

2.4.2. Cadastral Units (Plot System)

Cadastral units are the basic result of dividing private land into individual plots, creating various patterns of land division. This classification delineates the territorial boundaries of ownership and distinguishes between public and private domains. (Elzeni, Emokadem, & Badawy, 2022)

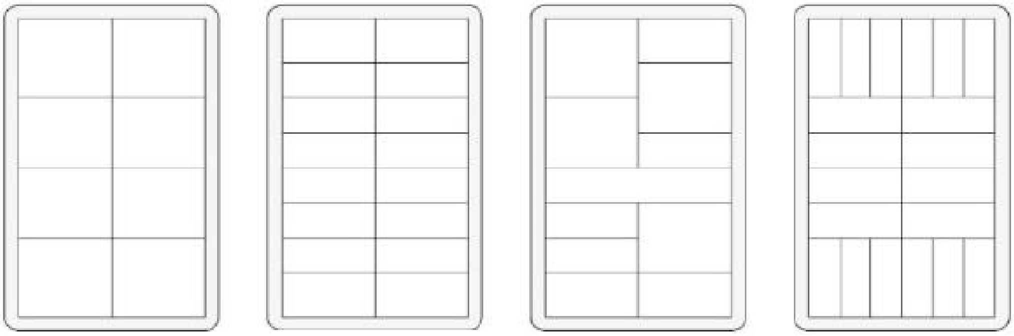


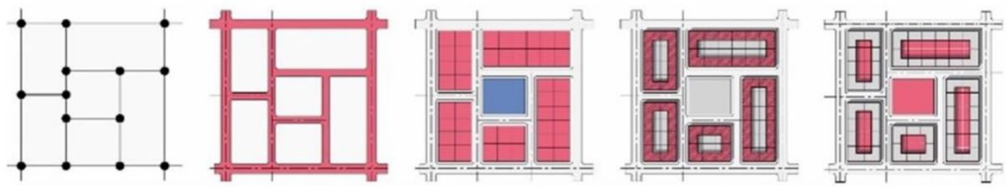
Figure 11 Examples of Plot Subdivisions

2.4.3. The Building Block

Urban blocks refer to the smallest enclosed areas containing multiple buildings. Unlike a single architectural element, a block consists of a cluster of interconnected building plots surrounded by a network of streets. Urban blocks encompass various typologies, and unlike other elements, buildings within these blocks continuously adapt to changes in their usage. A single building can transition from being a high-end single-family home to an office space or student accommodation throughout its life. (Elzeni, Emokadem, & Badawy, 2022)

2.4.4. Urban Morphology Generation

Optimization has become a key method in generative urban design due to its complexity. Research typically employs evolutionary multi-objective optimization and hybrid approaches. In the parametrization process, design requirements are translated into interconnected parameters via rule systems, central to parametric architecture. These parameters drive the generation of urban morphology, which involves five phases: establishing the street grid, converting it into a street composition, plotting subdivisions, creating building blocks, and defining open spaces. (Elzeni, Emokadem, & Badawy, 2022)



P1: Street Configuration	P2:Street Composition	P3: Plot System	P4:Building Block	P5: Open Spaces
• Design urban grid	• Indicate Streets width • Design Street shape • Indicate street directions	• Indicate built. • Indicate non-built (open spaces). • Plot subdivision.	• Block typology. • Extrude building heights. • Building typology	• Public open spaces (Unbuilt plots) • private spaces (Unbuilt area at each plot)

Table 6 Urban Morphology Generation Steps (Elzeni, Emokadem, & Badawy, 2022)

2.4.5. Urban Morphology Indicators (UMIs)

Indicators use morphological relationships—such as numbers, sizes, volumes, areas, orientations, and percentages—between various parts of urban morphology to define the built environment's shape, geometry, and type. Elzeni et al. (Elzeni, Emokadem, & Badawy, 2022) review multiple studies, organizing indicators into groups. Their study employs a dual-tiered classification system: an initial level based on the vocabulary of urban morphology, and a second level with subcategories for each element. Urban Morphology Indicators (UMIs) are categorized by three factors: UM elements, generation process, and spatial relations. The study identifies UMIs for producing urban morphology and presents 4 main subdivisions targeting streets, plots, buildings, and open spaces. (Elzeni, Emokadem, & Badawy, 2022)

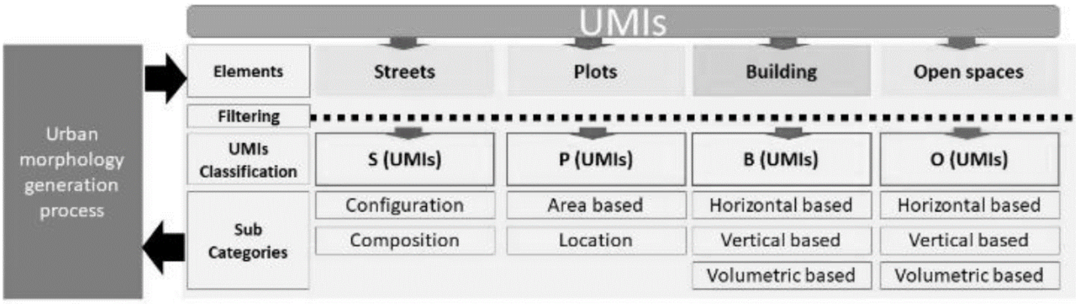
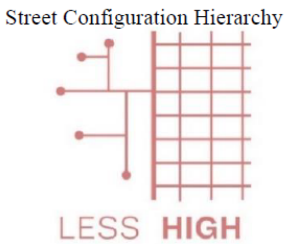
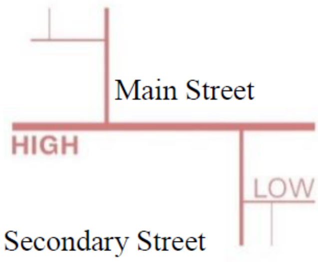
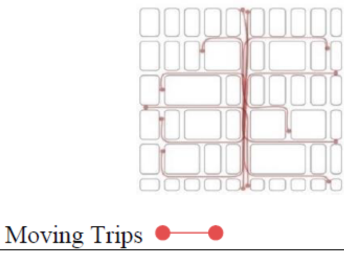


Figure 12 Urban morphology Indicators Classification Strategy (Elzeni, Emokadem, & Badawy, 2022)

2.4.6. Street Morphology Indicators (SUMIs)

S (UMIs)	Definition and Calculation	Illustrative Figure
Configuration Degree of centrality (connectivity)	The ratio of the number of links to the number of nodes in the network is the connectivity index. Links are street segments, while nodes are intersections **[32]**. $$Conn_A = \frac{S_t}{S_c} \quad (1)$$ S_c: the number of connected segments S_t: the number of total segments	
Configuration Closeness centrality (integration)	Closeness centrality represents the average distance, or average shortest path, to all other vertices in the network. $$Int_A = \frac{1}{Depth_A} = \frac{S_t}{\sum_0^n S_C * R} \quad \textbf{(2)}$$ Int: the integration value of segment A Depth A: the total depth of segment A St: the total number of segments S_C: the number of connected segments to segment A R: radius of analysis.	
Configuration Betweenness centrality (choice)	Betweenness centrality indicates how many times a vertex is located on the shortest path between two other vertices [33]. .	

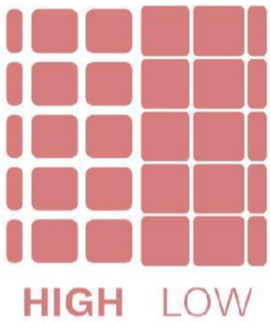
Composition Permeability (Per)	Permeability can be defined as the extent to which an urban morphology is pervaded with publicly accessible space. This feature refers to the ease of travel between any two points through an urban area as well as the multiplicity of route choices. Low AwaP scores indicate high permeability within the measured area [30]. $$\text{AwaP} = \sum_{i=1}^{n} p_i * \frac{A_i}{A_t} \qquad ((3)$$ N: is the number of blocks Pi and Ai: the perimeter and area of each block i, AT: the total area of all blocks.	
Composition Accessibility (Ac)	Movement permeability: explains how the environment allows people to choose routes through and within it. In general terms, it is a measure of the opportunity for movement.	
Composition Visibility (VI)	Visual permeability: refers to the disability of the destination routes through an environment [8].	

Table 7 Street Indicators: Classification, Definition and Calculation (Elzeni, Emokadem, & Badawy, 2022)

2.4.7. Plot Indicators (PUMIs)

Plot indicators are derived from a theoretical review that measures structures using geometric terms like openness and compactness (area-based indicators) and considers the number and variety of accessible plots in configurational terms. (Elzeni, Emokadem, & Badawy, 2022)

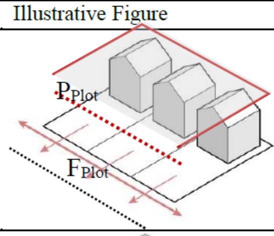
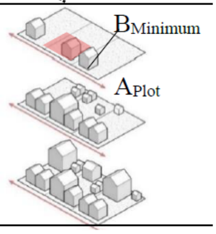
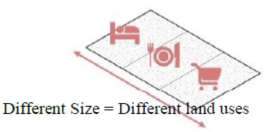
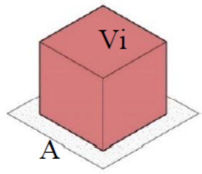
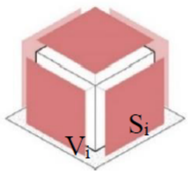
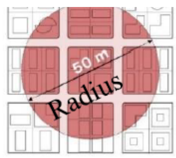
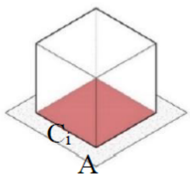
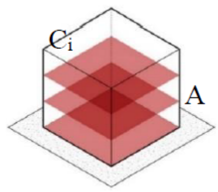
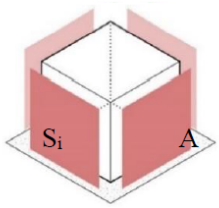
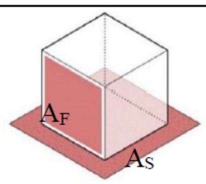
P(UMIs)	Definition and Calculation	Illustrative Figure
Area-based Plot openness	The degree of openness of each plot, for which the notion of plot frontage is essential. $$O_{Plot} = \frac{F_{plot}}{P_{plot}} \qquad (4)$$ $O_{plot:}$ the plot openness. $F_{plot:}$ the street frontage. $P_{plot:}$ the plot perimeter.	
Area-based Plot compactness	The urban fabric's ability to adapt to land-use changes is related to the extent that plots can amalgamate into bigger plots or divide into smaller ones. $$C_{Plot} = \frac{A_{plot}}{B_{Minmum}} \qquad (5)$$ C_{plot}: plot compactness. A_{plot}: plot area. $P_{Minimum}$: Minimum boundary rectangle area.	
Location-based Plot diversity	The ability to incorporate difference, the measure of the number of plots and the diversity of plots in terms of sizes.	

Table 8 Plot Indicators: Classification, Definition and Calculation (Elzeni, Emokadem, & Badawy, 2022)

2.4.8. Building indicators B (UMIs)

B (UMIs)	Definition and Calculation	Illustrative Figure
Volumetric based Indicators Volume area ratio (V/A)	The volume-area ratio expresses the building density in terms of volume units. It is measured as the ratio of the building's volume to the area of the urban site [27]. $V/A = \frac{\sum_{i=1}^{n} Vi}{A}$ **(6)** Vi: the building's volume. A: the size of the land lot. N: is the total number of buildings on that lot.	
Volumetric based Building aspects (S/V)	Building aspects (S/V) are more related to the compactness of the shape of a single building; this term defines the amount of exposed envelope per unit volume [27]. $\frac{S}{V} = \sum_{i=1}^{n} \frac{S_i}{V_i}$ **(7)** Si: the total area of building outer skin. Vi: the Building's volume. N: the total number of buildings on the lot.	
Horizontal slice-based Building distribution factor	of 50 meters [36]. $BDF(\%)\left(1 - \frac{\text{Ncluster }(d=50)-1}{100}\right) * 100$ **(8)** BDf: Building distribution factor	
Horizontal slice-based Gross space index (GSI)	The gross space index is defined as the ratio of the built-up area to the area of the urban site [27]. It reflects the area of a building's footprint over the area of the site [34]. $GSI = \frac{\sum_{i=1}^{n} C_i}{A}$ **(9)** Ci: the building coverage area A: the size of the land lot N: the total number of buildings on the lot	
Horizontal slice-based Floor space index (FSI)	The floor space index is defined as the ratio of the area of a building's total floor space to the size of the piece of the land [27]. $FSI = \frac{\sum_{i=1}^{n} C_i * L}{A}$ **(10)** Ci reflects the coverage area of building L: the number of floors A: the size of the land lot N: number of buildings.	
Vertical -based Façade to site ratio (VHurb)	The façade-to-site ratio is an index of vertical density for the urban texture. It is the ratio of the total façade area of the building to the area of the urban site. VH_{urb} is proportional to the extent of vertical surfaces in the urban area [27]. $VHurb = \frac{\sum_{i=1}^{n} S_i}{A}$ **(11)** A: the size of the land lot Si: total Surface Area	
Vertical -based Frontal area index (FAI)	The frontal area index alludes to a building's frontal area over the area of a site and is calculated [34] . $FAI = \frac{A_F}{A_S}$ **(12)** AF: the total area of frontal façade. As: total area [35].	

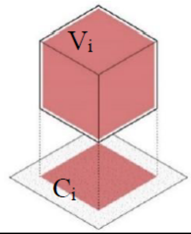
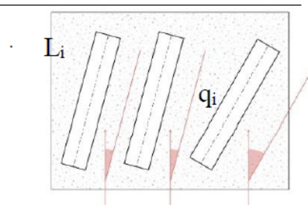
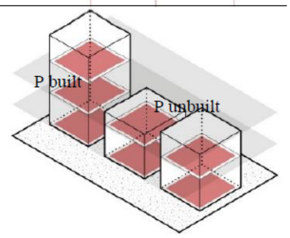
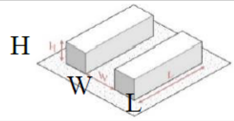
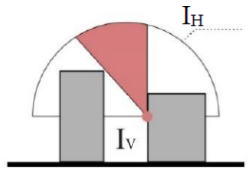
Vertical -based Average building height (Hbuild)	The average building height (verticality) is calculated as the ratio of the buildings volume to the built-up area [27]. $$Hbld = \frac{\sum_{i=1}^{n} Vi}{Ci} \quad \textbf{(13)}$$ Ci: reflects the coverage area of building i Vi: the building's volume N: the total number of buildings on a land lot [34].	

Table 9 Buildings Indicators: Classification, Definition and Calculation (Elzeni, Emokadem, & Badawy, 2022)

The study by Elzeni et al. suggests three classifications for open space indicators: horizontal, vertical, and volumetric approaches, all influenced by building height. Horizontal indicators assess the horizontal morphological connections between urban morphology elements impacted by built areas. Vertical indicators evaluate the vertical morphological relationships between components of urban morphology. Volumetric indicators measure the volumetric morphological relationships among urban morphology elements. (Elzeni, Emokadem, & Badawy, 2022)

Horizontal slice-based Sinuosity (SI)	The angle of change of space denotes sinuosity. In the case of a flow normal to the street, the sinuosity is equal to zero, which is consistent with the fact that this street can be the azimuth of the linear segment I [39]. $$SI = \frac{AL_i * \cos^2 q_i}{AL_i} \quad \textbf{(14)}$$ Li: the length of the linear segment i Qi: the angle between the given azimuth (of flow)	
Horizontal slice-based Occlusivity (Oc)	The average of urban spaces openness to the sky [40]. The distribution of built elements against the height above ground, It is calculated by way of a series of horizontal cuts of the urban fabric. $$Oc = \frac{1}{N_H} \sum_N \frac{P_{built}}{P_{unbuilt}} \quad \textbf{(15)}$$ N_H: the number of horizontal cuts P_{built}: the built perimeter for the current cross section. $P_{unbuilt}$: the unbuilt perimeter for the current cross section [41].	
Vertical slice-based urban canyon (UCI)	The ratio of building height to road width (H/W). It is a simplified model for the study of urban geometry [42].	
Vertical slice-based Sky view factor (SVF)	SVF is calculated as the mean value of the ratio of the solid angle of the visible sky from each point of the façades to the sky vault [27]. $$SVF = \frac{I_V}{I_H} \quad \textbf{(16)}$$ I_V: the ratio of the solid angle of the visible sky I_H: the sky vault.	

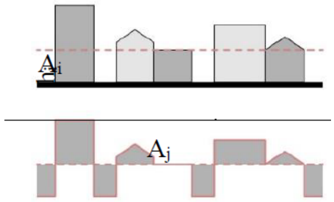
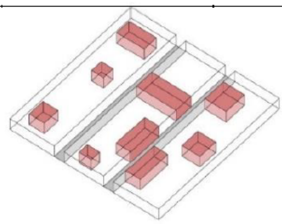
Vertical slice-based Rugosity (RU)	Absolute rugosity represents the average height of the urban canopy. Relative rugosity describes the variance of the average height of the urban canopy (including constructed and non-constructed elements) from the given direction. $$H_m = \frac{\sum_{built} A_i h_i}{\sum_{built} A_i + \sum_{nonbuilt} A_j} \quad (17)$$ H_m :absolute rugosity Ai :area of building element i Hi: height of building element i A_j: area of non-building element j $$R_\alpha = \frac{\sqrt{\sum_i (h_j - h_\alpha)^2 * I_i^2}}{\sum_i I_i} \quad (18)$$ h_α:average height of urban canopy of from the direction α R_α:relative rugosity h_i :height of urban canopy (including construction and non-construction elements) I_i:average height of urban canopy from the direction of i $\sum_i I_i$: equivalent diameter of urban canopy	
Volumetric indicators Porosity (Po)	Porosity is the ratio between the open volume and the total volume of a certain area [38]. A further indicator of porosity measures the ratio of the open space against the total urban area [37]. $$Po = \frac{\sum_{openspaces} \pi r_{hi}^2 * L_i}{\sum_{openspaces} V_j + \sum_{built} V_i} \quad (19)$$ Li: Length of the open space i. r_{hi}: Equivalent hydraulic radius of the open space i. Vi: Mean volume of the built volume j. Vj: Mean canopy volume above open.	

Table 10 Open Space Indicators: Classification, Definition and Calculation (Elzeni, Emokadem, & Badawy, 2022)

2.5 Computational Design in Architecture

Computational design in architecture refers to the use of computer algorithms and digital tools to create, analyze, and optimize architectural designs. It involves the application of computational methods to solve complex design problems, enhance creativity, and improve efficiency in the design process (Caetano, Leitão, & Santos, 2020). Computational design can be categorized into three main typologies:

1. ***Parametric Design:***
   - Uses parameters to define relationships between different design elements.
   - Enables the creation of complex forms and structures by adjusting parameters.
2. ***Algorithmic Design:***
   - Involves writing algorithms or scripts to generate design solutions.
   - Allows for the automation of repetitive tasks and the exploration of

numerous design variations.

3. ***Generative Design:***

- Employs algorithms to generate a multitude of design options based on predefined goals and constraints.
- Helps optimize designs for various criteria such as aesthetics, functionality, and sustainability.

2.6 Generative Design

Architects can now co-create with computers, find novel and surprising ideas, and weigh trade-offs between high-quality designs, project objectives, and restrictions thanks to the new design method known as generative design (Villaggi & Nagy, 2017). Moret (2022) asserts that GD offers tools to help the designer address a particular issue inside a project, rather than fixing the project as a whole. Compared to a traditional method, GD enables the designer to examine more options and alternatives for resolving a given problem. Using a computer algorithm allows for the quick generation of tens to thousands of results, whereas the traditional design process might take a long time to produce a small number of results (Moret 2022).

The GD process is often split into three stages (Villaggi & Nagy, 2017). First, there is the Pre-Generative Design Phase, during which the designer collects information, establishes the project's objectives, specifies limitations and specifications, and creates an assessment standard. The second step is called the Generative Design Phase, during which the algorithm generates a set of solutions, assesses them, and allows them to change by producing a new set. By repeating this process, it is possible to identify answers that are closer to the objectives the designer had originally established. Lastly, the designer selects a design solution, incorporates it into the project, and manually refines it during the Post-Generative Design Phase.

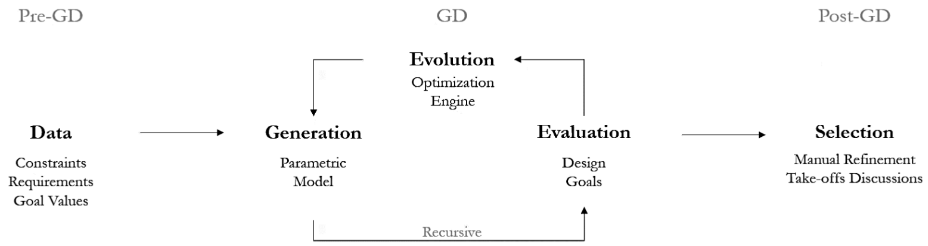


Figure 13 Generative Design workflow

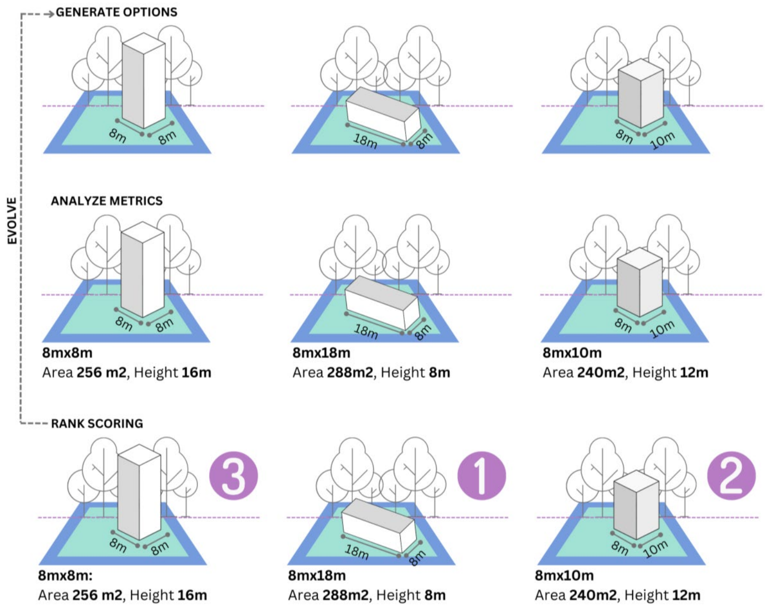


Figure 14 Example of Generating, Analyzing, Ranking and Evolving process

2.7 Voronoi Diagrams

In generative urban design, a Voronoi diagram is a spatial division method that partitions a plane into regions based on the distance to a specified set of points. Each region contains all the points closest to a given seed point, resulting in a tessellation that can be used to optimize land use, ensure equitable distribution of resources, and create organic, efficient urban layouts.

