URBAN MORPHOLOGY GENERATION FROM THE PERSPECTIVE OF PUBLIC SPACE INDICATORS

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Approval sheet of the Thesis

This is to certify that we have read this thesis entitled **“Urban morphology generation from the perspective of public space indicators”** and that in our opinion it is fully adequate, in scope and quality, as a thesis forthe degree of Master of Science.

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

URBAN MORPHOLOGY GENERATION FROM THE PERSPECTIVE OF PUBLIC SPACE INDICATORS

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The application of parametric tools based on the big data assessment allow to study the city's organization in a qualitative way. Urban morphology is a complex subject that may be characterized by its spatial relationships, built typologies and dimensions. Urban Morphology Indicators (UMIs) and Open Space Indicators (OSIs) help to define and evaluate the built environment. The present studies within the framework of analysis have already generated efficient urban morphologies, but mainly consider Building, Plot and Street indicators, with very few acknowledging OSI and almost none take them into account. This study establishes a framework by integrating different UMIs and OSIs that are most suitable for simulating urban generative design from the perspective of public spaces. Classification of the necessary indicators is a crucial step in receiving the data from the urban context. The developed framework is applied in the urban context of Tirana, at the site of Astir which is located at the southwest periphery. The existing urban development is used to calculate the UMIs which are used as a reference for the further generation of the public space scenarios. The urban analysis is performed using QGIS while the development scenario is generated using GH (grasshopper). The evaluation of the scenarios based on the calculation of various morphological indicators and visibility analysis help to define the best performing scenario. The proposed strategy aids urban planners and architects in developing public space-based sustainable strategies and efficient urban planning.

Keywords: urban morphology, generative urban design, parametric tools, public space, open space, indicators, evaluation

ABSTRAKT

GJENERIMI I MORFOLOGJISE URBANE NGA PERSPEKTIVA E TREGUESVE TE HAPESIRES PUBLIKE

Sallaku, Kledina

Master Shkencor, Departamenti i Arkitekturës

Udhëheqësi: Dr. Anna Yunitsyna

Aplikimi i mjeteve parametrike bazuar në vlerësimin e nje numri të madh të dhënash mundëson studimin e organizimit të qytetit në mënyrë kulitative. Morfologjia urbane është një temë komplekse që mund të karakterizohet nga marrëdhëniet e saj hapësinore, tipologjitë e ndërtesave dhe dimensionet e tyre. Indikatorët e Morfologjisë Urbane (UMIs) dhe Indikatorët e Hapësirës së Hapur (OSIs) ndihmojnë për të karakterizuar dhe vlerësuar mjedisin e ndërtuar. Studimet aktuale brenda strukturës së metodologjisë kanë gjeneruar tashmë morfologji urbane efiçente, por këto kryesisht marrin në konsideratë vetëm indikatorët e ndërtesave, parcelave dhe rrugëve. Shumë pak prej studimeve konsiderojnë OSIs dhe puthajse asnjë nuk i merr parasysh. Ky studim krijon një strukturë metodologjie duke integruar UMIs dhe OSIs që janë më të përshtatshmet për të planifikuar një plan urban parametrik nga këndvështrimi i hapësirave publike. Klasifikimi i treguesve të nevojshëm është një hap vendimtar në marrjen e të dhënave nga konteksti urban. Metodologjia e studimit aplikohet në kontekstin urban të Tiranës, në zonën e Astirit e cila ndodhet në periferinë jugperëndimore të Tiranës. Zhvillimi urban ekzistues përdoret për të llogaritur indikatorët morfologjikë të cilët më pas përdoren si referencë për gjenerimin parametrik të mëtejshëm të skenarëve të hapësirës publike. Analiza urbane kryhet duke përdorur QGIS ndërsa skenaret parametrike janë gjeneruar duke përdorur grasshopper. Evaluimi i skenarëve është bazuar në llogaritjen e indikatorëve të ndryshëm morfologjikë dhe në analiza të vizibilitetit, të cilat ndihmojnë në përcaktimin e skenarit me performancë më të mirë. Strategjia metodologjike e propozuar ndihmon planifikuesit urbanë dhe arkitektët në zhvillimin e strategjive të bazuara në gjenerimin

e hapësirave publike dhe në planifikimin e një plani urban efiçent.