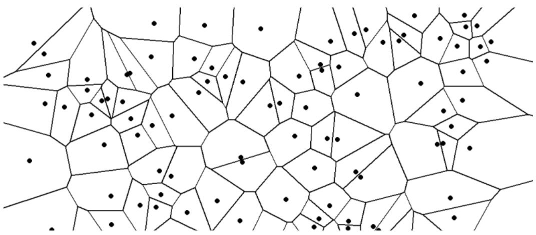


Figure 15 Voronoi Diagram

2.8 Related Studies

1. *Generative Methods for Urban Design and Rapid Solution Space Exploration* (Sun & Dogan, 2022)

This work presents an application of a generative urban tool based on tensor fields, which integrates with the Rhino/Grasshopper ecosystem and its tools for environmental performance simulation and urban analysis to enable fast design space investigation and optimization. With the help of this tensor-field modeling technique, users can encode design ideas like directionality, densities of streets, buildings, and people, as well as contextual constraints as forces that modelers can weigh. With very few model inputs, users may create a wide variety of urban fabric configurations that closely mimic actual cities. (Sun & Dogan, 2022)

The framework for this research intends to give designers the ability to build a vast range of urban morphologies by allowing them to arbitrarily mix input data and add significant features of these subsystems to determine the driving forces for urban form development. The user refers to these generating driving forces as tensor fields, which function as an extended and abstract way to define input data that the generative procedure samples. For instance, designers can use the tensor fields to encode constraints for urban strategies, like slopes of mountains or rivers, as well as design intentions, like links to significant locations, a view axis with landmarks, zoning targets, and demographic data to guide the urban from generation to generation. (Sun & Dogan, 2022).

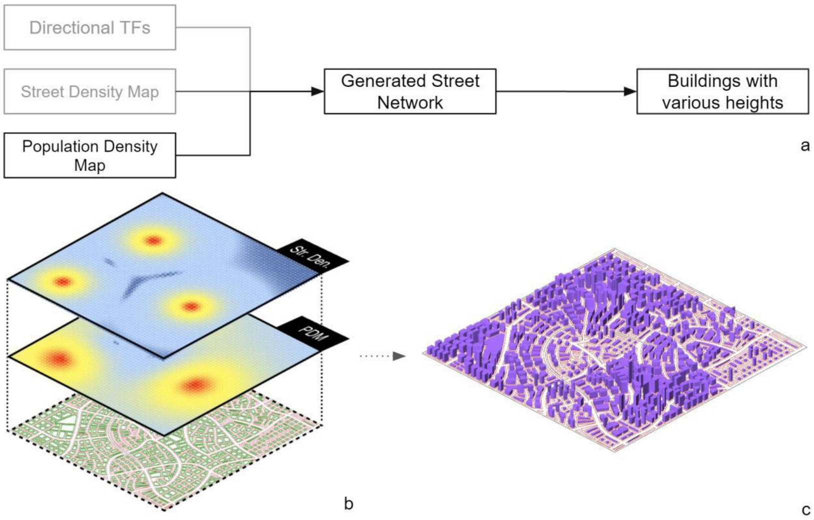


Figure 16a) The process of constructing buildings with varying heights. b) The input to the PDM, aligned with the street density map prior to generating the street network. c) The resulting 3D city model.

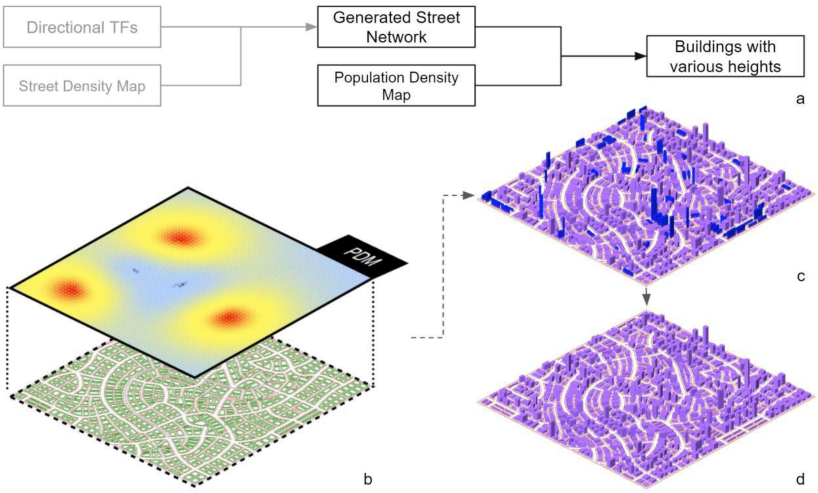


Figure 17 a) The process of constructing buildings of different heights. b) The PDM input, which may not align with the street density map, along with the generated street network. c) The created 3D city model. d) The outcome after incorporating building area constraints.

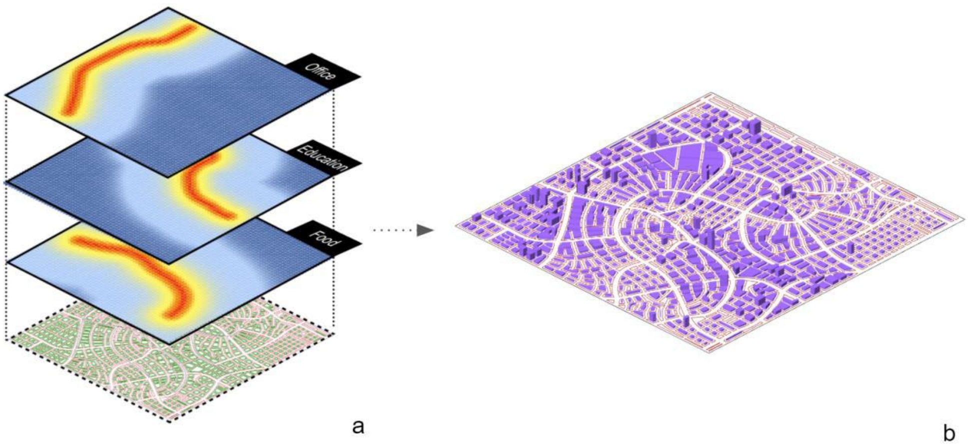


Figure 18 a) Integration of amenity features with the road network. b) Created 3D city model.

2. *A methodology for urban planning generation: A novel approach based on generative design*

Using generative design concepts as its foundation, this process divides a given plot and places several dwelling typologies on it to produce urban design alternatives. To produce solutions within a specified shape, style, and proportion, among other constraints, the suggested software needs 3D urban model files as a reference. It also needs input from the planner to direct the program following project specifications and established local norms.

1. The first step consists of the generation of a 3D parametric model, which contains encoded urban planning know-how and deals with two main tasks: first the subdivision of a plot into smaller parcels and later the allocation of different housing units into these parcels.

2. The second step deals with the collection of parameter values such as zoning plan constraints, planer design objectives, and other parameters obtained from a referenced 3D urban model. The pipeline for collecting this information is through a user interface.

3. The third step deals with the combination of the input parameters into fitness functions. To achieve a correct combination, a correlation analysis between the parameters is performed.

4. Finally, the optimization of the parametric model is performed based on the values of the fitness functions. Urban variants are obtained as the optimization result. (Ignacio Pérez-Martínez, 2023)

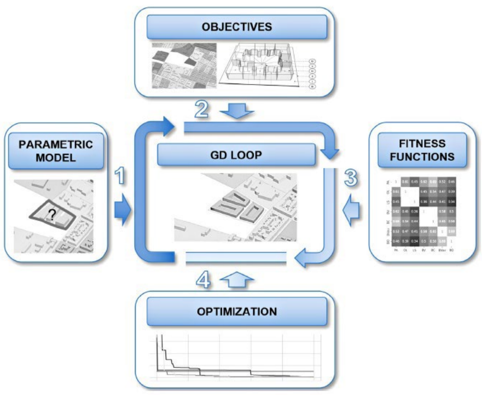


Figure 19 Methodology structured in 4 steps

Figure 20 3D parametric model parts

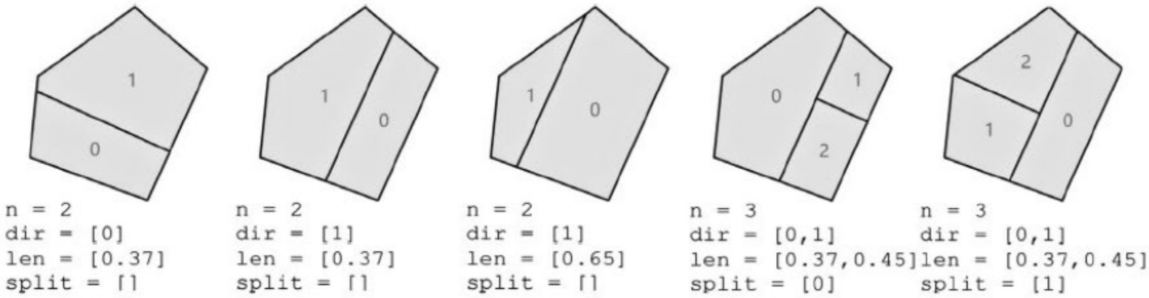


Figure 21 Plot subdivision

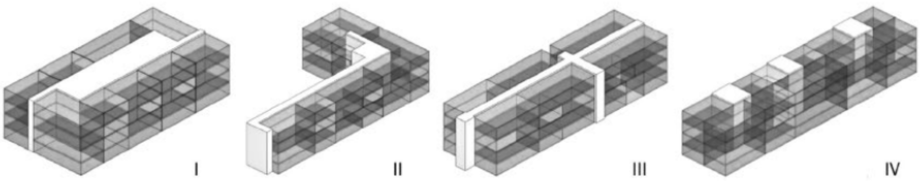


Figure 22 Housing Typologies

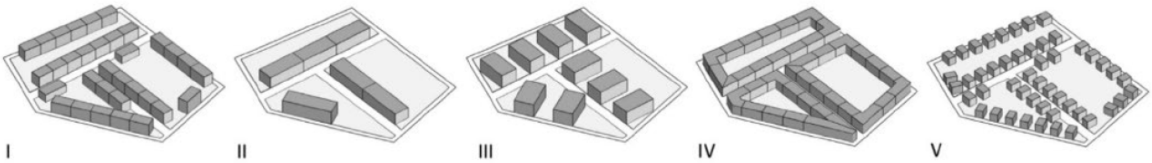


Figure 23 Location Typologies

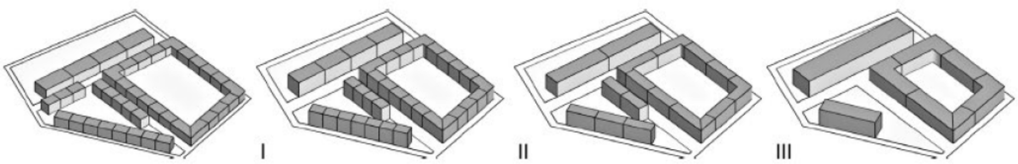


Figure 24 Model Parameters

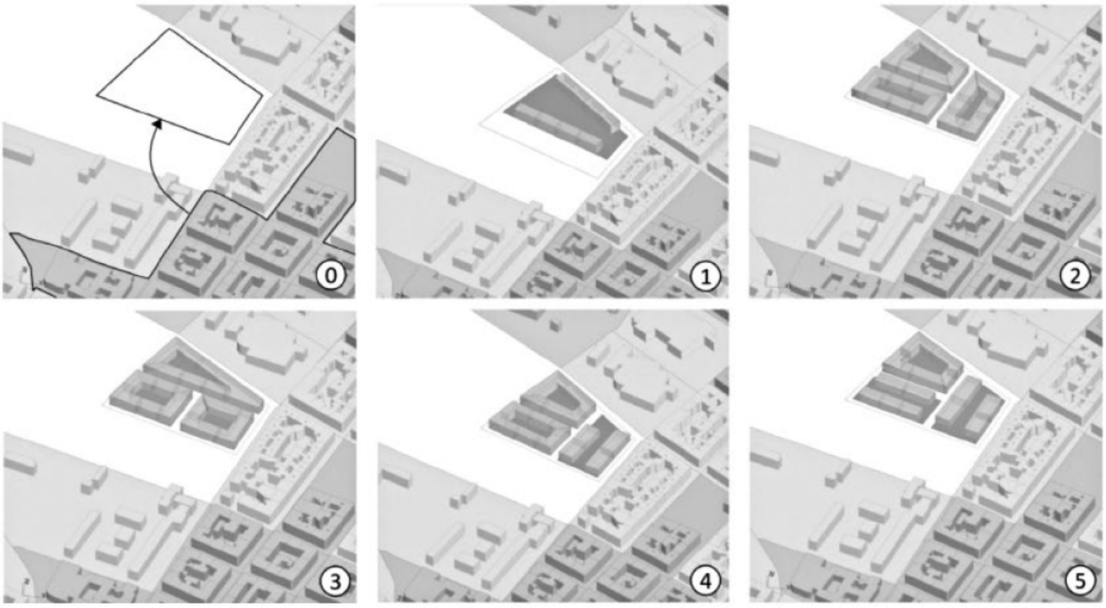


Figure 25 Process of Generation

3. *Generative design and performance modeling for relationships between urban built forms, sky opening, solar radiation, and energy*

This study attempts to answer the following question: by taking into account all possible options for urban design, what are the links between many independent factors of geometric urban form and multiple dependent variables of performance? Creating a model of urban design choices based on knowledge about geometric urban form and combined multi-performance criteria is the main goal of the project. The test bed was the Georgia Institute of Technology's international campus in Shenzhen, China. This study's findings advance the field of performance-based urban design. The connections between performance standards and urban geometric forms will serve as a framework for creating a sustainable campus.

This research evaluates the three performance measurements, sky opening, solar radiation, and thermal loads, in a single Grasshopper script to automate the three major performance criteria by considering topography as well as geometric element generated from reinforcement learning. This provided a computational pipeline to connect the generative system and the analysis component.

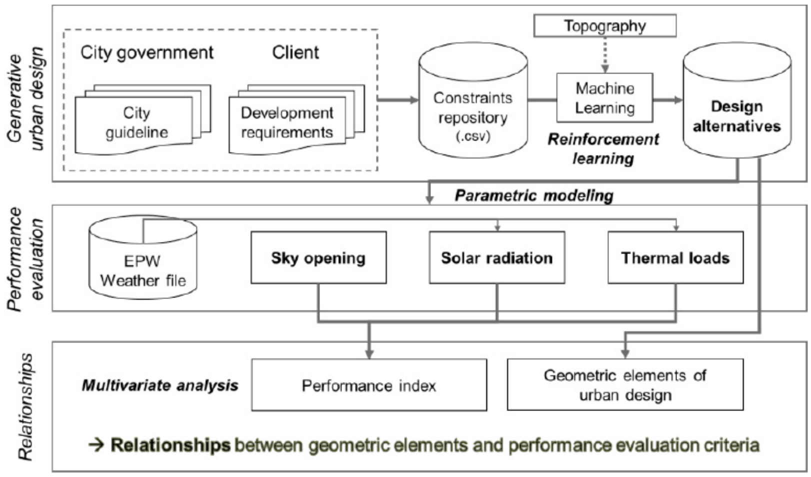


Figure 26 Proposed methodology

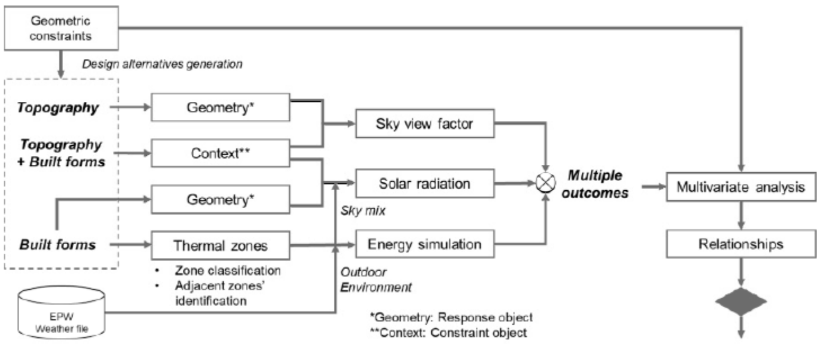


Figure 27 Overall methodology

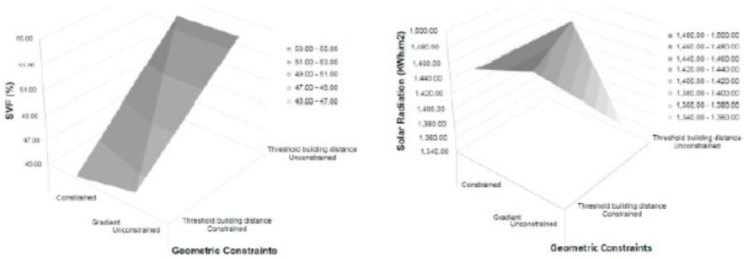


Figure 28 Comparison of generations SVF(left) and Solar Radiation (right)

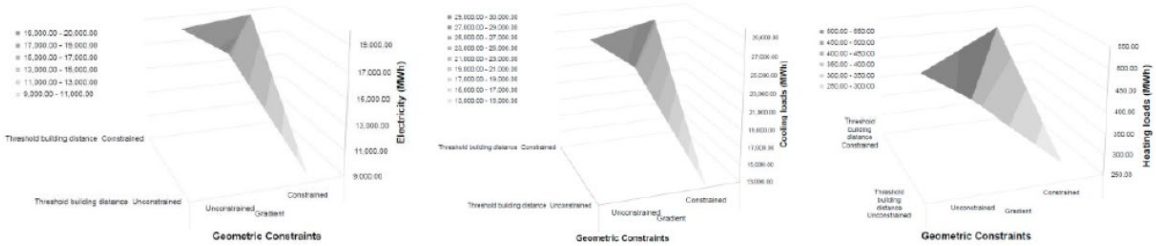


Figure 29 Comparisons of generations for the expectes energy consumption electricity(left), cooling (middle), and heating(right)

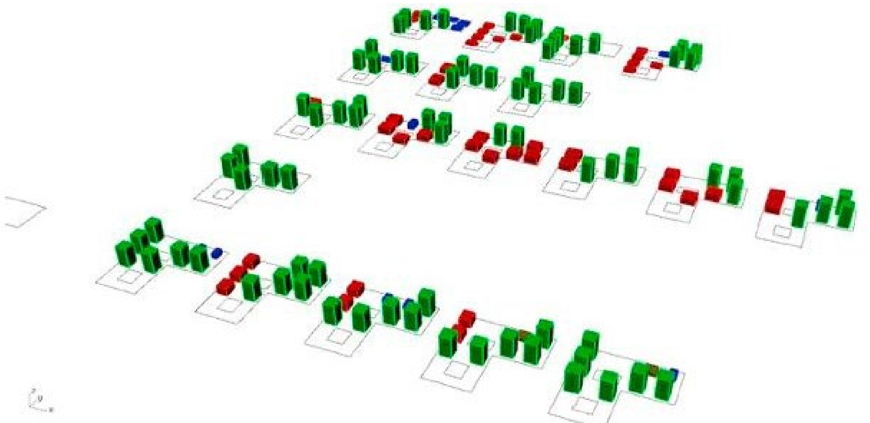


Figure generated design alternatives

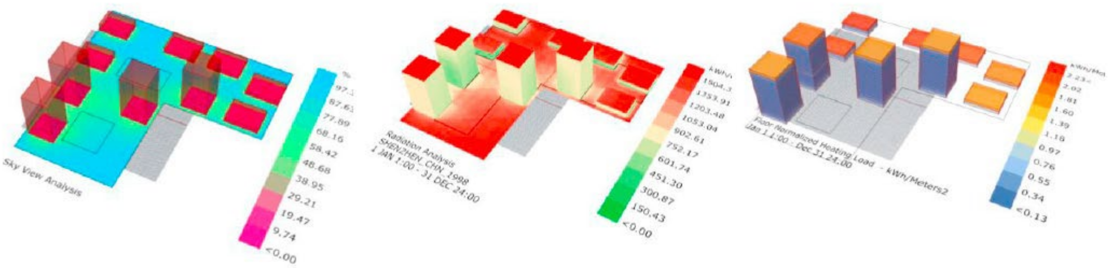
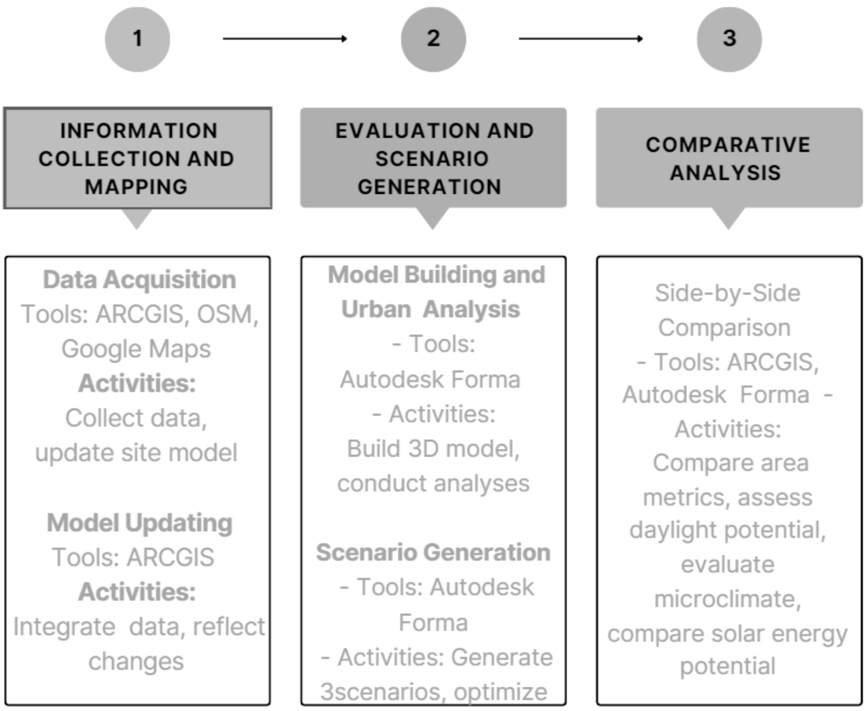


Figure 30 SVF (left), solar radiation(middle), and thermal loads (right) generations

CHAPTER 3

METHODOLOGY

3.1 Comprehensive structure and algorithmic tools



In this section of the thesis is presented a detailed overview of the three phases of the research framework and the tools employed throughout the study.

Phase 1: Information Collection and Mapping

The first phase involves the comprehensive collection and mapping of data for the selected area. ArcGIS software is a robust Geographic Information System (GIS) for efficient data management and spatial analysis. Using ArcGIS, the following steps were undertaken:

- *Data Acquisition:*

Data was gathered from various sources, including OSM (OpenStreetMap) and Google Maps imagery, to ensure that the site context model was up-to-date and accurate.

- *Model Updating:*

The collected data was integrated into ArcGIS to reflect the latest changes in the site's layout and infrastructure. This integration was crucial for creating a reliable base model for further analysis.

Phase 2: Evaluation and Scenario Generation

The second phase focused on the evaluation of the existing Grimshaw Project and the generation of alternative scenarios. This phase was divided into two key steps:

- *Model Building and Urban Analysis:*

Using Autodesk Forma, a detailed 3D model of the Grimshaw Project was built. Autodesk Forma was chosen for its advanced modeling capabilities and suitability for conducting urban analyses.

Various urban analyses were performed on the Grimshaw Project model, assessing factors such as building density, green space distribution, and transportation infrastructure.

- *Scenario Generation:*

Based on the analyses, three different design scenarios using Autodesk Forma were generated. This software facilitated the exploration of various design possibilities and configurations, allowing comparisons for multiple urban planning criteria.

Phase 3: Comparative Analysis

The final phase involved a comparative analysis of the generated scenarios and the original Grimshaw Project. This phase was essential for evaluating the effectiveness and feasibility of each design alternative. The comparison was conducted as follows:

- *Side-by-Side Comparison:*

The generated scenarios and the Grimshaw Project were compared across several key metrics, including area metrics (Gross Floor Area, Gross Internal Area, Net Internal Area), daylight potential, microclimate conditions, and solar energy potential.

Tools such as ArcGIS and Autodesk Forma were used to visualize and quantify these comparisons, providing a clear and objective basis for evaluation.

By employing these tools and following this structured framework, a systematical assessment and evaluation of the urban design proposals could be made, ensuring a comprehensive and data-driven approach to urban planning.

- *Tools Used:*

ArcGIS: ArcGIS is a geographic information system (GIS) software that allows users to create, manage, analyze, and map spatial data. It helps visualize geographic information, perform spatial analysis, and share data and maps, supporting decision-making across various fields such as urban planning, environmental management, and transportation.

OSM (OpenStreetMap): OpenStreetMap (OSM) provides a free, editable map of the world created and maintained by a community of mappers. It offers detailed and accurate geographic data, including streets, buildings, and landmarks, which can be used for navigation, urban planning, and various location-based applications.

Google Maps: Google Maps is a web-based mapping service that provides detailed maps, satellite imagery, and street views. It offers route planning, real-time traffic updates, and location searches, helping users navigate and explore places worldwide.

Autodesk Forma: Autodesk Forma's generative design capabilities empower architects and urban planners to explore a wide range of design solutions by leveraging advanced algorithms and computational power. The platform generates numerous design options based on specific criteria and constraints, enabling extensive exploration of possibilities through parametric modeling. It optimizes performance metrics, including energy efficiency, daylight access, structural integrity, and cost, with a strong focus on sustainability. By integrating real-time data from various sources, Autodesk Forma informs design decisions through contextual analysis and scenario testing. Its cloud-based nature facilitates collaboration, providing access to design data and tools from any location, and its robust visualization tools, including 3D modeling and virtual reality, enhance stakeholder engagement. Automated workflows streamline the design process, allowing designers to focus on creative and strategic aspects, while iterative feedback helps refine and improve designs quickly. Overall, Autodesk Forma supports informed decision-making and balanced solutions, ensuring holistic, innovative, and sustainable urban development.

This framework facilitated a thorough and efficient evaluation process, ensuring that all design scenarios were rigorously analyzed and compared.

3.2 Introduction of the study area

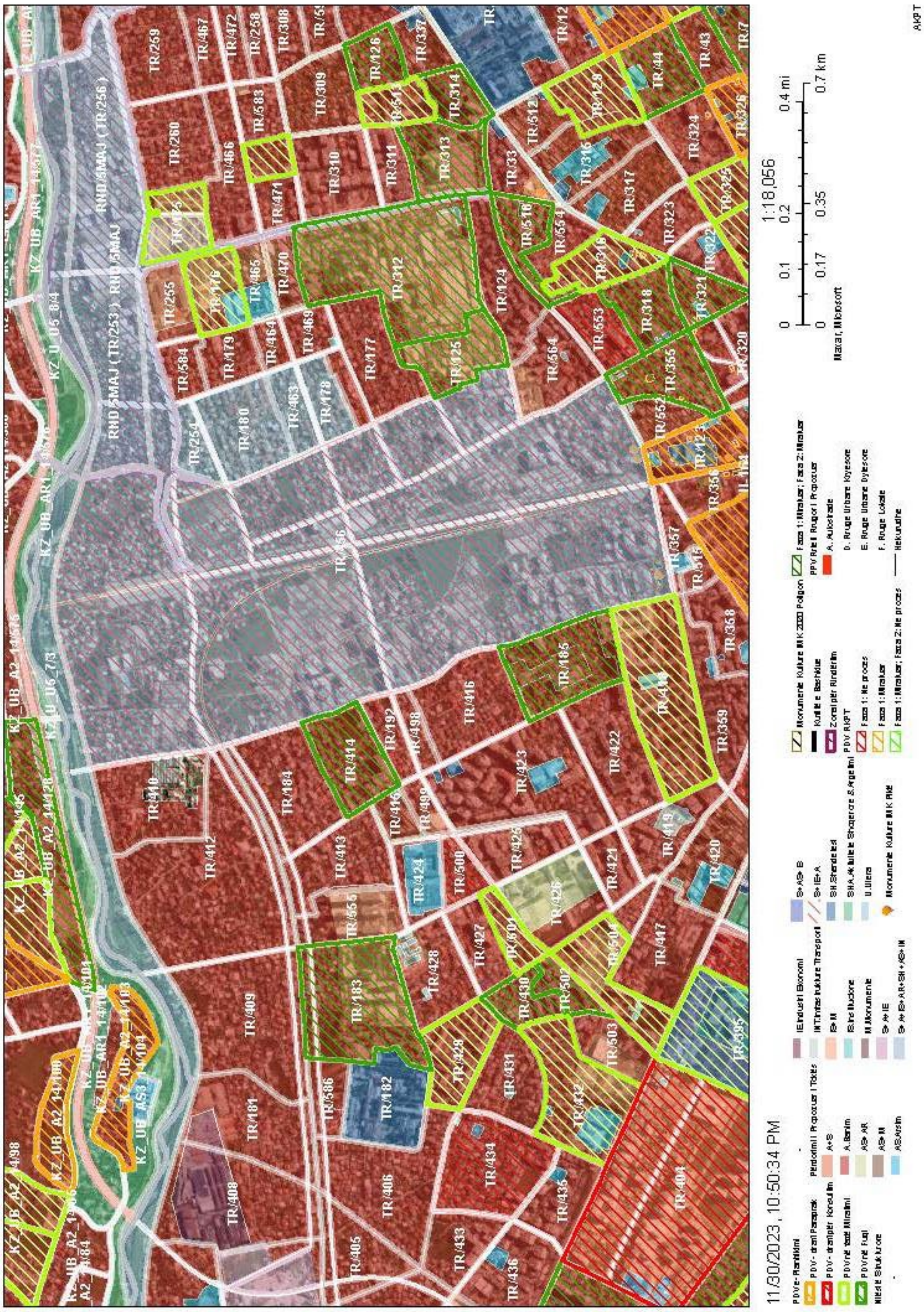


Figure 31 TR/456 Territorial Unit

The site is situated in an urban area on the periphery of Tirana, falling within the TR/456 Territorial Unit. This area is currently undergoing significant changes as part of the implementation of the Tirana Master Plan, designed by Grimshaw Architects. The master plan aims to transform and modernize the urban fabric, integrating sustainable and functional urban design elements. It emphasizes the creation of green spaces, improved infrastructure, and enhanced public transportation networks to support the city's growing population. The plan also includes mixed-use developments that combine residential, commercial, and recreational spaces, promoting a vibrant and dynamic urban environment. Overall, the Grimshaw plan seeks to create a more livable, resilient, and interconnected urban area that meets the needs of its residents while preserving the natural landscape and cultural heritage of Tirana.

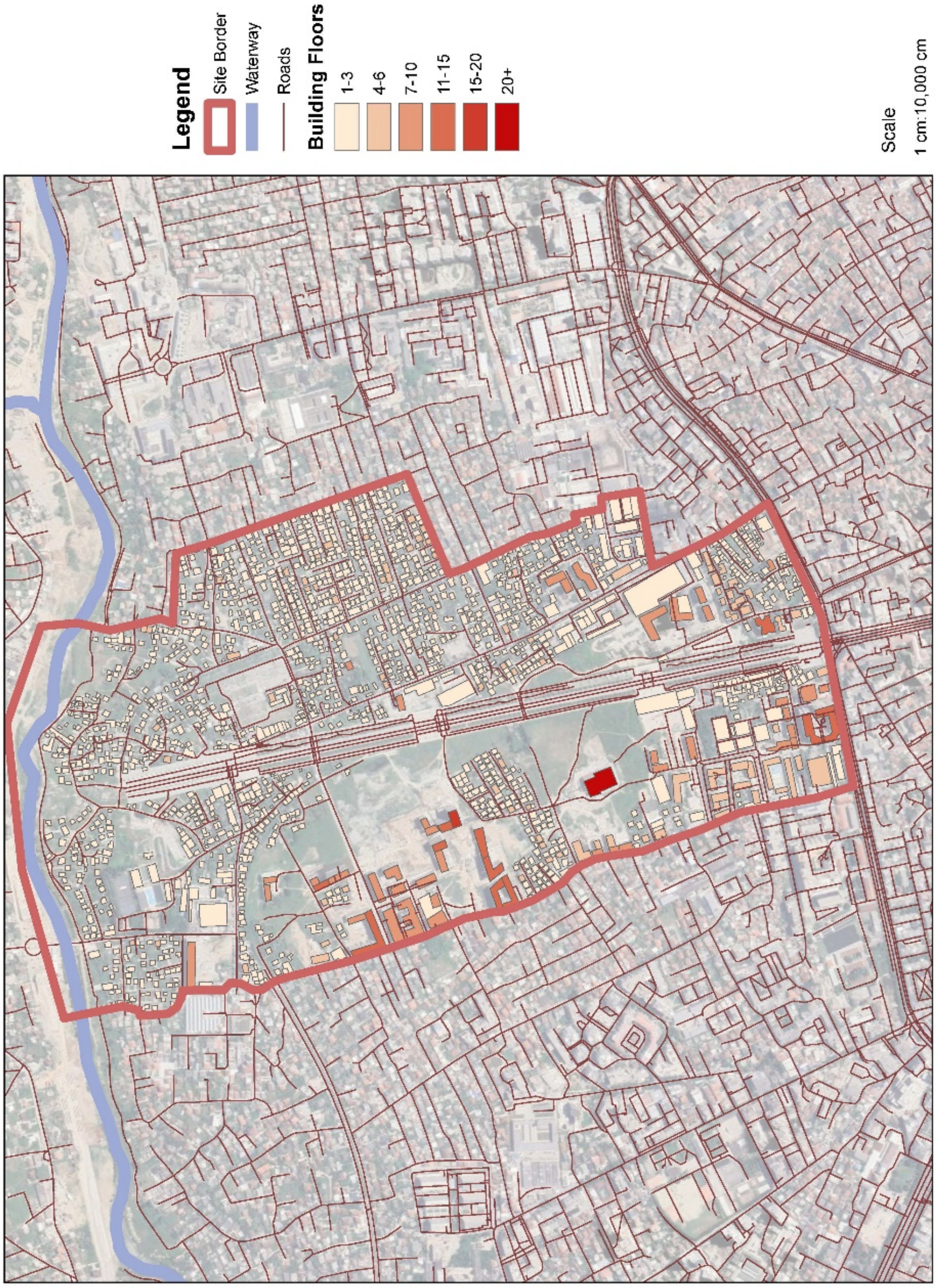


Figure 32 Building Floors

The buildings of the site are predominantly residential, constructed over the past 20 to 30 years. These buildings are generally low-rise, with heights ranging from one to three floors. This modest building height contributes to a relatively uniform skyline, typical of suburban residential areas. The highest buildings are currently under construction according to the Grimshaw project.

Figure 33 Greenery

The site features informal greenery, with trees primarily located in private house gardens and scattered along the boulevard. These green spaces, although not formally planned, contribute to the area's overall aesthetic and environmental quality. The informal nature of the greenery indicates a potential area for development within the master plan, which could include formal parks and public green spaces to enhance urban livability.

Figure 34 Road Network

The site's main circulation axis is the newly constructed "Bulevardi I ri" (New Boulevard). This road is a central feature of the area's transportation infrastructure, providing improved accessibility and connectivity to other parts of Tirana. The boulevard is designed to facilitate efficient vehicular movement while also accommodating pedestrians and cyclists, reflecting the modern urban planning principles emphasized in the Tirana Master Plan.

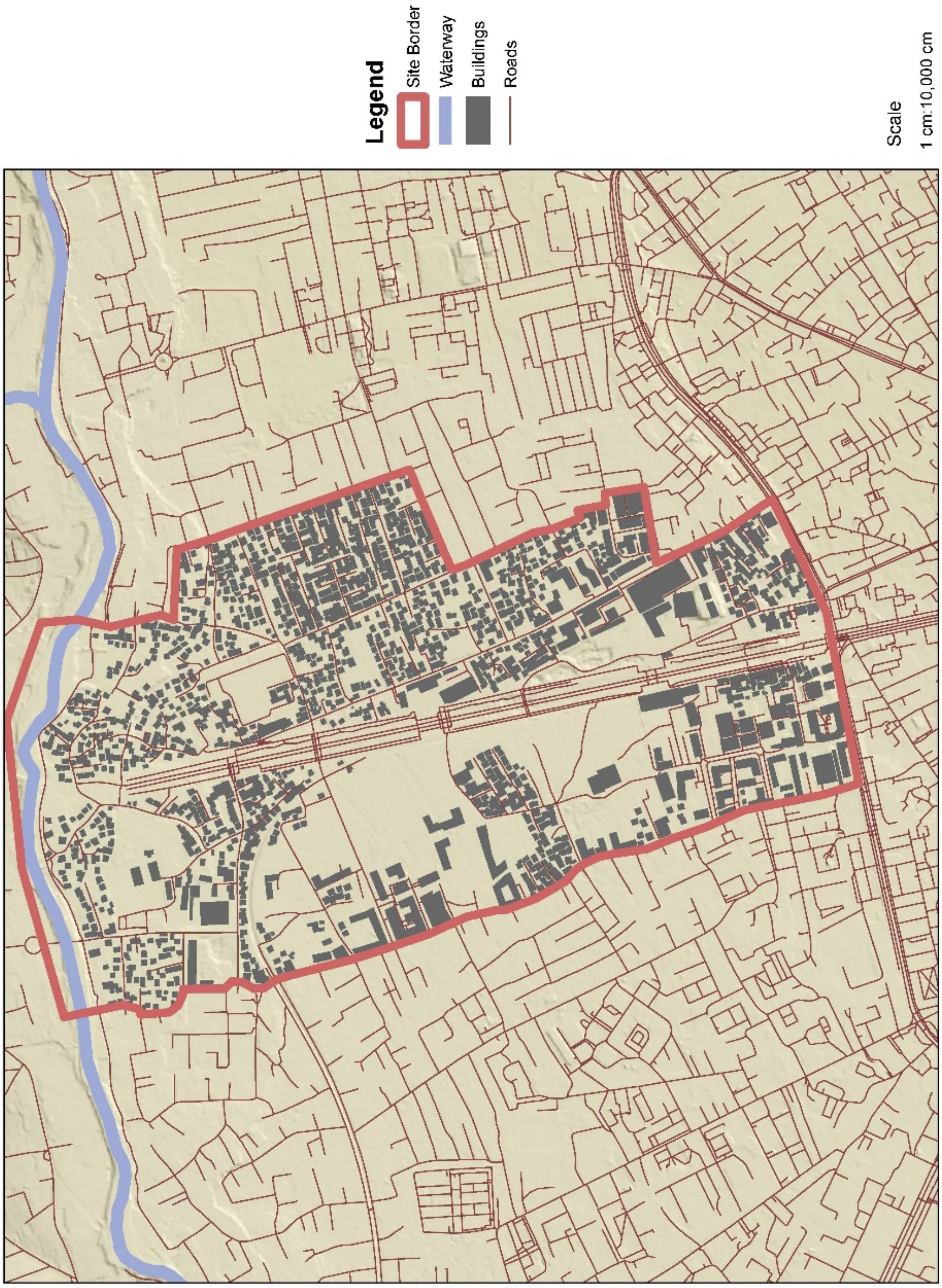


Figure 35 Topography

The site's flat topography offers ideal opportunities for wide streets, expansive parks, and accessible infrastructure. This type of terrain is well-suited for biking, walking, and other forms of transportation, contributing to a convenient and user-friendly urban environment.

CHAPTER 4

4.1 Introduction

This part consists of a thorough analysis of the Grimshaw proposal, building the corresponding 3d model using Autodesk Forma and then evaluating its performance based on Sun Hours, Daylight Potential, Wind Analysis, Microclimate and Annual Solar Energy Potential.

4.2 Analysis of the Grimshaw Proposal

The Grimshaw proposal for the new Boulevard of Tirana is a comprehensive urban development plan aimed at revitalizing the city's infrastructure and public spaces. The project is part of a broader master plan to transform central Tirana with a focus on sustainability, connectivity, and cultural integration. Key elements of the proposal include:

Boulevard Extension: The historic north-south axis of the boulevard will be extended by an additional 3 kilometers, connecting Skanderbeg Square to the two large lakes of Tirana. This extension aims to enhance urban connectivity and better integrate various parts of the city (Grimshaw, 2015).

Riverside Park: A new 7-kilometer riverside park along the Tirana River is planned, turning the river into a central feature of the city. This park will offer recreational spaces, improve ecological health, and provide flood control measures (Arquitectura Viva, 2012).

Urban Living Rooms: The design introduces a series of public spaces, referred to as "urban living rooms," along the boulevard. These areas are designed to reflect the outdoor culture of Tirana, providing spaces for social interaction, public art, and community activities. Each space will have a distinct character and use, creating a "symphony of squares" (Grimshaw, 2015).

Sustainability and Green Spaces: Emphasis is placed on sustainability, with extensive green spaces and eco-friendly design elements. The plan includes green infrastructure, such as parks and tree-lined streets, which aim to enhance urban biodiversity, reduce heat islands, and improve air quality (Furuto, 2012).

Public Transportation and Walkability: The proposal integrates efficient public transportation options and promotes walkable neighborhoods. The aim is to reduce traffic congestion and promote sustainable modes of transport, such as cycling and walking, making the city more accessible and environmentally friendly (Arquitectura Viva, 2012).

Cultural and Social Integration: The design respects Tirana's cultural heritage while introducing modern elements. It aims to create spaces that are not only functional but also culturally significant, fostering a sense of community and belonging among residents (Furuto, 2012).

Economic and Social Benefits: The master plan is expected to stimulate economic growth by creating attractive urban spaces that draw businesses, tourists, and residents. The focus on public spaces and transport infrastructure is designed to improve the quality of life and make Tirana a more vibrant and livable city (Arquitectura Viva, 2012).