Fjalët kyçe: morfologjia urbane, dizajn urban parametrik, mjete parametrike, hapësira publike, hapësira të hapura, indikatorë, evaluim

Dedicated to my family

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Motivation

The global population is currently experiencing a significant surge in growth, with a notable concentration of individuals residing in urban centers. These urbanized cities are actually where human influences on the environment are most significant and long-lasting. Consequently, it is commonly understood that careful planning of the ecology of urban settlements would be a critical step to assuring a sustainable future [1]. Urban planners, architects and other decision-makers in these disciplines have been motivated to explore environmentally friendly methods of planning that enhance the built environment [2]. Taking into account that urban morphology analysis explains the logic of urban development, it can be a useful method to generate a sustainable urban form with computational tools. Generative urban planning has been proven to be an effective method in designing sustainable cities by using quantitative data and different criteria of evaluation over the experience-based design workflow. Just like other cities of the world, Tirana is going through a large increase in urban population with 54% in 2015 and an expected 80% in 2050. This increase in population is followed up by inflation in urban developments and its impact on the environment. To mitigate these impacts, a framework with integrated OSIs and UMIs that are most suitable for generating sustainable future urban morphologies that reflect positive public space qualities should be reviewed and studied.

1.2 Aim

There are many studies related to urban morphologies and generative urban morphologies. Their framework of analysis consists of Building Urban Morphology Indicators (BUMIs), Street Urban Morphology Indicators (SUMIs), and Plot

Morphological Indicators (PUMIs). Very few studies consider OSIs and there are almost no studies in regard to incorporating these morphological indicators for the purpose of Public Space (PS) generation. There is also a lack of metrics and analysis regarding the evaluation of public spaces and almost none of the previously developed generative frameworks include them. As a result, this gap in the field of Urban Morphology (UM) and generative urban design is the main drive in delivering a framework that is a combination of UMIs and different criteria of evaluating public spaces. This framework will serve in generating sustainable urban plans for cities.

1.3 Objective

This study focuses on the peripherical part of Tirana, that of Astir. The selected site of Astir presents an original urbanization with the suburban area which is mainly comprised of housing developments, courtyards within these complexes, office spaces and an extensive number of commercial spaces. The first objective of the paper is to use existing open data, in order to comprehend the current state of the neighborhood. The information that is generated is intended to facilitate urban planners' ability to analyze the city and to propose a new aspect for urban development initiatives, which in our case is planning by quantifying public spaces. The second objective of the thesis involves creating multiple parametrically derived public space scenarios based on the existing context of ‘Astir’. The primary aim of this study is to construct a framework for the purpose of design-based research that enables urban planners or architects to generate multiple design proposals in 3D using a previously calculated UMIs form the original context of the area. From the comparative evaluation of the different generated proposals, the research seeks to find the best-performing scenario in regard to the characteristics of a good public space.

1.4 Organization of the Thesis

The present thesis is structured into eight distinct chapters. The arrangement is structured in the following manner: Chapter 1 provides an overview of the thesis by presenting its introduction. Chapter 2 comprises the literature review. Chapter 3 presents the overall methodology of the study and the data collection phase of the methodology. Chapter 4 explains the phase of parametric modelling. Chapter 5 outlines the evaluation phase of the methodology, while Chapter 6 provides a comprehensive discussion. Lastly, the final chapter, Chapter 7, comprises of the conclusion and the future work of the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Cities are growing exponentially around the globe with new neighborhoods being built every day, resulting into expanded boundaries [3]. The expansion typically occurs in the periphery of the city. This phenomenon has strong parallels with the current situation in Tirana. The city of Tirana is expanding daily with new residential construction in the suburban parts of the city. These suburban areas have been transformed to new residential neighborhoods like the case study of Astir. These expanding grids in suburban areas oftentimes result in unplanned developments. These new neighborhoods demand a sustainable and efficient urban design. Proposing a generative design framework by using computational tools is an ideal solution to deliver neighborhoods that are optimized on a certain criteria. This literature review is going to examine all topics that will develop the framework for this research. It explains topics such as public space, open space, urban morphology, generative design and organizes typologies of public space and urban morphology indicators. It also analyses similar papers to better understand how they relate to our research and case study.

2.2 Public space definition

From the earliest civilizations to the present, urban public spaces serve as essential hubs for cultural, political, and economic activities [4]. Public space is a complex topic to define since many authors use different terms and definitions. The paper by Madanipour [5] defines the public space as the "space that is not controlled by private individuals or organizations and hence is open to the general public". Mehta [6] considers as public space those spaces that are privately owned but accessible to the public, while he does not consider as public space those spaces that are publicly-owned but cannot be accessible to the public. Stanley *et al*. [4] defines public space as "any urban ground space, regardless of public accessibility, that is not roofed by an architectural structure". Due to the many definitions and categorizations of public space, it is regarded as a complex topic. Under the complex category of public spaces, open space is frequently mentioned. A large number of contemporary open areas are characterized by their unrestricted accessibility, yet public space also encompasses covered spaces, such as civic institutions and religious buildings. Conversely, Mehta [6] states that many types of open spaces are open to the public, but that does not imply that all open spaces are open to public access.