Figure 36 Grimshaw Proposal

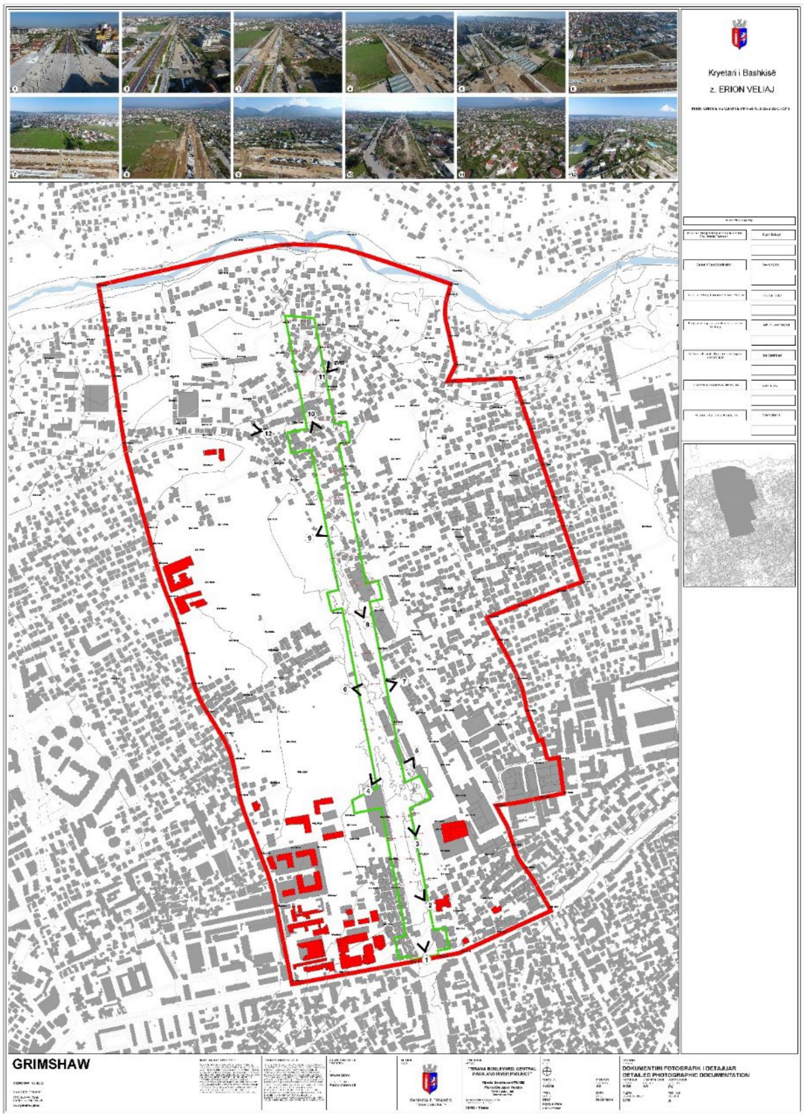


Figure 37 Detailed Photographic Documentation

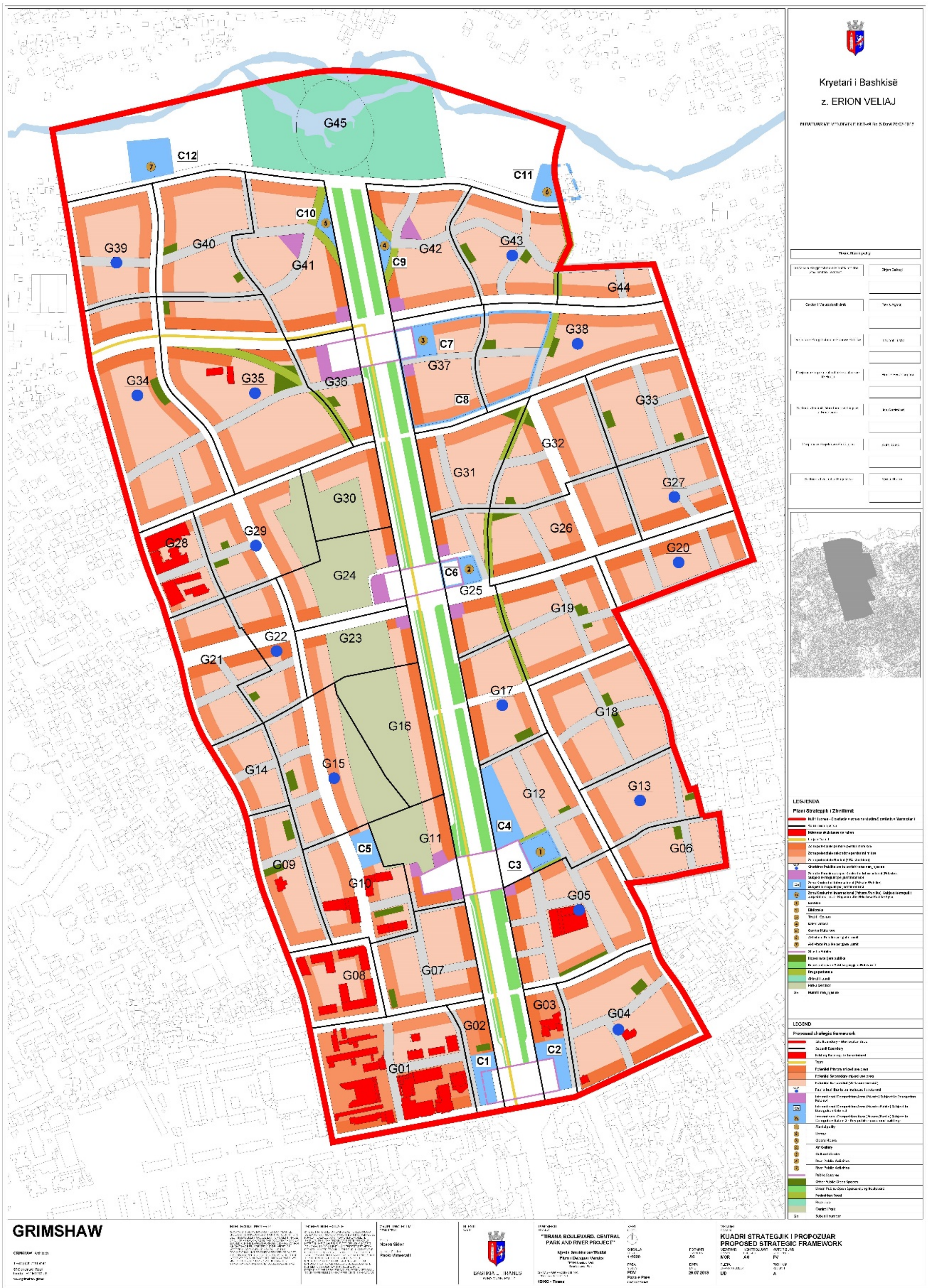


Figure 38 Proposal of Strategic Framework

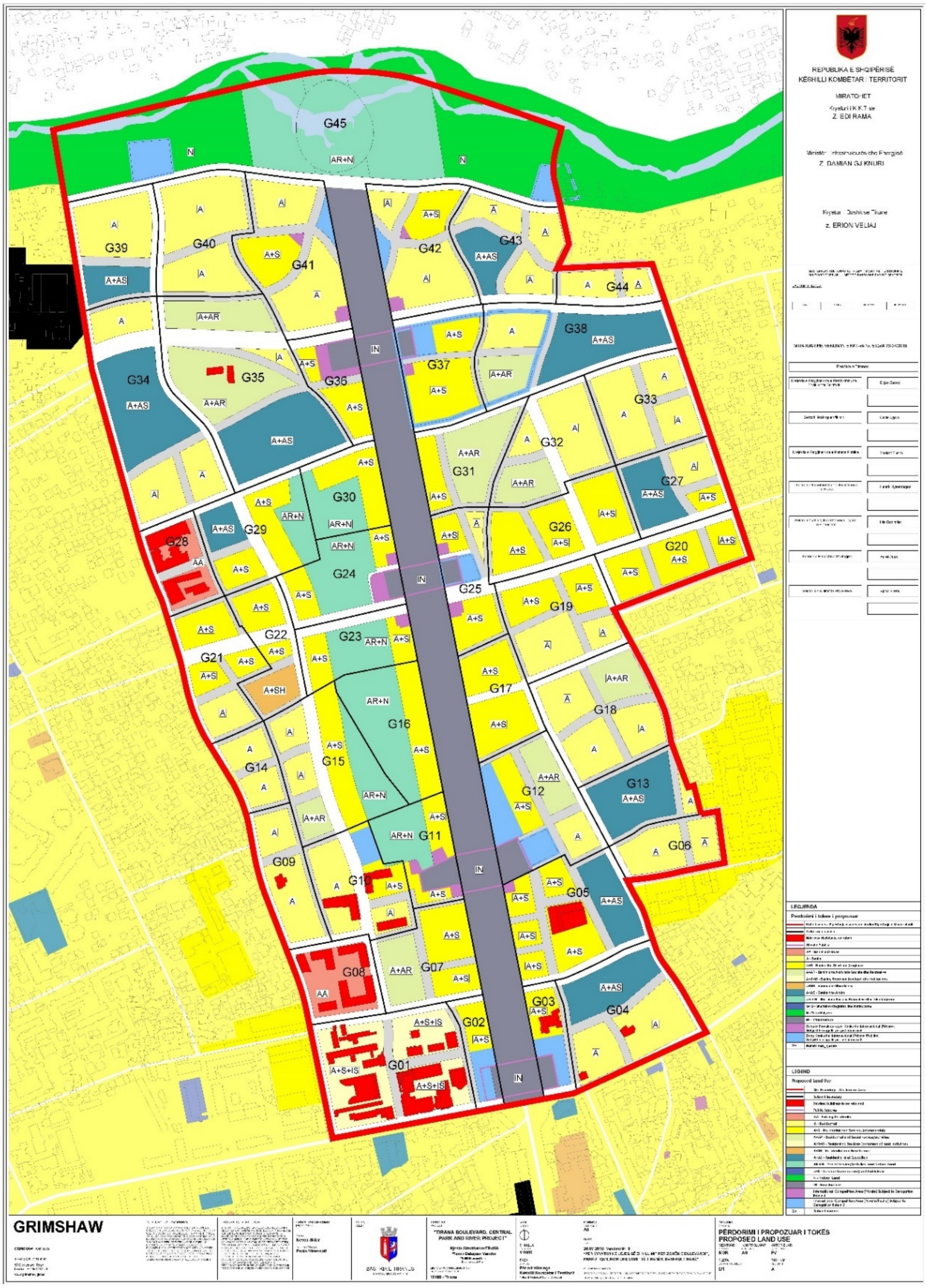


Figure 39 Proposed Land Use

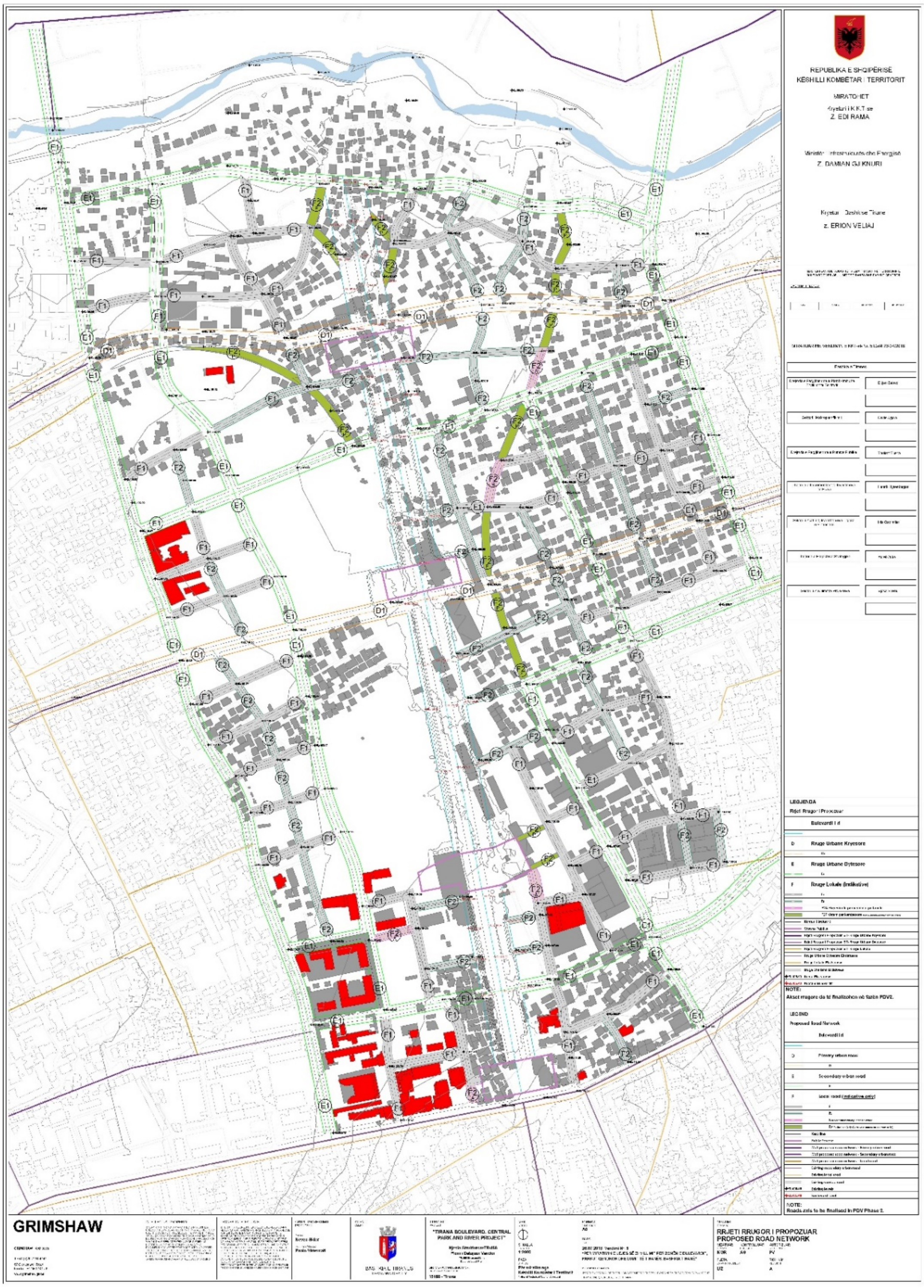


Figure 40 Proposed Road Network

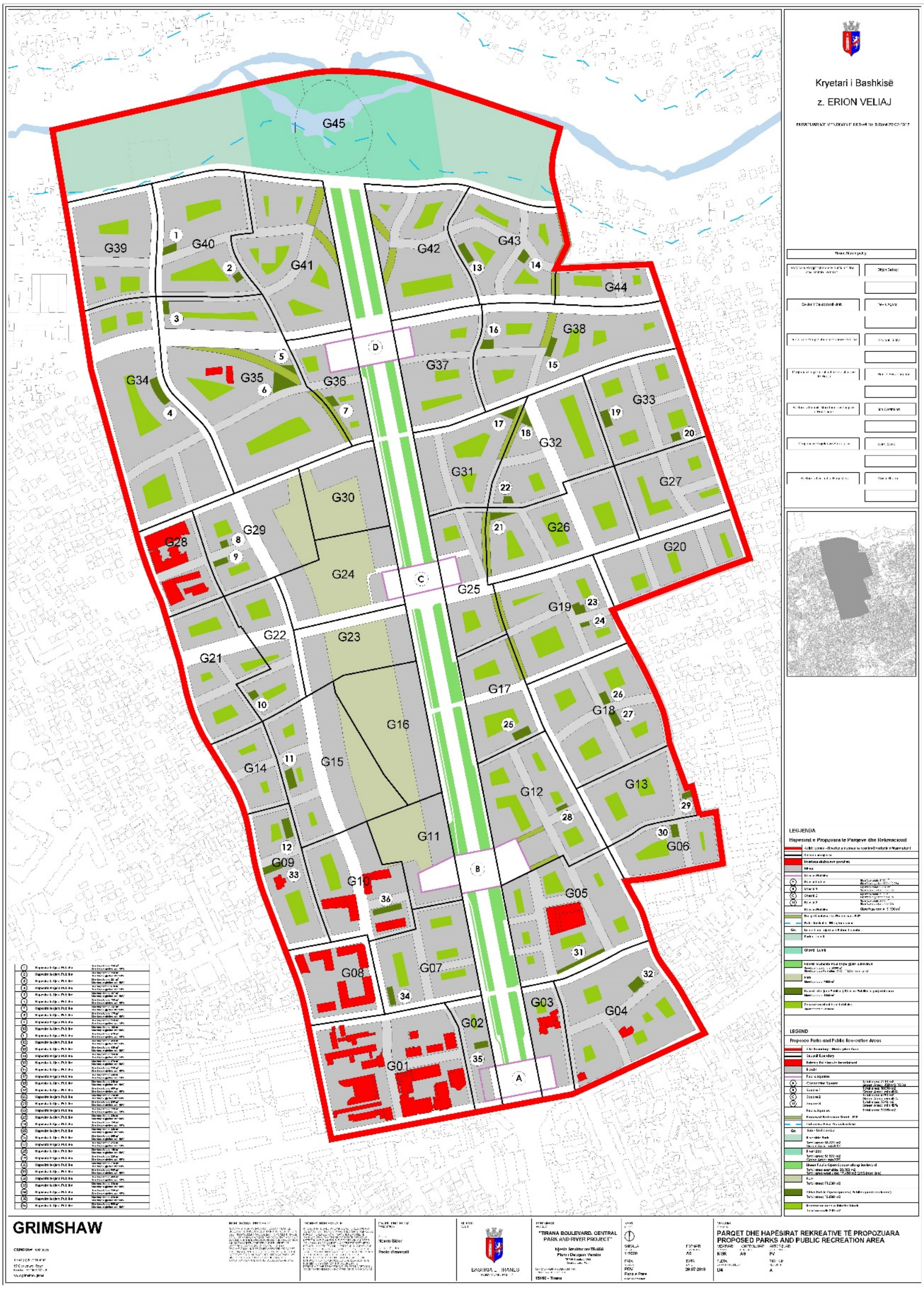


Figure 41 Proposed Parks and Public Recreation Areas

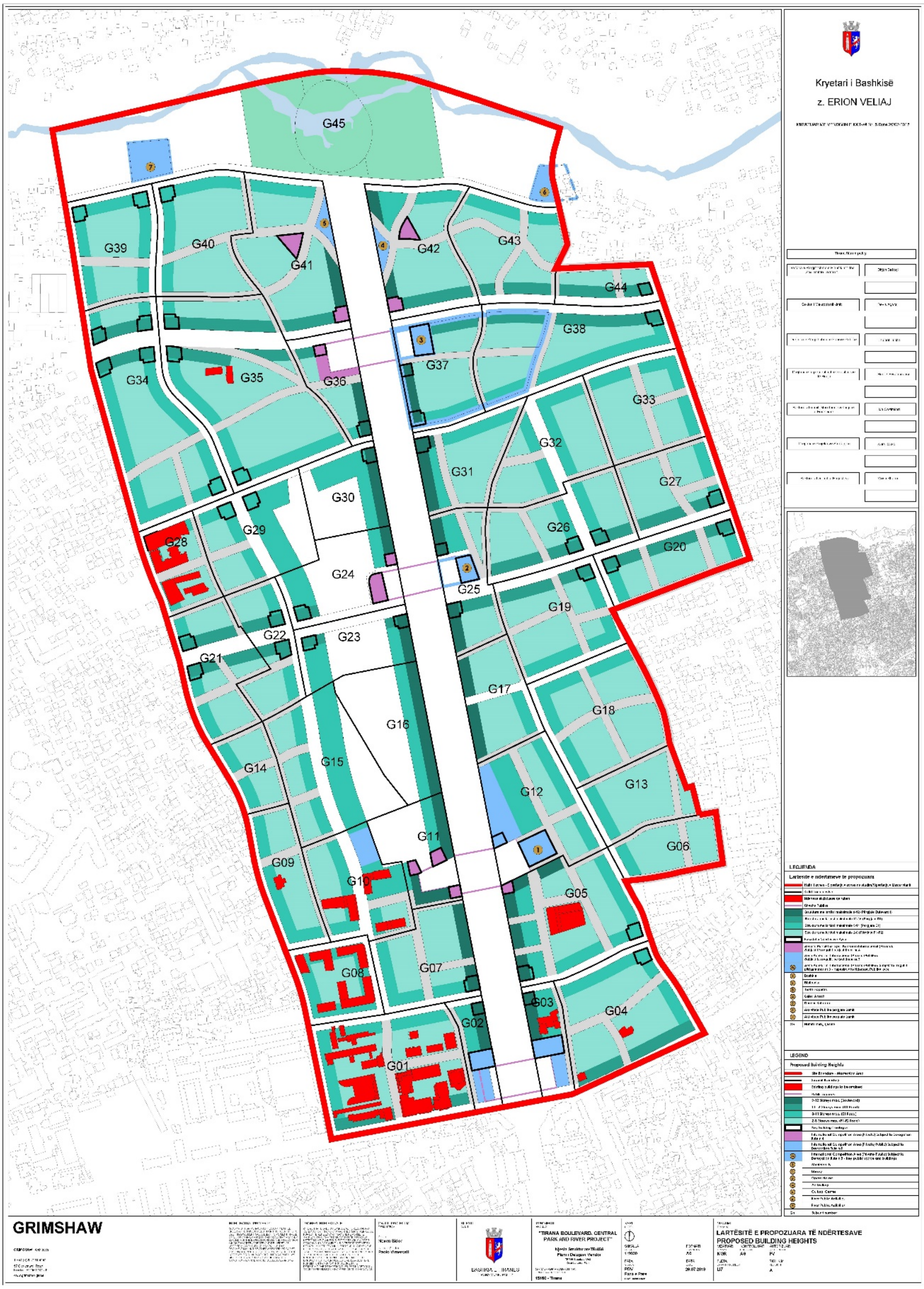


Figure 42 Proposed Building Heights

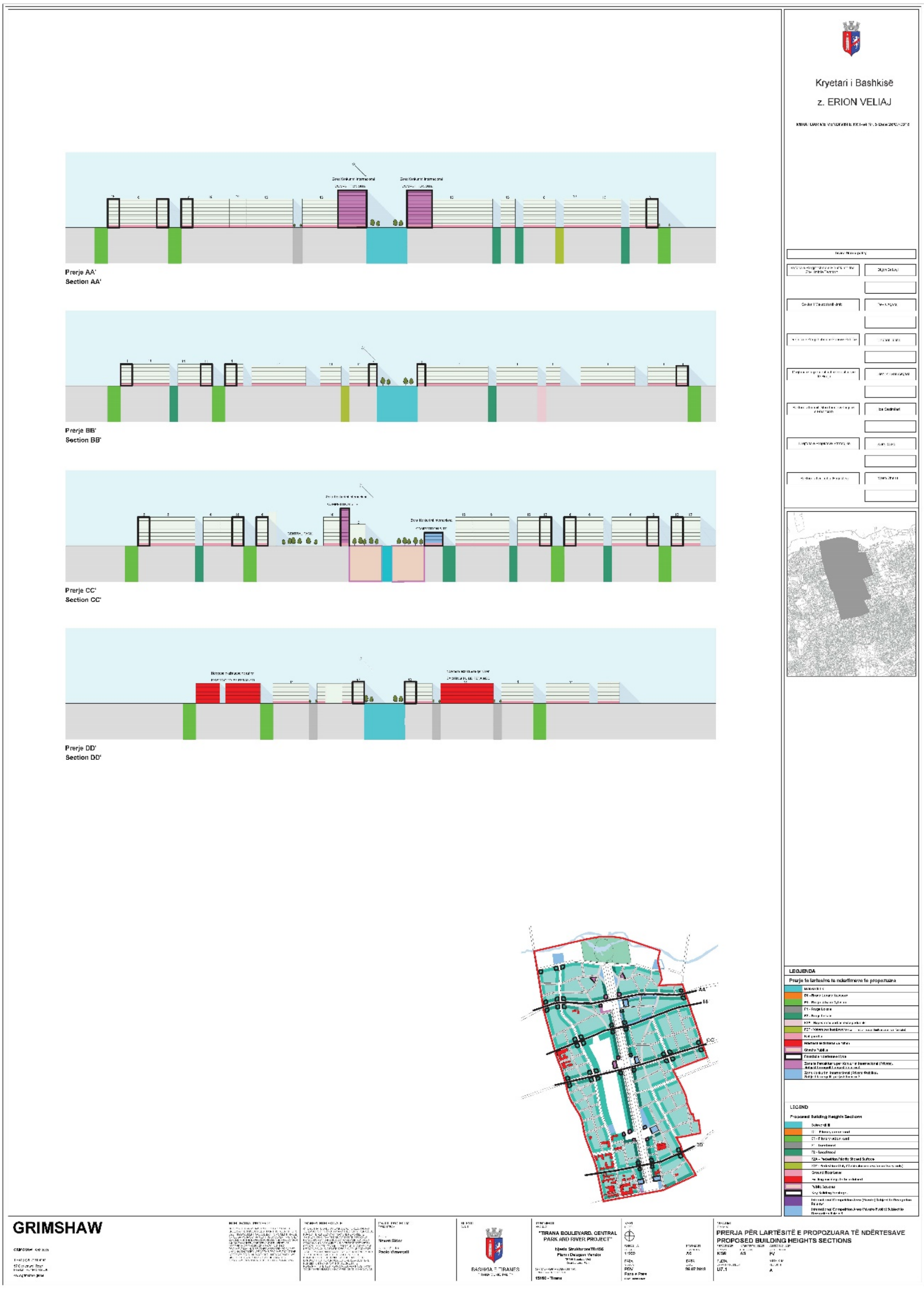


Figure 43 Proposed Building Heights Sections

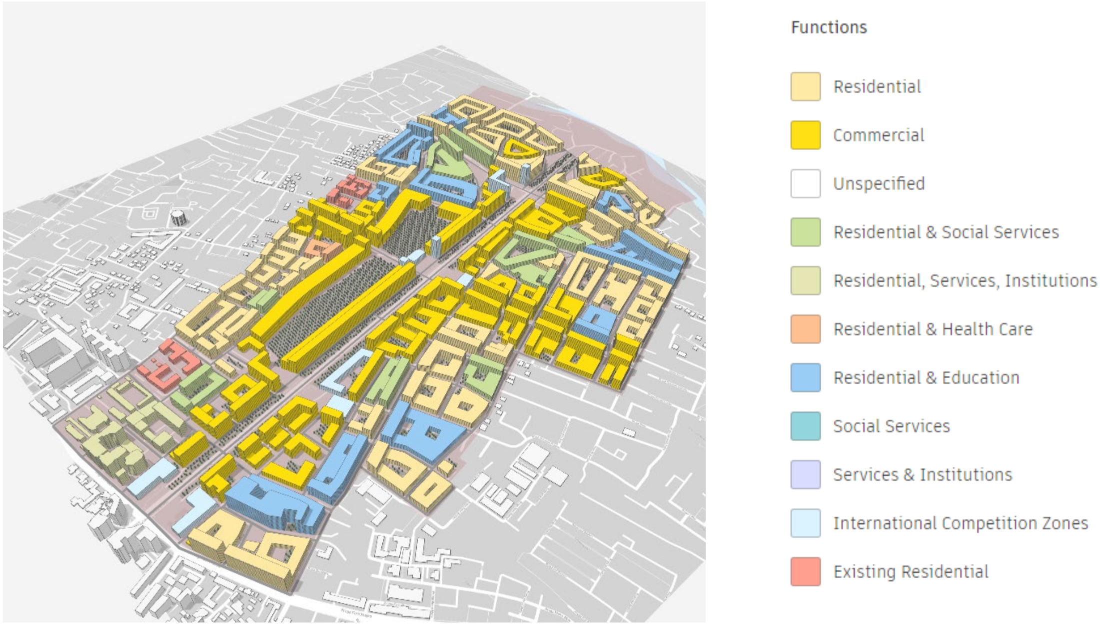


Figure 44 Proposed Block Functions

Figure 45 GFA (Gross Floor Area)

4.2.1. Sun Hours

Figure 46 Sun Hours, March 21

Figure 47 Sun Hours, June 21

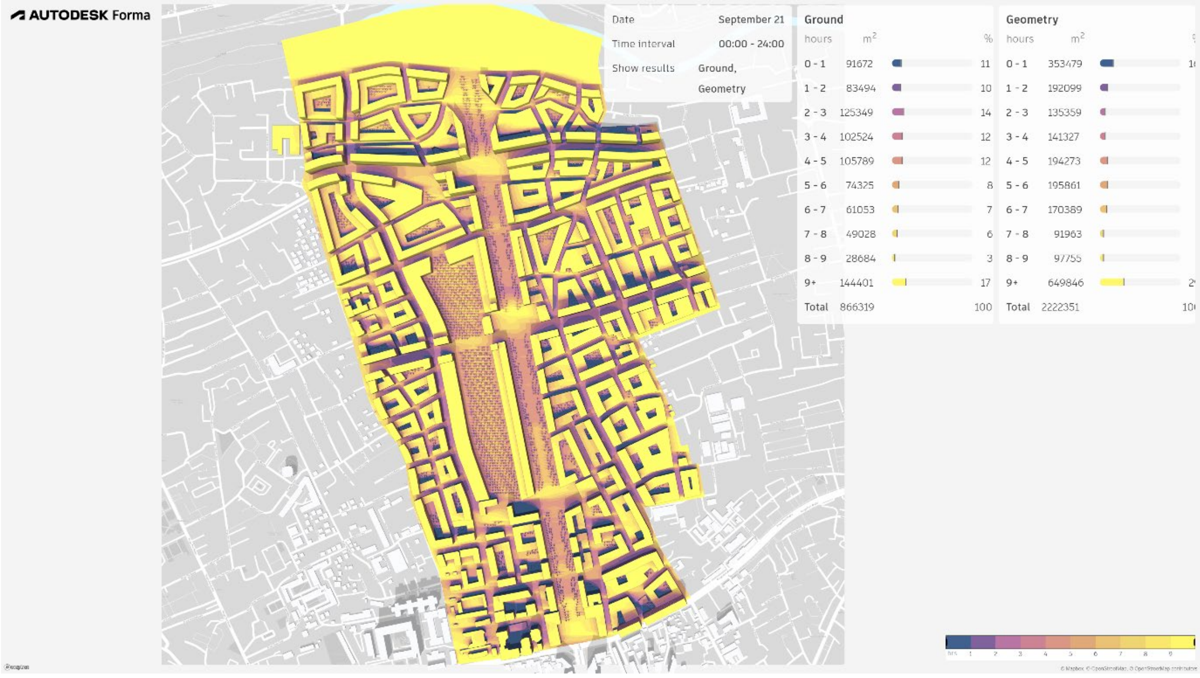


Figure 48 Sun Hours, September 21

Figure 49 Sun Hours, December 22

The Sun Hour Analysis conducted on the site during the equinoxes and solstices reveals significant issues with the current design geometry. The positioning of higher buildings on the perimeters of the blocks creates substantial shading problems for the lower-rise buildings situated within the interior of these blocks. This shading is particularly problematic during the winter solstice when the sun is at its lowest angle, and even during the equinoxes, when day and night are of equal length. This not only reduces the amount of natural light these buildings receive but also affects their potential for passive solar heating, increasing energy demands for lighting and heating. The insufficient natural lighting can affect the comfort and health of the occupants, reduce the buildings' appeal, and potentially violate local building codes and daylighting standards. This necessitates a re-evaluation of building heights and positioning to ensure equitable light distribution. There is a need to consider decreasing the height of buildings or increasing the spacing between them to allow for more sunlight penetration.

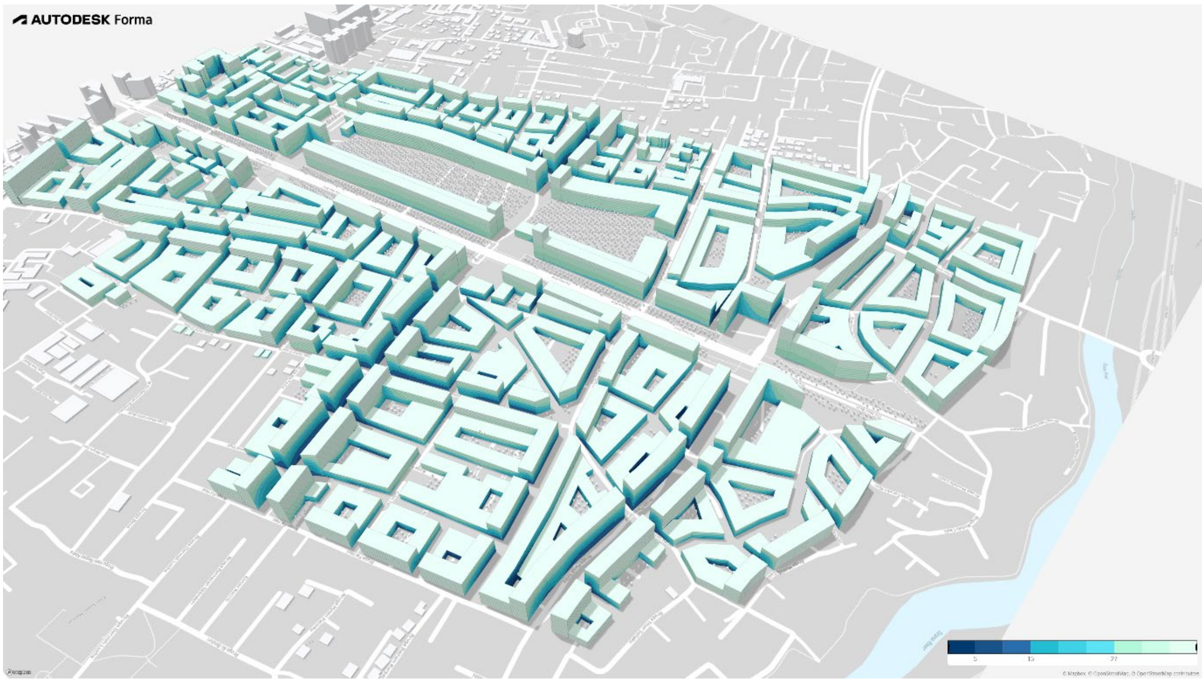
Potential Design Solutions:

Terracing and Setbacks: Implementing terraced building designs or setbacks can help ensure that lower-rise buildings receive more light by reducing the shadowing effect of higher buildings.

Strategic Placement of Open Spaces: Creating open spaces such as parks or plazas within the blocks can act as light wells, improving sunlight penetration to adjacent lower-rise buildings.

Use of Transparent or Translucent Materials: Incorporating materials that allow light to pass through, such as glass facades on higher buildings, can help reduce the shading impact.

4.2.2. Daylight Potential



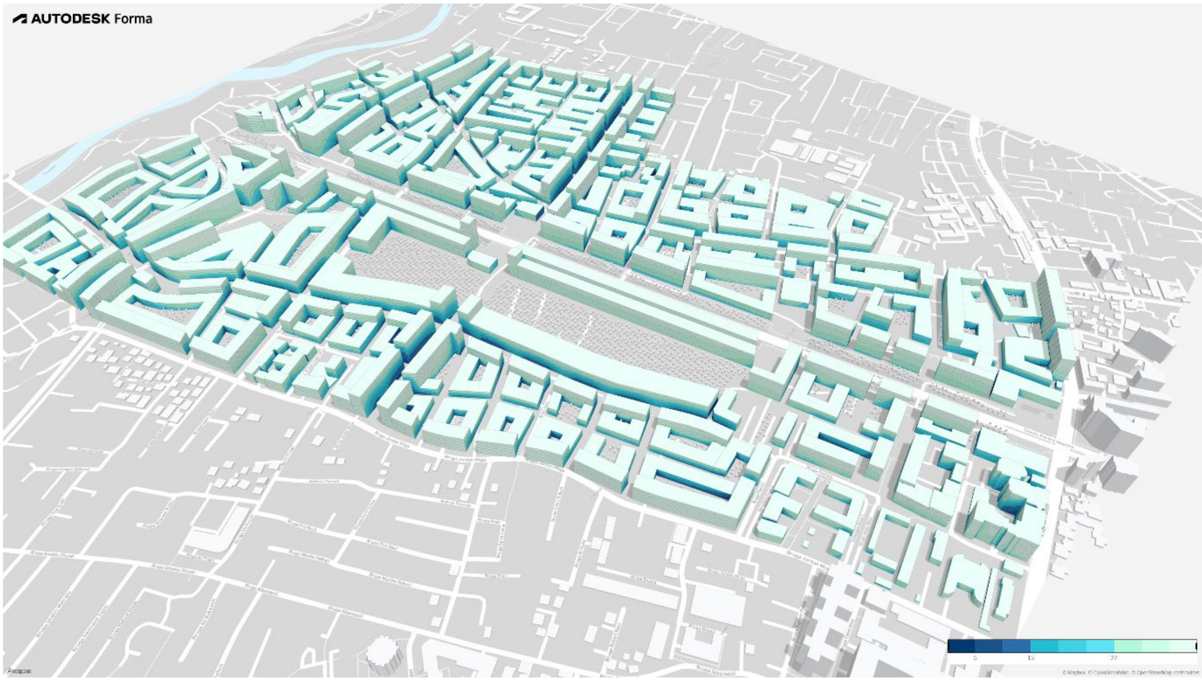


Figure 50 a,b Daylight Potential