This research will consider public spaces only those spaces that are not roofed and open to public access. These spaces can also be referred to as open spaces that are accessible to the public which are commonly referred to as streets, parks or squares and are directly administered by the municipality.

2.3 Public space classification and typologies

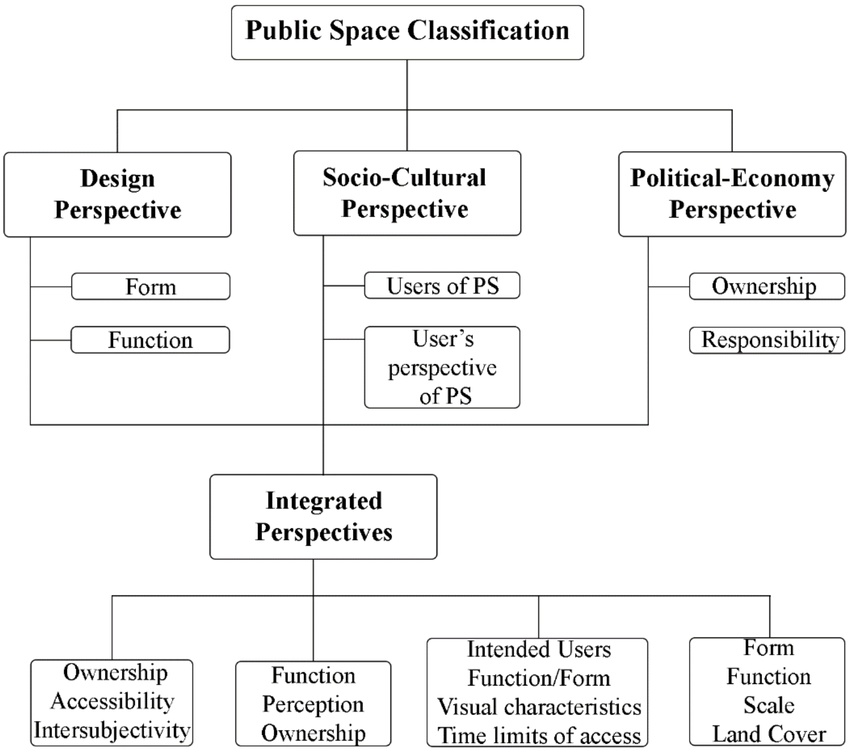

Figure 1. Public Space Classification summary derived from the literature review. (by author)

Public space is a very diversified topic within the field of urban planning, with numerous factors influencing the degree of publicness; consequently, categorization is a necessary tool for understanding the complexity of this topic. In order to categorize a space, there are two methods that help: classification and typology. Classification is employed when the features of objects are taken into account in the categorization, while the typology method of categorization describes the type of objects independent of their features [7]. For each typology, it is essential to identify the typical spaces that will serve as model spaces.

In the case of the public space, the categorization is conducted depending on seven criteria. Several studies [8], [9], [4] categorize public space based on the criteria of morphology and function. Other studies of [7], [10] classify it based on the criteria of function. Studies of [7], [10] classify public space based on the criteria of form/landscape character. Other criteria of public space classification consist of: Formal status (ownership/rights and responsibility) [10], [11]; Type of surface [12], Spatial scale [4] and Catchment hierarchy [7]. All the criteria mentioned above are the most cited in the field of urban design with new typologies of open public space continuously being updated by researchers.

2.3.1 Classification of public space from the design perspective

The most commonly used criteria in categorizing public space are form and function. These typologies have a universal character, regardless of regional context. Mantey & Kepkowicz [13] and Carmona [10] consider the form and function criteria or physical type and function as a classification of public space from the design perspective. The challenge with utilizing morphologically-based classifications is that the variations of types are boundless whereas the designed function is easier to classify.

The classifications of Sitte [14] present the initial efforts to develop open space typologies focused on morphology. The research by Zucker [15] classified five types of public space: closed, dominated, nuclear, grouped and amorphous, while Krier [16] classified all urban open spaces into two categories, namely streets and squares, and correlated them with fundamental geometric forms.