The daylight potential analysis provides a crucial understanding of how the current urban design impacts natural light distribution. The darker shades on the map underscore the challenges faced by buildings in achieving optimal daylight, while the lighter shades illustrate the effectiveness of open spaces and lower density areas. By addressing these issues through thoughtful urban planning and design modifications, it is possible to create a more balanced and light-filled environment.

4.2.3. Wind Analysis

Figure 51 Point A, Wind Analysis

Figure 52 Point B, Wind Analysis

Data Integration and Simulation: Utilizing data from the Global Wind Atlas 3.0 allows for high-resolution, real-time simulations. This approach provides accurate predictions of wind comfort levels and directional flow across different surfaces. The integration of this data is crucial for understanding localized wind conditions and their effects on pedestrian comfort and building design.

Comfort Zones: The analysis employs a color-coded system to represent different levels of wind comfort:

Lighter Green: Indicates areas where the wind conditions are comfortable for walking. These zones are characterized by lower wind speeds and minimal turbulence, making them suitable for pedestrian activities.

Red: Highlights areas where wind conditions are uncomfortable for walking. These zones are affected by higher wind speeds and increased turbulence, posing challenges for pedestrian movement and comfort.

4.2.4. Microclimate Analysis

Microclimate analysis in urban design examines localized atmospheric conditions like temperature, wind patterns, solar radiation, and humidity to enhance human comfort and environmental quality. Utilizing data from sources like the Global Wind Atlas 3.0, this analysis helps identify areas of varying wind comfort and solar exposure, guiding planners to optimize building orientation, green infrastructure, and public spaces. By addressing issues like the urban heat island effect and wind turbulence, strategies such as adding green roofs, reflective surfaces, and shaded walkways can be implemented to create a more sustainable and comfortable urban environment.

The analysis below depict the microclimate conditions for January and July, representing the months with the lowest and highest temperatures, respectively. In January, the microclimate is characterized by comfortable conditions, likely due to moderate temperatures that provide a pleasant atmosphere for residents and visitors. Conversely, in July, the microclimate becomes uncomfortable, primarily due to the peak summer temperatures that result in excessive heat, making outdoor activities challenging and potentially hazardous. These variations highlight the seasonal extremes and their impact on the local environment and daily life.

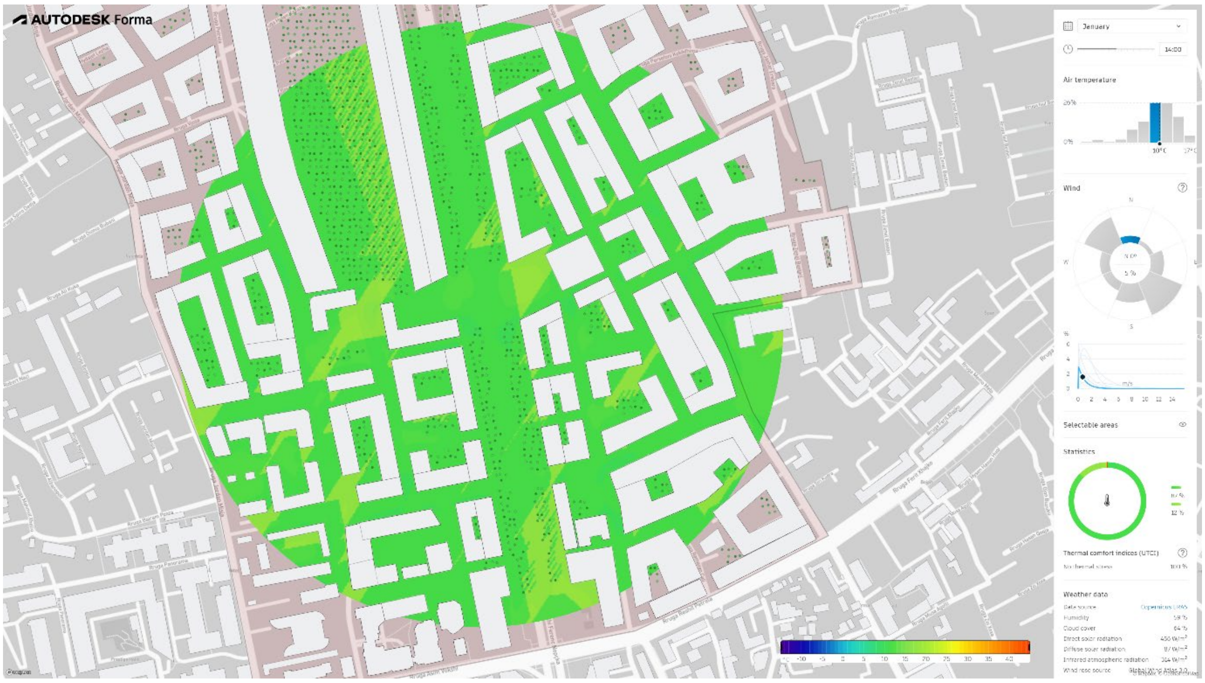


Figure 53 Point A, Microclimate Analysis, January

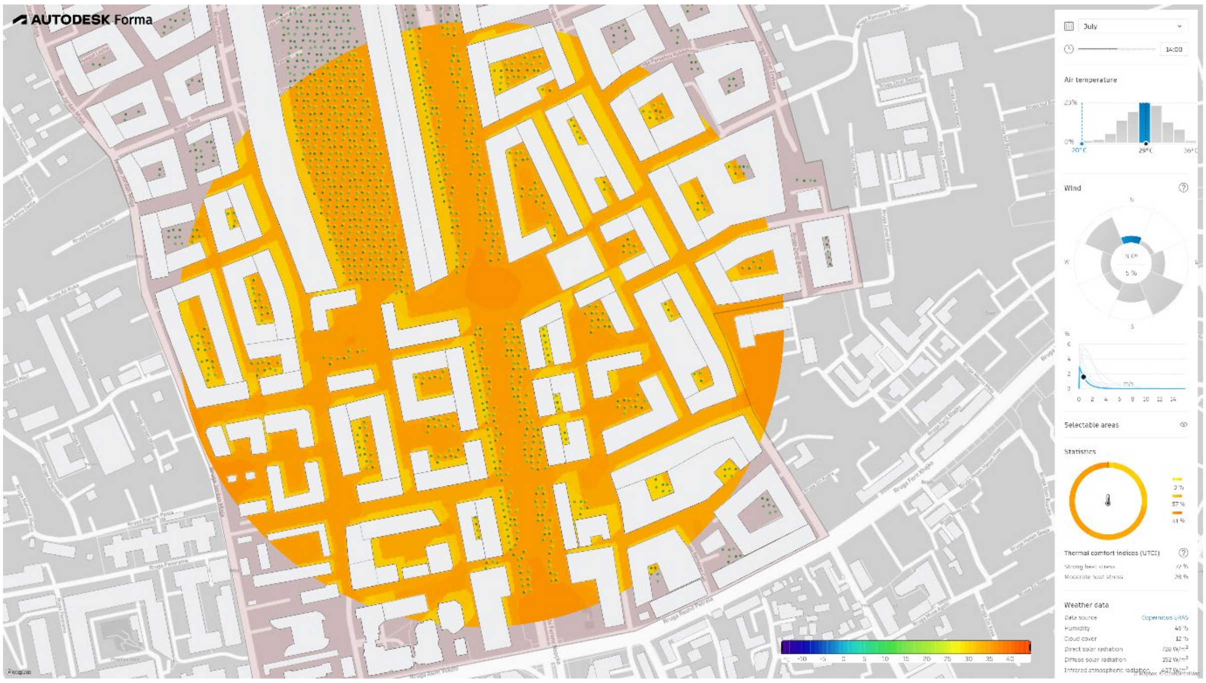


Figure 54 Point A, Microclimate Analysis, July

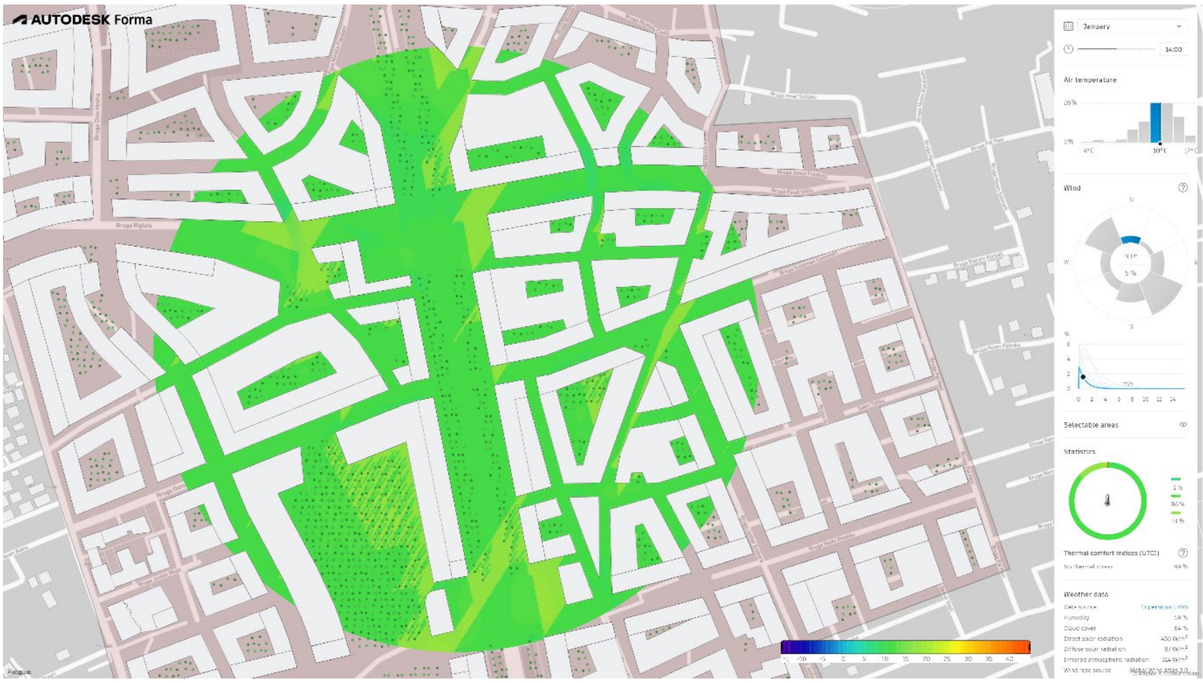


Figure 56 Point B, Microclimate Analysis, January

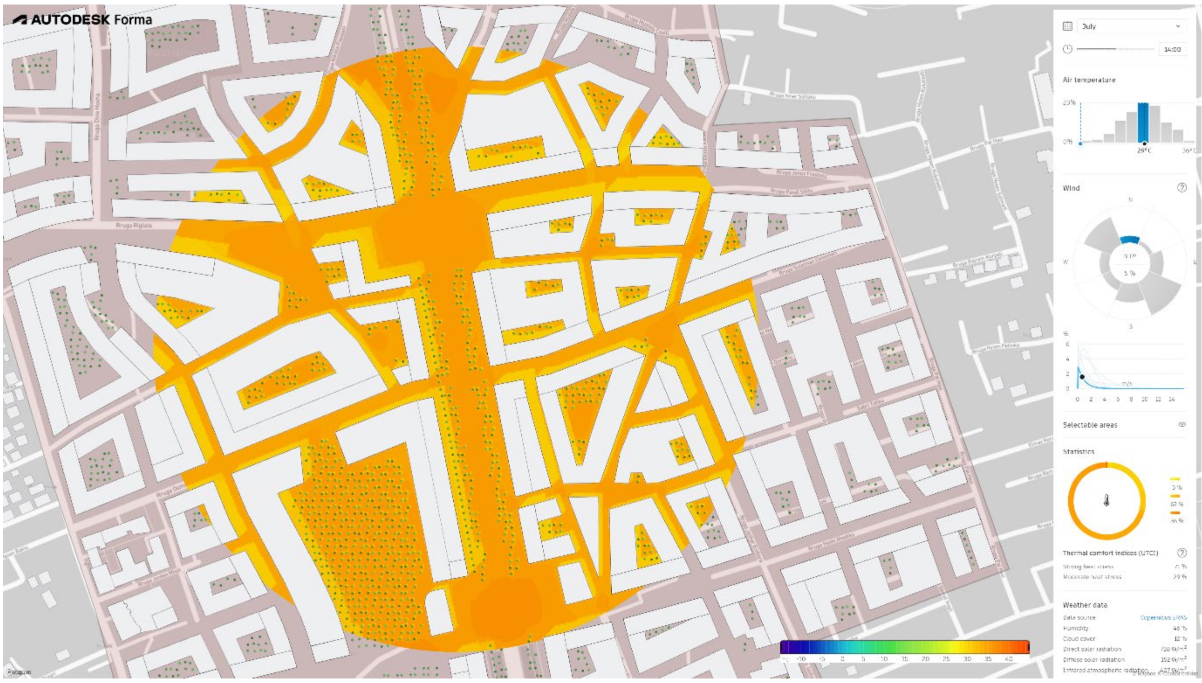


Figure 55 Point B, Microclimate Analysis, July

4.2.5. Solar Energy Potential

The solar energy analysis evaluates the site's capacity to generate electricity using solar panels. The model considers local weather patterns and shading from nearby buildings. The solar energy displayed on the 3D model represents the annual insolation, which is the amount of solar radiation energy received on a surface over a specified period, measured in kWh/m². The images illustrate how building height and shading affect the capacity to utilize sunlight for energy. Darker shades indicate lower capacity, while lighter shades represent higher capacity for meeting energy needs with solar power. Low-rise buildings are often depicted in darker shades because taller nearby buildings block sunlight, limiting their solar energy potential. In contrast, taller buildings, shown in lighter shades, have better sunlight exposure, allowing them to generate more solar energy. This highlights the importance of strategic urban planning to optimize the use of renewable energy in urban areas.

Figure 57 Solar Energy Potential

4.3 Generation of Scenarios

The process of developing urban design scenarios begins with defining the site boundary and incorporating existing incoming streets to ensure connectivity. The central concept, such as a boulevard, is maintained as a reference throughout the design process. Next, key building parameters are determined, including floor height, length, width, distance between blocks, and building shapes. This step is crucial for creating realistic and functional urban layouts. The final step involves evaluating the generated scenarios by running simulations to assess factors like solar radiation, wind patterns, and pedestrian comfort, allowing for informed adjustments and refinements to optimize the design.

4.3.1. Rectangular Parcel Proposal

The First Scenario uses rectangular grids to divide the parcels of the site. The buildings are then generated and adjusted according to parcel limits. The height is set to 10 floors for each building, the width 20m and the distance from building to building at least 12m. The minimum width of the street is 6m and the street network is generated and connected with the New Boulevard.

Figure 58 Rectangular Parcel Proposal Plan

Figure 59 Rectangular Parcel Proposal 3d

4.3.2. Voronoi Diagram Parcel Proposal

In generative urban design, a Voronoi diagram is a spatial division method that partitions a plane into regions based on the distance to a specified set of points. Each region contains all the points closest to a given seed point, resulting in a tessellation that can be used to optimize land use, ensure equitable distribution of resources, and create organic, efficient urban layouts. This scenario applies this diagram to divide the parcels, and then generate the building forms accordingly. The height is 10 floors, the width 20m, and the minimal distance between blocks is 12m. The minimum width of the street is 6m and the street network is generated and connected with the New Boulevard.

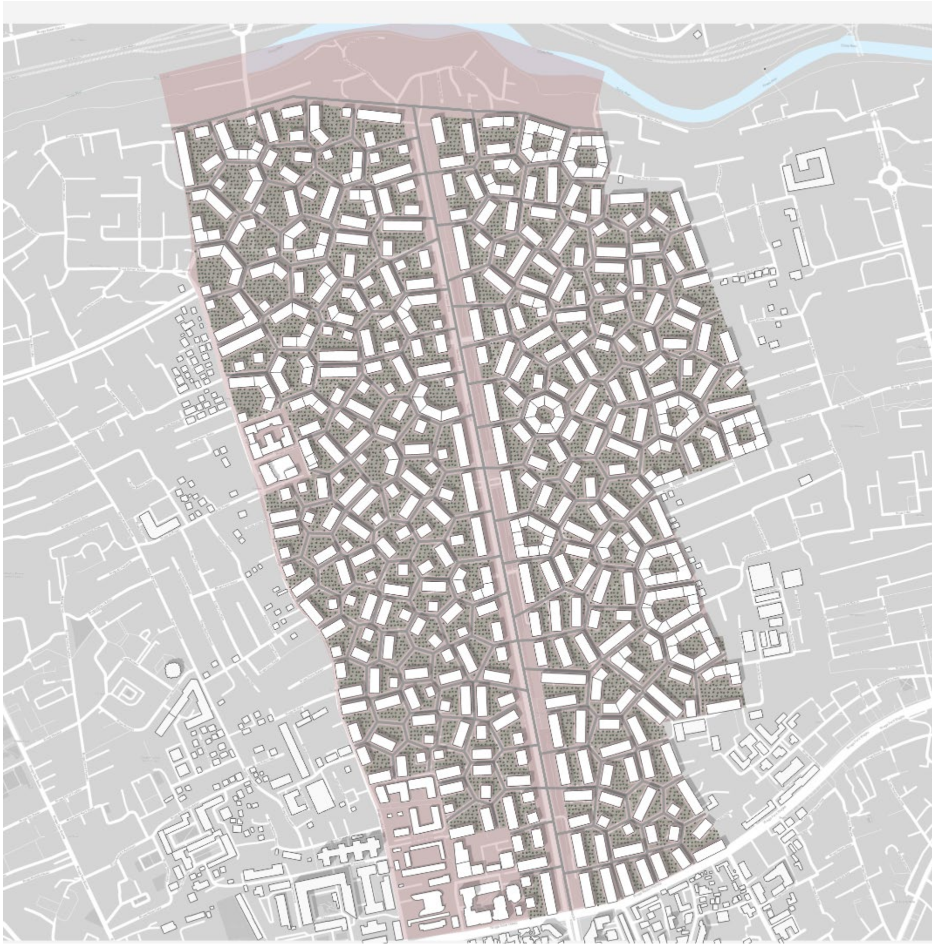


Figure 60 Voronoi Parcel Proposal, Plan

Figure 61 Voronoi Parcel Proposal, 3d

4.3.3. Grimshaw Parcel Proposal

The third scenario takes into account the proposed parcels by the Grimshaw Project and uses them as constraints to derive building proposals. The height of the buildings is again 10 floors, the width 20m and the distance from building to building is 12m. The minimum width of the street is 6m and the street network is generated and connected with the New Boulevard.

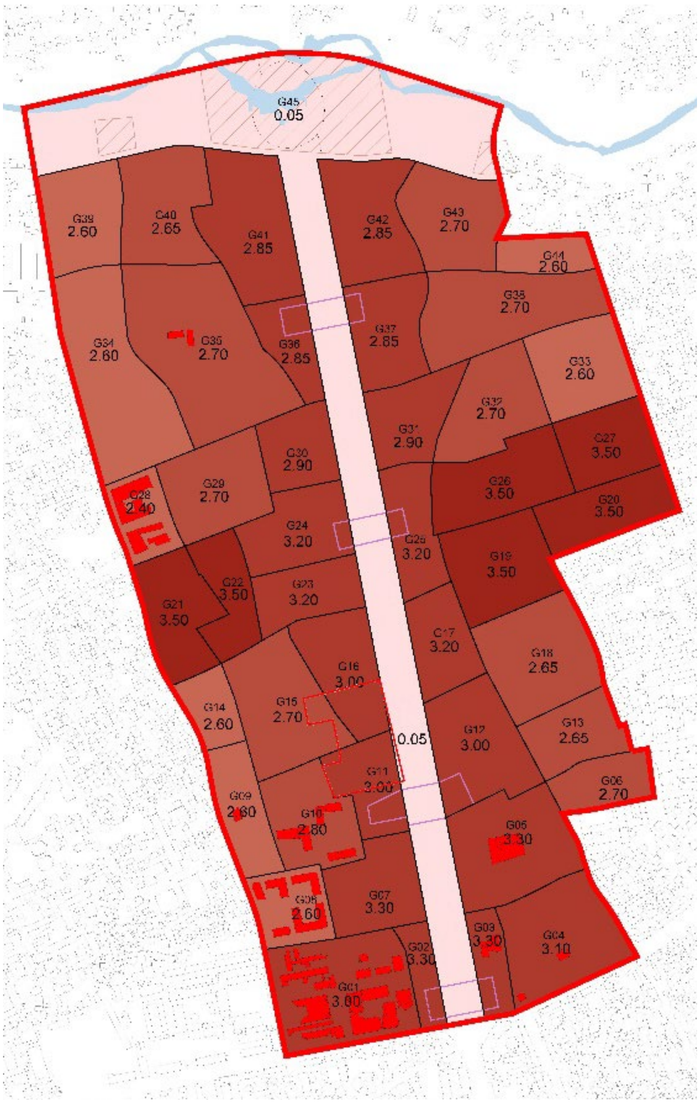


Figure 62 Parcel Division according to Grimshaw Plan

Figure 63 Grimshaw Parcel Proposal Plan

Figure 64 Grimshaw Parcel Proposal 3d

CHAPTER 5

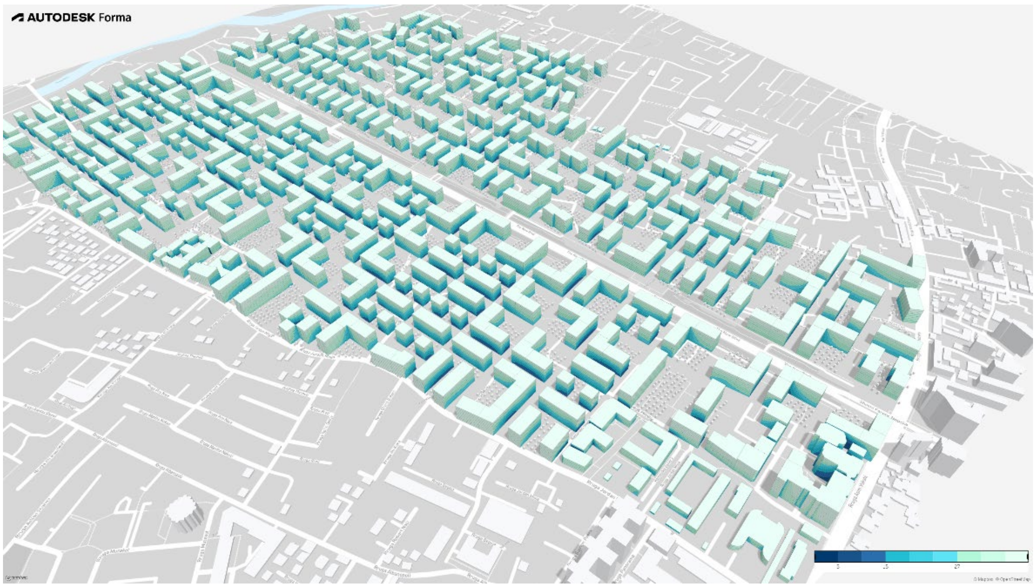
Evaluation and Comparison

5.1 Introduction

This part consists of the analysis of the 3 scenarios in terms of Wind Comfort, Microclimate, Daylight Potential and Solar Energy Potential. Then, each proposal is compared side by side with the Grimshaw Plan.