Following the classification, based on morphology other authors started to classify public space based on the criteria of function with research by Carr *et al.* [8] and Gehl

& Gemzoe [17]. The study by Carr *et al.* [8] classifies 11 categories of public space as well as the study by Gehl & Gemzoe [17] which classifies 39 new cityscapes into five typologies. All the classifications mentioned above are organized in this paper by Mantey & Kepkowicz [13] as illustrated in *Table 1.*

Table 1. Typologies of public space based on form and function [13], adopted by author

Types of open public space By Carr et al. (1992)	Types of open public space by Sandalack and Uribe (2010)	Types of open space by Stanley et al. (2012)	Types of open space by Gehl, J. & Gemzoe, L. (1996)
(1) Public parks (2) Squares and plazas (3) Memorials (4) Markets (5) Streets (6) Playgrounds (7) Community open spaces (8) Greenways and linear parkways (9) Atrium/indoor/ marketplaces (10) Found/neighborhood spaces (11) Waterfronts	(1) Streets (2) Squares (3) Park/garden/ cemetery (4) Linear system/green corridor/path (5) Outdoor sport and recreational facility (6) Campground and picnic area (7) Natural/seminatural green space	(1) Food production areas (2) Parks and gardens (3) Recreational space (4) Plazas (5) Streets (7) Transport facilities (8) Incidental space	(1) Main city square (2) Recreational square (3) Promenade (4) Traffic square (5) Monumental space

Besides the fundamental types of space defined by form or function, there are other classifications of urban space according to other criteria which recognize the sheer diversity of public spaces.

This paper by Carmona [10] organizes the classification of different authors on public space depending on a range of factors, including the design perspective and the socio-cultural and political economy perspectives.

2.3.2 Classification of public space from the socio-cultural Perspective.

From the socio-cultural perspective, typologies are dependent on how people use and perceive public space [10]. This study by Burgers [18] classifies spaces by their customers, as a collection of landscapes that form the realms of different social or interest groups. He classifies 6 types of public space which are: Erected public space defined as landscapes that demonstrate increasing economic and governmental potential; Displayed space which the author refers to it as landscapes of temptation; Exalted space which it is considered as landscapes of excitement and ecstasy; Exposed space which the author refers to as landscapes of reflection and idolization; colored space which is defined as landscapes of immigrants and minorities and lastly the 6th public space type of Burgers is marginalized space which refers to landscapes of deviance and deprivation [18].

Another study by Dines & Cattell [19] employs social involvement with space and perception to identify five categories: Everyday places, Places of meaning, Social environments, Places of retreat, and Negative spaces (antisocial spaces).

2.3.3 Classification of PS from the political-economic perspective

The perspective of political economy relates to the criteria of ownership and responsibility in society. This study by Gulick [20] defines three types of public spaces: Public property (state-owned space); ‘Semiotic’ (comprised of "spatial identities" that promote rivalry and division in urban areas) [21, p. 1]; ‘Public sphere’ (social and political space for residents).

According to Kilian [22], there are two types of public spaces: those that serve as sites of contract and those that serve as sites of representation (i.e., Gulick's "Public sphere" and "Semiotic" public spaces, respectively). Kilian contends that critics of each type are unclear with both public and private space. He contends that all spaces have access or activity constraints, whether they are stated clearly or not, and are both public and private at the same time.

Other authors such as Flusty [23, pp. 48-59] categorizes public space based on the criteria of exclusion. All typologies from the social-cultural and political perspectives are fluid and overlap with each other.

2.3.4 Integrated typologies of PS

Based on combinations of the three main perspectives on public space that were explained above, other authors come up with new typologies. A study by Kohn [24] develops a new typology of urban space by identifying three main criteria: ownership, accessibility and intersubjectivity, but he states that categorization is more challenging as the public and private spheres become more interconnected.

Based on Kohn’s three-part classification, this research by Carmona [10] develops an original typology that utilizes elements of function, perception, and ownership from design, socio-cultural, and political-economic perspectives to differentiate between various types of spaces as illustrated in *Table 2*. According to Camona's typology, the assessment of a space's function is dependent not only upon functional criteria, but also upon the type of its users.

Table 2. Types of urban space by Carmona [10].