5.2 Rectangular Parcel Scenario

5.2.1 Daylight Potential



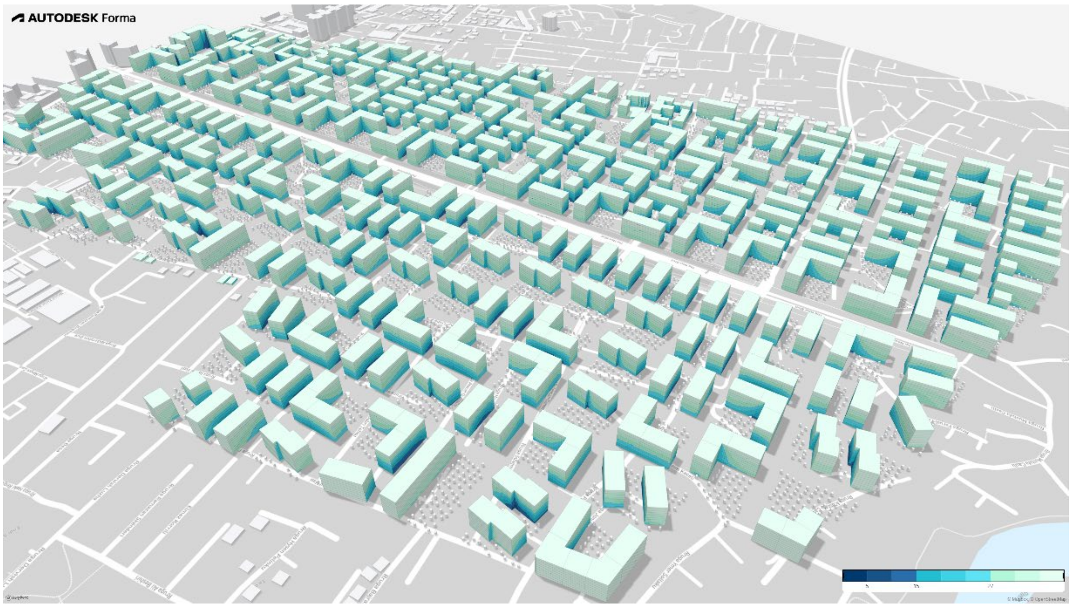


Figure 65 a,b Daylight potential Rectangular Parcel Scenario

5.2.2 Wind Comfort Analysis

Figure 66 Point A, Wind Comfort Analysis

5.2.3 Microclimate Analysis

Figure 67 Point A, Microclimate, January

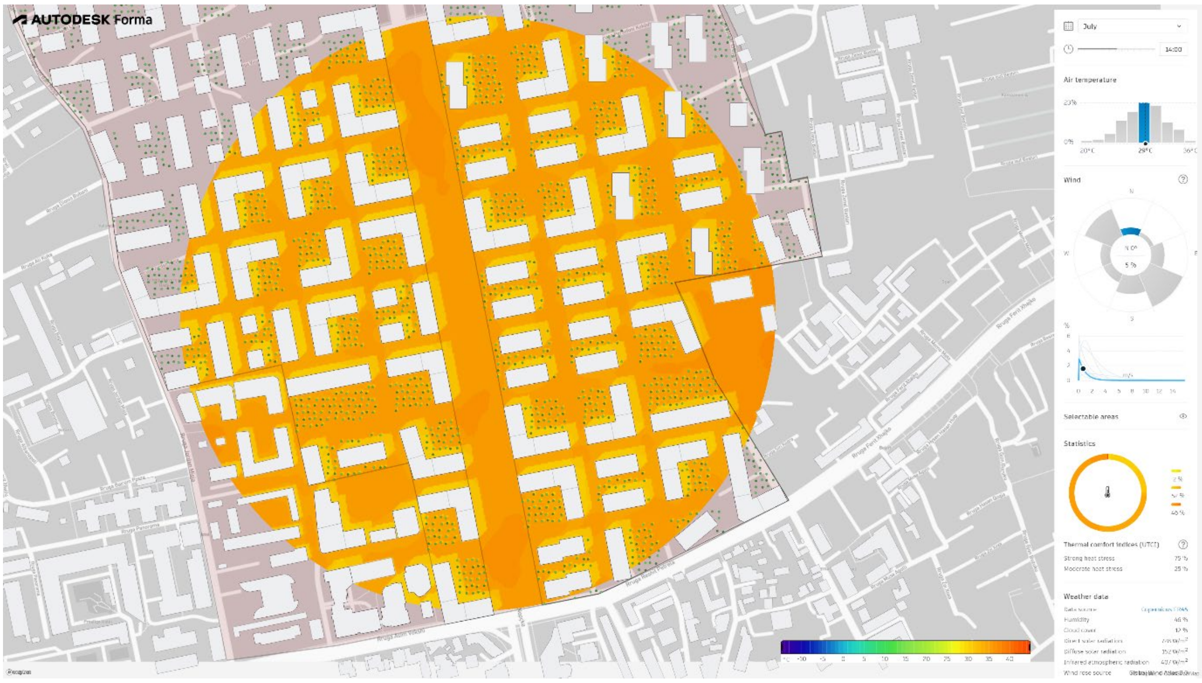


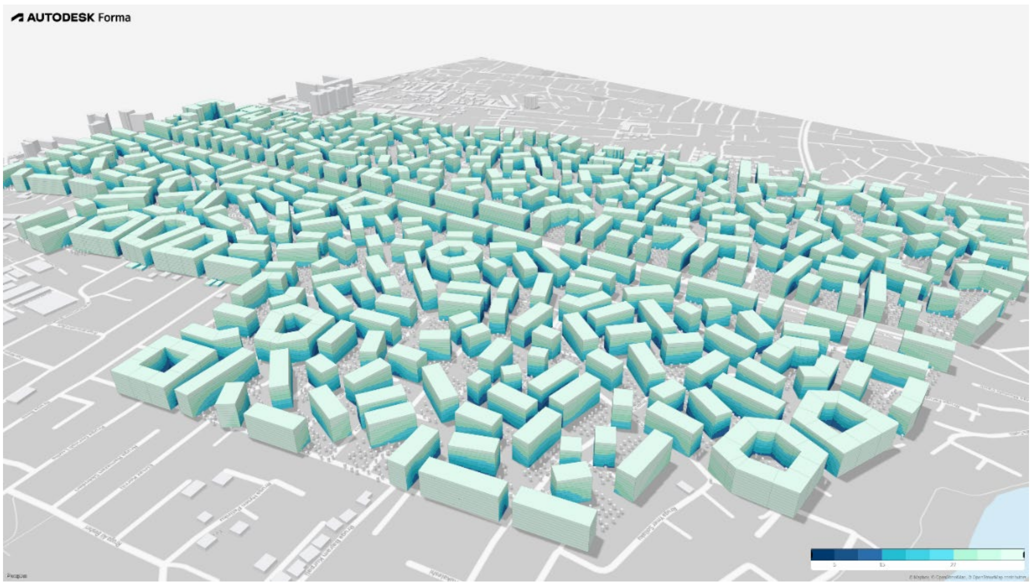
Figure 68 Point A, Microclimate, July

5.2.4 Solar Energy Potential

Figure 71 Solar Energy Potential, Rectangular Parcel Proposal

5.3 Voronoi Parcel Proposal

5.3.1 Daylight Potential



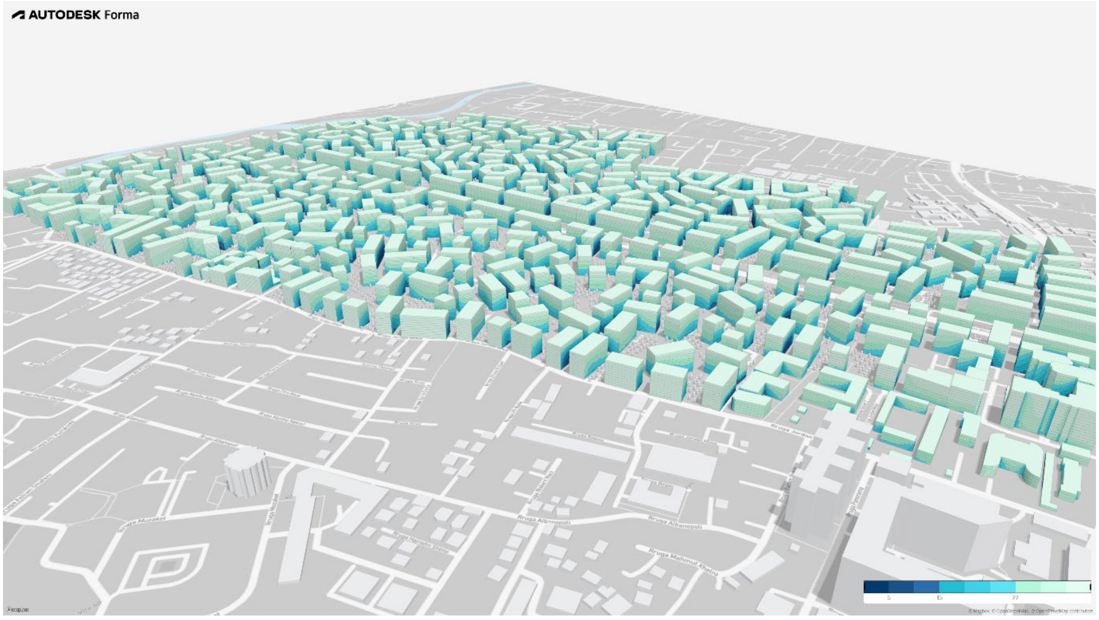


Figure 72 a,b Daylight Potential, Voronoi Parcellation

5.3.2 Wind Comfort Analysis

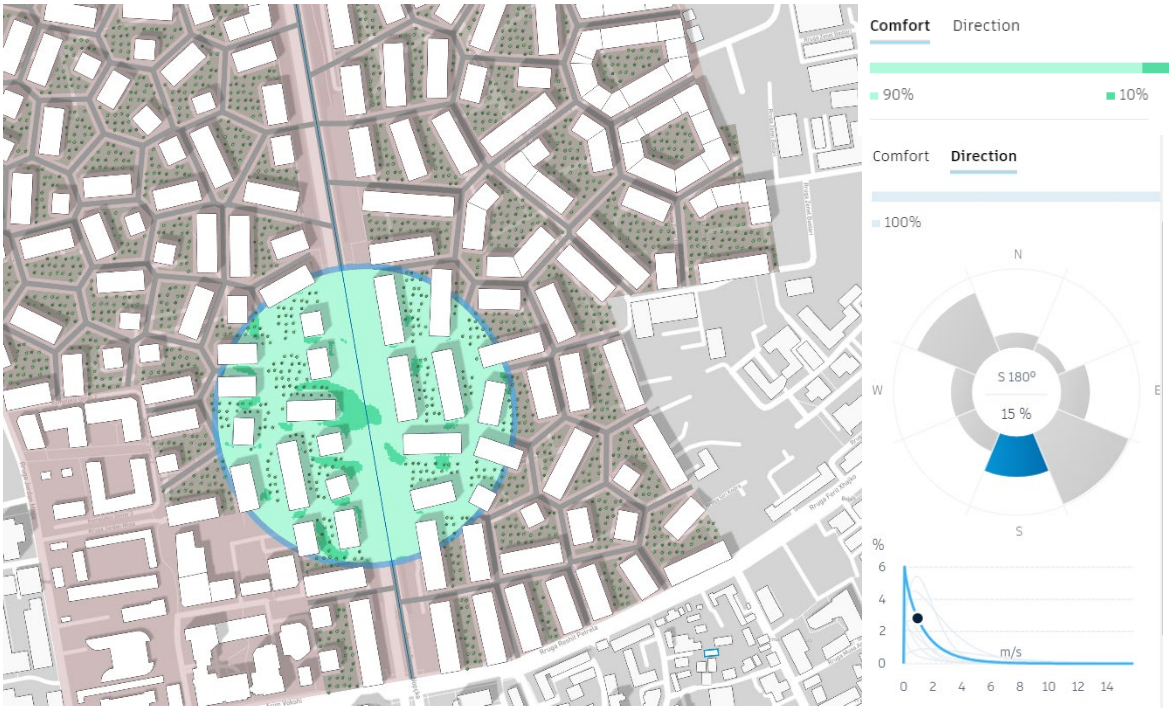


Figure 73 Point A, Wind Comfort Analysis

5.3.3 Microclimate Analysis

Figure 74 Point A, Microclimate, January

Figure 75 Point A, July

5.3.4 Solar Energy Analysis

5.4 Grimshaw Parcel Proposal

5.4.1 Daylight Potential

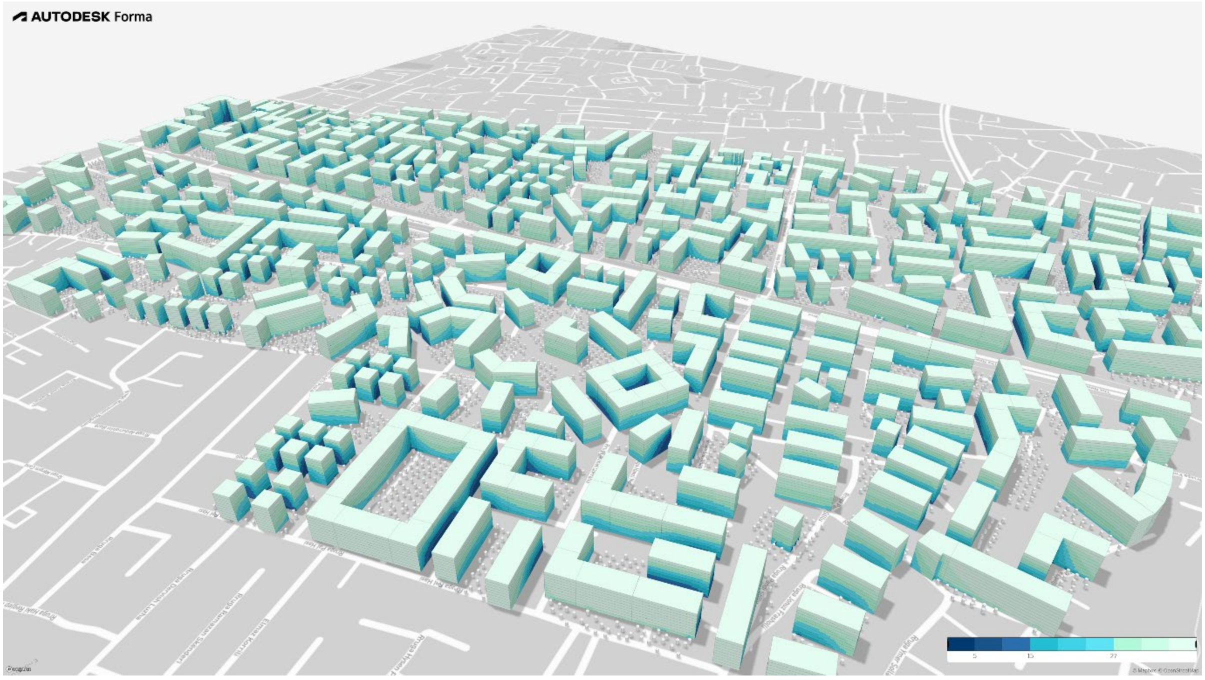


Figure 76 a,b Daylight Potential, Grimshaw Parcel Scenario

5.4.2 Wind Comfort Analysis

Figure 77 Point A, Wind Comfort Analysis

5.4.3 Microclimate Analysis

Figure 78 Point A, Microclimate Analysis, January

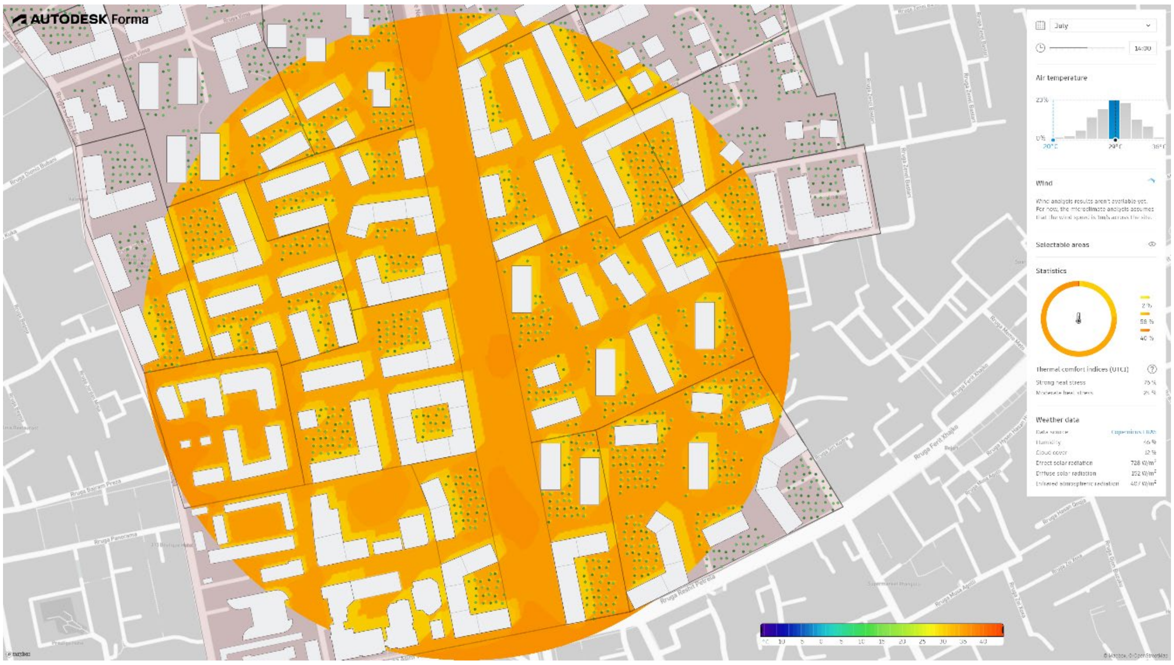


Figure 79 Point A, Microclimate Analysis, July

5.4.4 Solar Energy Potential

Figure 80 Solar Energy Potential

5.5 Comparison

The comparison of the three generated scenarios and the Grimshaw Proposal focuses on several critical aspects: Area Metrics, Daylight Potential, Microclimate, and Solar Energy Potential. This comprehensive evaluation aims to determine the most optimal urban design solution based on quantitative and qualitative analyses.

Area Metrics

The area metrics consist of three primary measurements: Gross Floor Area (GFA), Gross Internal Area (GIA), and Net Internal Area (NIA).

Gross Floor Area (GFA):

GFA represents the total floor area of all the buildings, including external walls and excluding unoccupied spaces like basements and rooftops.

Comparing the scenarios and the Grimshaw Proposal in terms of GFA helps determine the overall building density and development scale.

Gross Internal Area (GIA):

GIA includes all internal areas within the external walls, excluding common spaces such as corridors and staircases.

This metric is essential for understanding the usable interior space, which impacts the functionality and livability of the buildings.

Net Internal Area (NIA):

NIA represents the usable floor area available for occupancy, excluding internal walls and common areas.

NIA is crucial for evaluating the efficiency of space utilization in each design scenario.

Daylight Potential

The Daylight Potential analysis assesses the probability of achieving optimal natural lighting in different parts of the urban area. This analysis uses a color-coded system, with lighter colors indicating areas with high daylight potential and darker colors indicating areas with low daylight potential.

Grimshaw Proposal:

Problematic in the areas between high-rise and low-rise buildings.

Generated Scenarios:

Each scenario is analyzed for daylight distribution, with adjustments made to optimize natural lighting.

The comparison highlights areas of improvement and identifies potential shading issues.

Microclimate Analysis

The Microclimate analysis evaluates temperature variations at specific spots within each proposal, highlighting how different designs influence local climate conditions. This analysis includes:

Temperature Differentiation:

Measurement of temperature differences (in °C) at key locations to assess the impact of building layouts on heat retention and dispersion.

Important for understanding how each design affects pedestrian comfort and energy efficiency.

Grimshaw Proposal:

Designed with considerations for creating comfortable microclimates, potentially showing lower temperature variations.

Generated Scenarios:

Each scenario is analyzed to identify hotspots and areas with significant temperature fluctuations.

Adjustments can be made to mitigate adverse microclimate effects, such as increasing greenery or altering building materials.

Solar Energy Potential

The Solar Energy Analysis compares the average solar energy potential (in kWh/m^2) across the proposals, providing insights into the feasibility and efficiency of solar energy installations.

Grimshaw Proposal:

Likely to feature optimized solar panel placements to maximize energy generation.

Analysis results may show higher average solar energy potential.

Generated Scenarios:

Each scenario is evaluated for its solar energy potential, with adjustments made to improve solar access and panel efficiency.

Comparison highlights the most effective design for harnessing solar energy.

5.5.1. Grimshaw and Scenario 1

Figure 81 Area Metrics Comparison

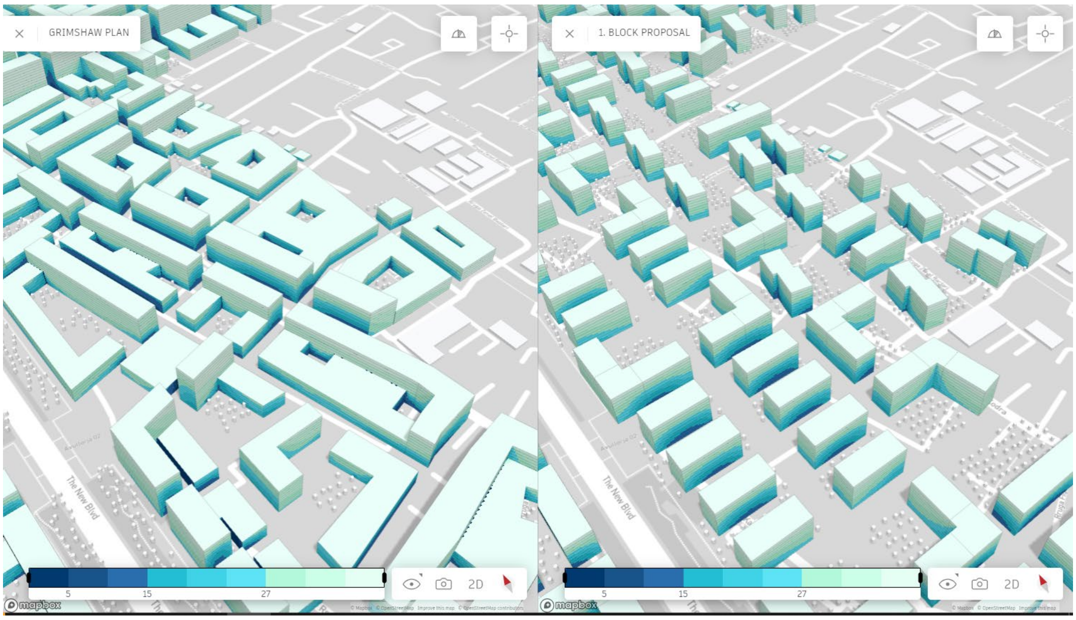


Figure 82 Daylight Potential Comparison

Scenario 1 is better at maximizing daylight compared to the Grimshaw plan. It allows more natural light into buildings and public spaces, reducing the need for artificial lighting and lowering energy use. The distance between the volumes on Scenario 1 allows for more daylight for the first floors, compared to the Grimshaw plan.

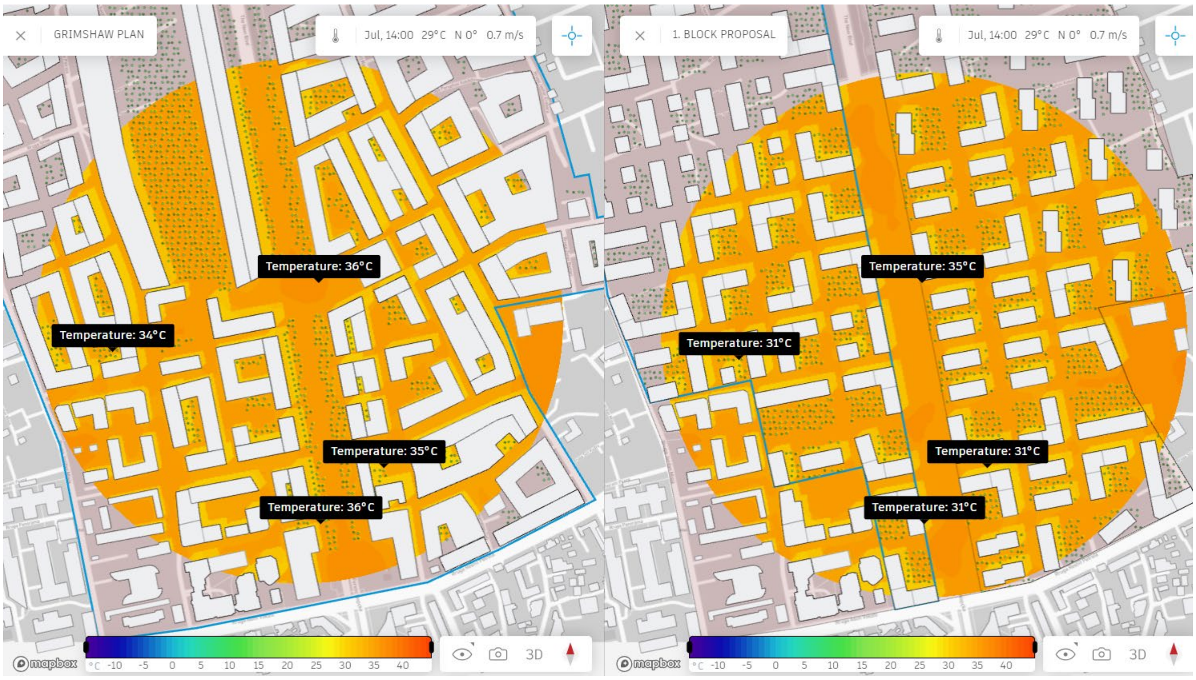


Figure 83 Microclimate Analysis, July

In terms of microclimate analysis, temperature varies depending on the specific points chosen on the site. The Grimshaw plan performs better in some areas, while Scenario 1 is more effective in others. These differences are important for designers to consider. By understanding which plan works best in different locations, designers can combine the best features from both plans to reduce summer temperatures across the site. For example, they might use more shading and green spaces where they are most effective and incorporate reflective materials or better ventilation in other areas. This approach helps create a more comfortable and cooler environment throughout the year.

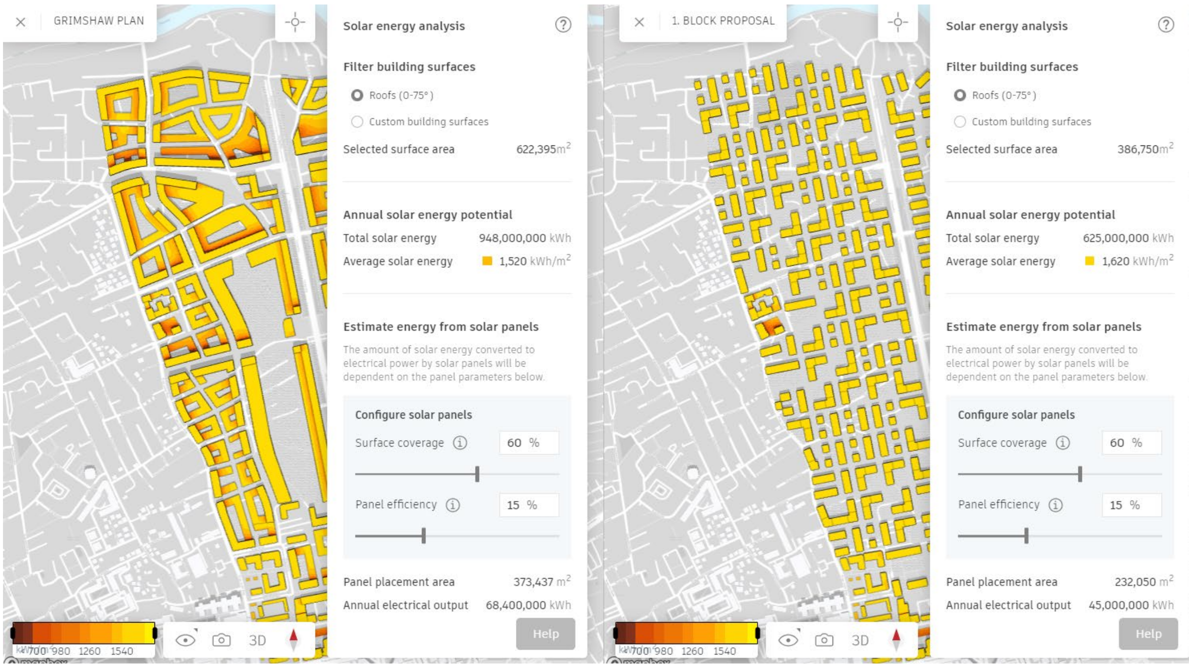


Figure 84 Solar Energy Potential Analysis

In terms of solar energy generation, the Grimshaw plan's more compact design results in more building surface area, which allows for better solar energy collection. This is because the compact layout provides larger and more continuous surfaces for solar panels. On the other hand, Scenario 1 maintains consistent lighting on the terraces with the same building height, but taller buildings in the Grimshaw plan can cast shadows on low-rise buildings, limiting their sunlight and solar energy potential. To improve solar energy performance, we can make adjustments such as changing the building layout to reduce shading, increasing the space between buildings, or altering their heights. Optimizing the orientation of building surfaces and placing solar panels more effectively can also help make better use of available sunlight across the site.

5.5.2. Grimshaw and Scenario 2

Figure 85 Area Metrics Comparison

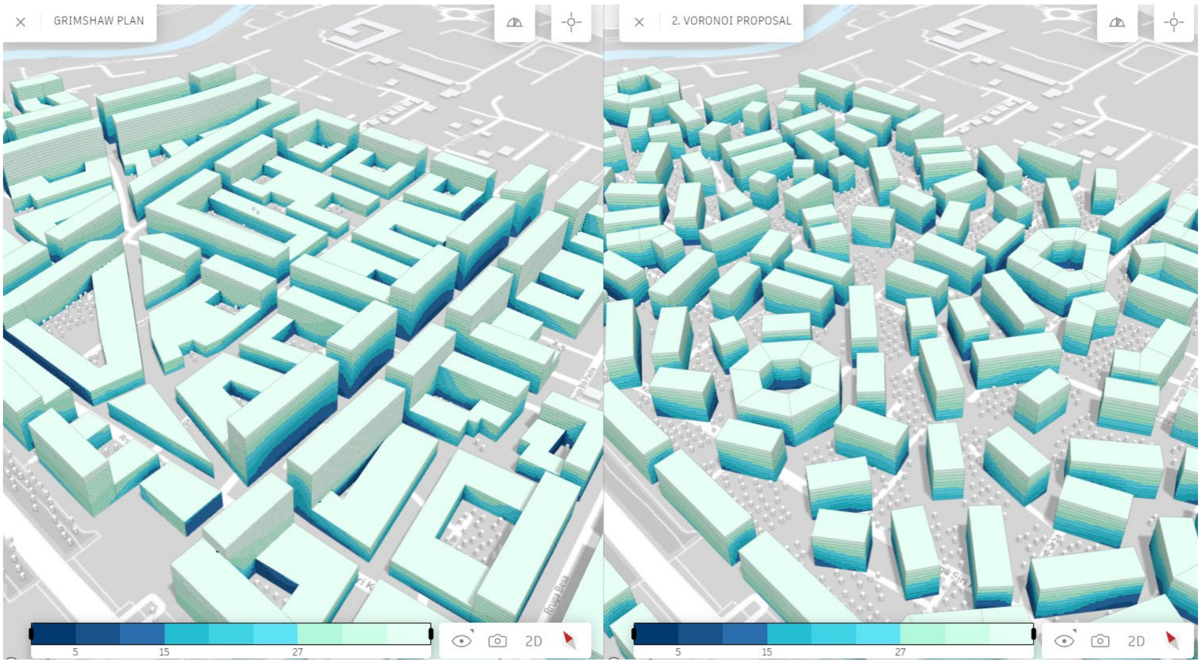


Figure 86 Daylight Potential Analysis

In Scenario 2, the greater distance between buildings improves daylight for the lower floors compared to the Grimshaw plan, as it reduces shading. However, the closed, compact shapes of the buildings in Scenario 2 can still limit daylight reaching the first floors. The compact design may obstruct sunlight, making it harder for natural light to penetrate deeply into the lower levels despite the increased spacing. Thus, while the spacing helps, the building shapes need to be optimized to ensure effective daylight distribution.

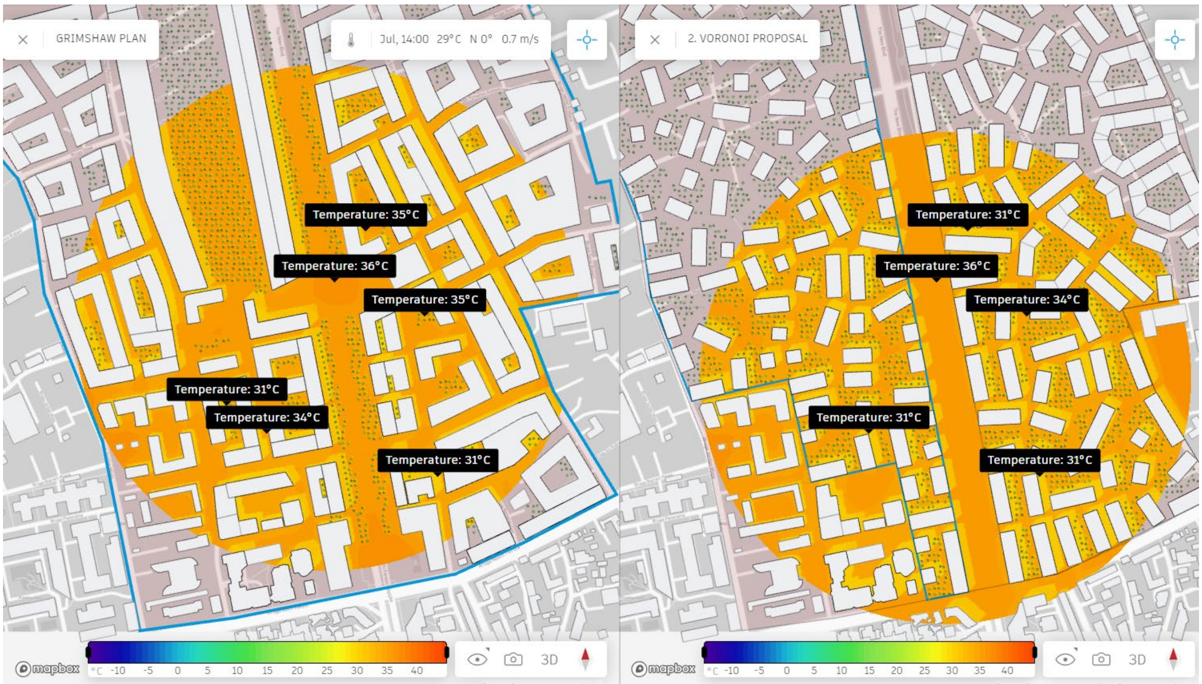


Figure 87 Microclimate Comparison

In microclimate analysis, temperatures vary depending on the specific points on the site. The Grimshaw plan works better in some areas for controlling temperatures, while Scenario 2 performs better in others. These differences are important for designers to consider.

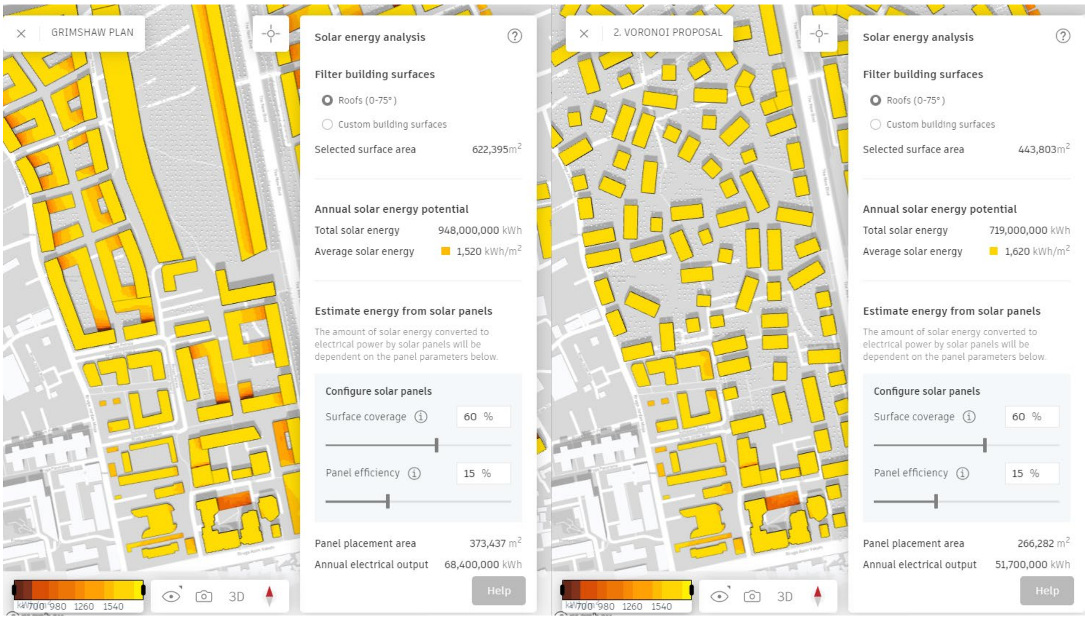


Figure 88 Solar energy Potential Analysis

The Grimshaw plan's compact design provides more building surface area, which enhances solar energy collection due to larger, continuous spaces for solar panels. In contrast, Scenario 2 maintains consistent lighting on terraces, but taller buildings in the Grimshaw plan can cast shadows on low-rise structures, reducing their solar energy potential. To improve performance, adjustments such as modifying building layouts to reduce shading, increasing spacing between buildings, and optimizing solar panel placement can help make better use of sunlight across the site.

5.5.3. Grimshaw and Scenario 3

Figure 89 Area Metrics Comparison

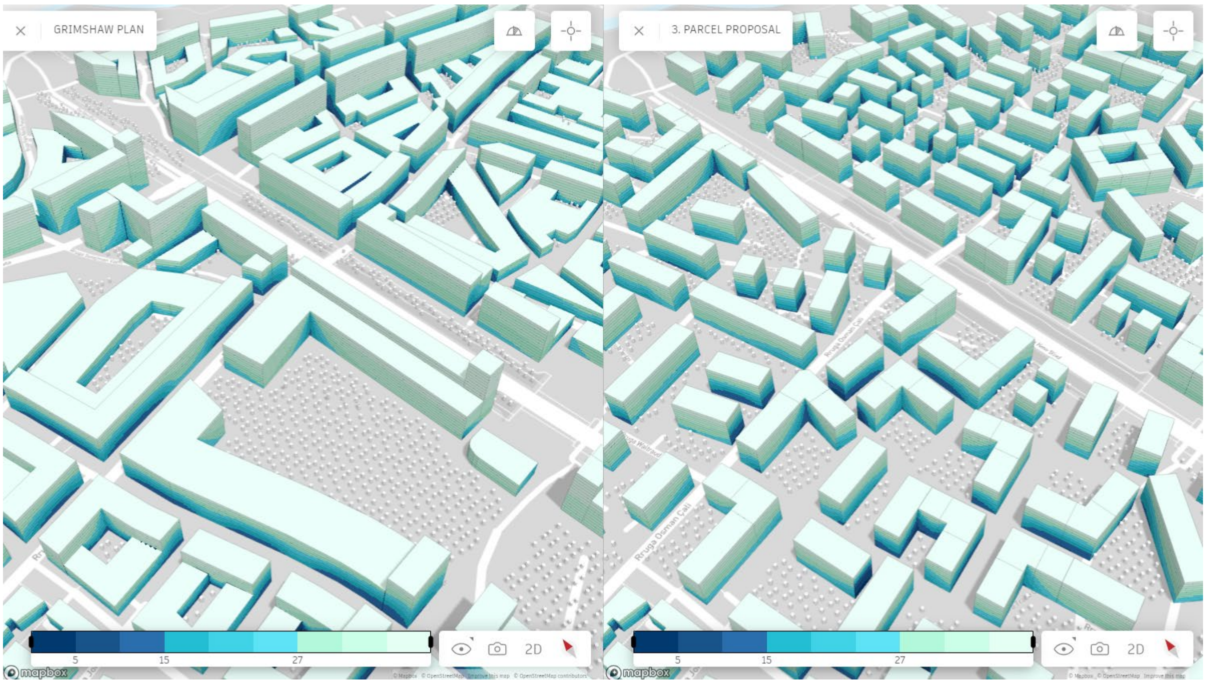


Figure 90 Daylight Potential Analysis

Again, in Scenario 3, the greater distance between buildings account for greater daylight potential compared to the Grimshaw Masterplan.

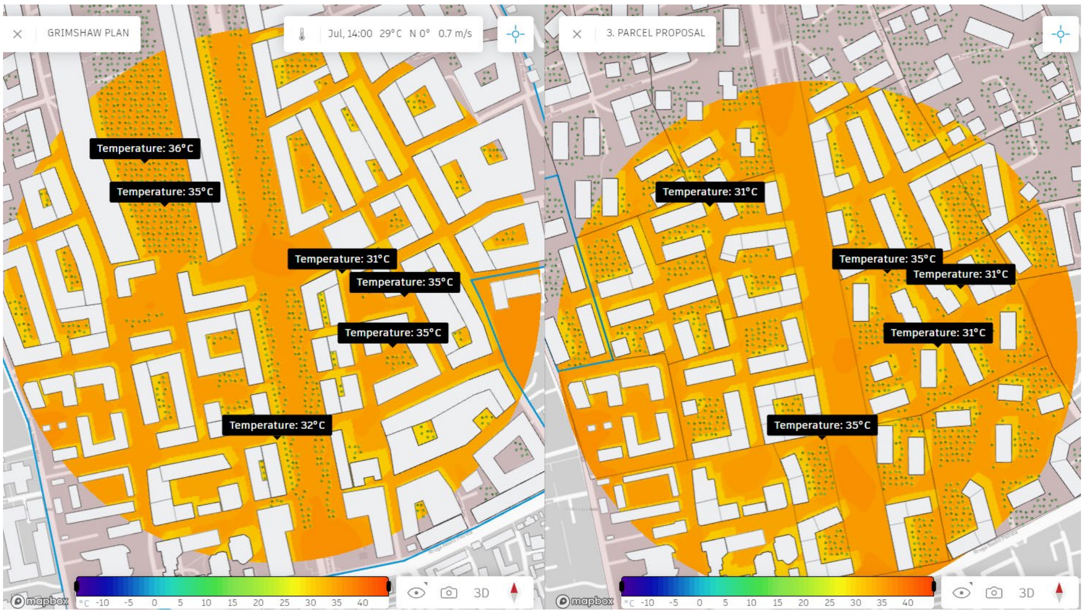


Figure 91 Microclimate Comparison, July

In microclimate analysis, temperatures vary depending on the specific points on the site. The Grimshaw plan works better in some areas for controlling temperatures, while Scenario 2 performs better in others. These differences are important for designers to consider.

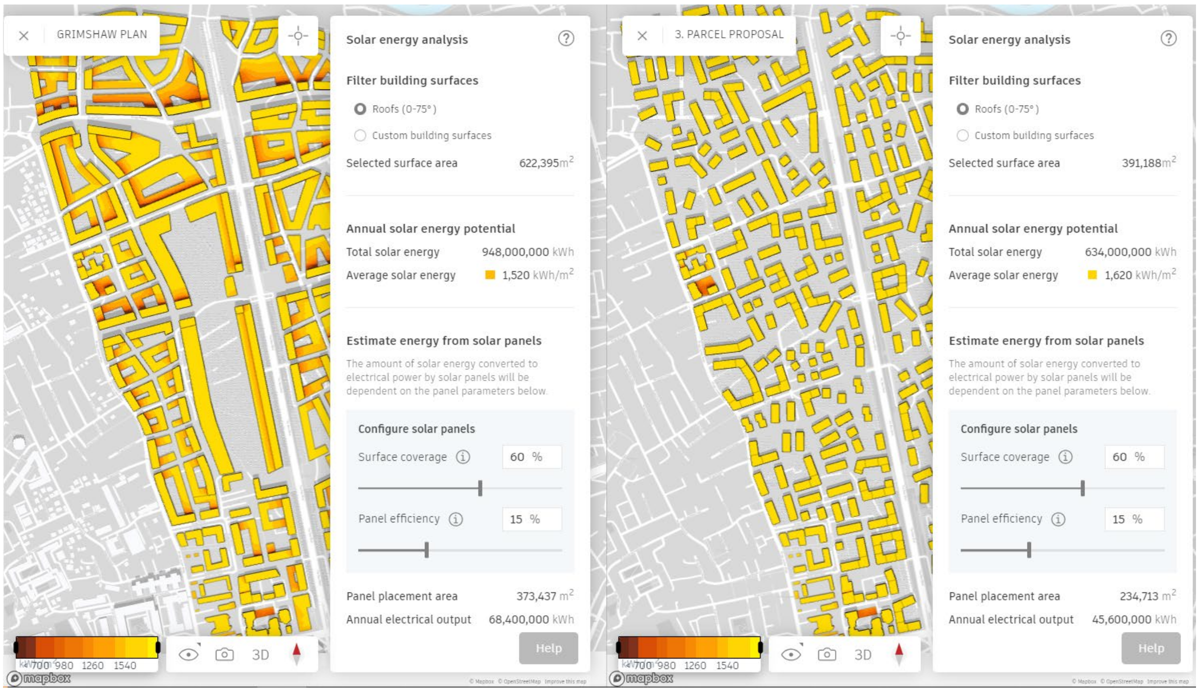


Figure 92 Solar Energy Potential Analysis

Again, compared to Scenario 3, the Grimshaw plan's compact design offers a larger and more uninterrupted surface area for solar panels, improving solar energy collection. In comparison, Scenario 3 ensures consistent lighting on terraces, but taller buildings in the Grimshaw plan can shade lower structures, limiting their solar energy potential. To enhance performance, adjustments like changing building layouts to minimize shading, increasing spacing between structures, and optimizing the placement of solar panels can help utilize sunlight more effectively across the site.

CHAPTER 6

Discussion and Conclusion

Discussion

Generative design represents a significant shift in urban planning and architecture, offering numerous strengths but also presenting several challenges.

Strengths:

Efficiency and Flexibility: Generative design enables rapid generation of multiple design scenarios, allowing planners to explore a wide range of options quickly. This flexibility is crucial in adapting to changing project requirements and constraints. By automating parts of the design process, it significantly reduces the time and effort needed to develop complex urban plans.

Data-Driven Decision Making: The use of data in generative design allows for informed decision-making. By integrating various data sources, such as environmental conditions, demographic trends, and transportation networks, generative design can optimize urban layouts for improved functionality and sustainability. This approach ensures that designs are grounded in real-world conditions and needs.

Optimization for Sustainability: Generative design excels in creating sustainable urban environments. It can optimize building orientation, material use, and green space distribution to enhance energy efficiency, reduce environmental impact, and improve overall sustainability. This capability is particularly important in addressing climate change and promoting green urban development.

Enhanced Aesthetic and Functional Integration: By considering both aesthetic and functional aspects simultaneously, generative design helps create urban spaces that are not only visually appealing but also highly functional. This holistic approach ensures that all elements of the urban environment work together harmoniously, enhancing the quality of life for residents.

Weaknesses:

Complexity and Learning Curve: The complexity of generative design tools can be a barrier to their widespread adoption. Urban planners and architects need to acquire new skills to use these tools effectively, which can involve a steep learning curve. This can slow down the integration of generative design into mainstream practice.

Data Dependency: Generative design relies heavily on the availability and quality of data. Inaccurate or incomplete data can lead to suboptimal designs. Ensuring access to reliable data sources and maintaining data integrity are critical challenges that need to be addressed for generative design to be effective.

Technical and Computational Limitations: High computational demands can limit the accessibility and scalability of generative design. Advanced algorithms and simulations require significant processing power, which can be a constraint for smaller firms or projects with limited resources.

Potential for Over-Optimization: There is a risk that generative design may focus too much on optimization, potentially overlooking qualitative aspects such as social dynamics and cultural context. While quantitative metrics are essential, a balanced approach that also considers human experiences and interactions is necessary for creating truly livable urban environments.

Conclusion

Generative design offers a powerful approach to urban planning, providing significant advantages in efficiency, data-driven decision making, sustainability optimization, and aesthetic-functional integration. These strengths make it an invaluable tool for addressing the complex challenges of modern urban development.

However, the adoption of generative design is not without challenges. The complexity of the tools, dependence on high-quality data, technical limitations, and the potential for over-optimization are critical issues that need to be managed. By addressing these weaknesses, urban planners and architects can fully harness the potential of generative design to create sustainable, efficient, and vibrant urban environments.

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