Space type	**Distinguishing characteristics**	**Examples**
	'Positive' spaces	
(1) Natural/semi-natural urban space	Typically state-owned, natural and semi-natural features within urban areas	Rivers, natural features, seafronts, canals
(2) Civic space	The traditional forms of urban space, which are accessible to all and serve a variety of purposes	Streets, squares, promenades
(3) Public open space	Managed open space, typically green and open to the public, even if temporarily regulated	Parks, gardens, commons, urban forests, cemeteries
	'Negative' spaces	
(4) Movement space	Space dominated by mobility requirements, primarily automobiles	Main roads, motorways, railways, underpasses
(5) Service space	Space dominated by contemporary service requirements	Car parks, service yards
(6) Left over space	Unused space left over after construction, typically designed without function	'SLOAP' (space left over after planning), Modernist open space
(7) Undefined space	Vacant land, either vacant or awaiting redevelopment	Redevelopment space, abandoned space, transient space
	Ambiguous spaces	
(8) Interchange space	Internal and external transport hubs and interchanges	Metros, bus interchanges, railway stations, bus/tram stops
(9) Public 'private' space	Apparent public outdoor space that is privately owned and to a greater or lesser extent governed	Privately owned 'civic' space, business parks, church grounds
(10) Conspicuous spaces	Public places that are intended to make visitors feel conspicuous and possibly unwelcome	Cul-de-sacs, dummy gated enclaves
(11) Internalized 'public' space	Originally public and external uses that have been internalized and frequently privatized	Shopping/leisure malls, introspective megastructures
(12) Retail space	Exchange spaces that are privately owned but open to the public	Shops, covered markets, petrol stations
(13) Third place spaces	Public and private, semi-public meeting and social spaces	Cafes, restaurants, libraries, town halls, religious buildings
(14) Private 'public' space	Spaces that are publicly owned but functionally and user-determined	Institutional grounds, housing estates, university campuses
(15) Visible private space	Space is physically private but visually public	Front gardens, allotments, gated squares
(16) Interface spaces	Interfaces that are physically separated but still allow public access to private spaces	Street cafes, private pavement space
(17) User selecting spaces	Designated areas for specific demographics, which are often regulated and supervised based on age or type of engagement.	Skateparks, playgrounds, sports fields/grounds/courses
	Private spaces	
(18) Private open space	Physically private open space	Urban agricultural remnants, private woodlands,

(19) External private space	Physically private spaces, grounds and Gardens	Gated streets/enclaves, private gardens, private sports clubs, parking courts
(20) Internal private space	Private or business space	Offices, houses, etc

Other authors such as Parysek, & Mierzejewska [25] suggest that space can be categorized into three distinct categories: public, semipublic, and private. Semipublic spaces are defined as areas that are only accessible to a particular group of individuals, under specific conditions, or for a designated period of time.

In their work, Mantey & Kepkowicz [13] propose a novel classification system for public spaces, which is based on five distinct factors. These factors include the designated user group, the temporal constraints on access, the predominant mode of regulation, the intended purpose, and the visual attributes of the space. From this categorization, it is clear which spaces are public, semi-public or private.

A study by Stanley *et al.* [4] also organizes a new typology based on the criteria of form, function, scale, and land cover of open spaces as illustrated in *Table 3*. This categorization aims to provide a flexible framework by broadly comparing various time periods, spatial scales, and human cultures on a broad scale [4].

Table 3. Typologies of urban space by Stanley [4].

	City	Intermediate	Residence
Transport Facilities	Harbors, Airport and Train Station Parking	Transit Stations, City Gate Areas	Driveways, Parking Areas
Streets	Central Boulevards	Street Space	Pedestrian Alleys, Paths
Plazas	Large Formal Plazas	Smaller Neighbohoods Plazas	Inner Courtyards
Recreational Space	Stadiums, Greenbelts, Beaches	Sports Facilities, Playgrounds	Houseyard Playspace
Incidental Space	Natural Features and Semi-Wild Areas	Empty Lots, Transit Borders	Marginalized Space Between Buildings
Parks and Gardens	Major Formal Park and Garden Space	Institutional Gardens, Small Parks, Cemeteries	Household Gardens
Food Production	Orchards, Agricultural Fields	Grazing Commons, Community Gardens	Kitchen Gardens, Small Horticulture

Grey space
Grey/ Green space
Green space

All these typologies of public space gathered from various studies and authors aid in informing policy and design decisions, in order to allow for better urban planning decisions.

2.4 Urban Morphology Definition

Urban morphology is an interdisciplinary field that draws on a range of other fields of study to understand the form and structure of cities. Some of the key fields that are closely related to urban morphology include Geography, Urban planning and design, Architecture, Sociology, Transportation planning and Environmental studies.

An early definition of the term morphology was first formulated by the great German philosopher and poet Goethe in 1790, who defined it as “the science that deals with the very essence of form, the science of form, or numerous factors that control and influence forms” [26].

In the Oxford dictionary, the word morphology is derived from two words: morph and logy, and it signifies the logic of form identification [26]. Many authors have stated the definition of urban morphology differently, yet they share the same meaning at its core.

Liley [27] defined morphology as a scientific field that investigates the fundamental characteristics of forms. Additionally, it was noted that the term morphology was initially utilized as a biological concept in central Europe prior to its adoption by urban science. The term refers to the investigation of the constituent elements and physical structure of urban environments. Subsequently, UM was defined by Stephen & Olgu [28] as a conceptual depiction of the tangible world that is exhibited through cartographic representations of shapes, attributes, and categories.

Other authors defined UM by relating it to the history of transformations within cities. Muratori in 1950 defined UM as an "operational history of urban form" because it documents the changes in urban form brought about by planners, architects, and builders over time [26]. Other authors, similar to Muratori related urban morphology to the stages of change in cities’ patterns, sizes and compositions over time [26].

2.5 Urban Morphology Elements

The cadastral pattern, also known as the street system, the cadastral units, also known as the plot system, and the building block are the three primary components which collectively make up urban morphology [26].

2.5.1 Cadastral Pattern (Street System)

Streets represent the public transportation system that links the various areas of the city [26]. Most commonly streets are represented in two ways: composition and configuration. The composition refers to the exact geometry of the street and considers all necessary geometrical data, including width, position, lengths, areas, and orientation [26]. Configuration, the other way of representing streets, refers to the topological shape represented in a diagram where only spatial relations can be examined [26].

Steet systems or road networks have different morphological configurations. The most common are gridiron roads, organic road networks and radial road networks.

Gridiron road networks consist of four orthogonal roads that surround buildings, enabling interaction with each façade [29]. This dense road network creates more intersections which facilitate the optimization of pedestrian mobility and develop human activities, therefore allowing this network to support intense urban vitality [29].

As for the organic road network, they are curved main roads that divide the land into superblocks [29]. By lengthening routes through curvature, organic networks also increase the number of facades for interactions [29]. It offers less effective interaction space than gridirons but also requires less road density [29].

The radial road network consists of main roads from various directions that gather at a central area. The movement between blocks would rely primarily on the main network, which encourages more interaction on the facades overlooking major roads but dampens the vitality of other areas [29].

In relation with this research the gridiron road network is used, as it relates to morphological context of the site and it is proven to provide intense urban vitality.

2.5.2 Cadastral Units (Plot systems)

Along with buildings and streets, French typo morphologists consider the plot as an essential element of urban space [30].

Cadastral units or Plot systems are a product of dividing and splitting a private area into a single parcel in order to create a land division pattern with numerous compositions [26]. This classification differentiates the public and private domains and handles the ownership boundaries [26].

Bobkova *et al.* [31] organizes the plot's three primary components. It firstly considers plots as a fundamental unit of control that connects spatial and non-spatial mediums. Secondly, plots act as a link between the built environment (buildings) and space of movement (street network) [31]. Lastly, the plot serves as the framework of building evolution over time.

2.5.3 The Building Block

Urban blocks are the smallest enclosed regions that contain multiple buildings. They contain a variety of building typologies, placed on plots bounded by a street network [26].

Buildings are a crucial element in the field of urban morphology. Over the last few years as a result of the growing volume of building data and the connection they share with various factors like energy, transportation, health and urban vibrancy, studies that incorporate building data will contain an increased value in the future [32]. In relation with this thesis the building block is studied and a dataset of various indicators is conducted in order to help parametrize the experimental site urban model.

2.6 Urban Morphology Indicators

These indicators use morphological relationships (numbers, sizes, volumes, areas, orientations, and percentages) between the different parts of urban morphology in order to characterize the built environment's shape, geometry, and type.

This paper by Elzeni *et al.* [26] looks at indicators from multiple studies and organizes them into respective groups. The study applies a dual-tiered system of classification, consisting of an initial level that draws upon the vocabulary of urban morphology, and an additional level that encompasses subcategories for each element.

UMIs are then categorized according to three factors: UM elements, generation process and spatial relations [26]. It first identifies the UMIs that can be employed in the production of urban morphology, and then introduces four primary categories that target streets, plots, buildings, and open spaces as UM elements [26]. The categorization scheme is organized as represented in *Figure 2*.

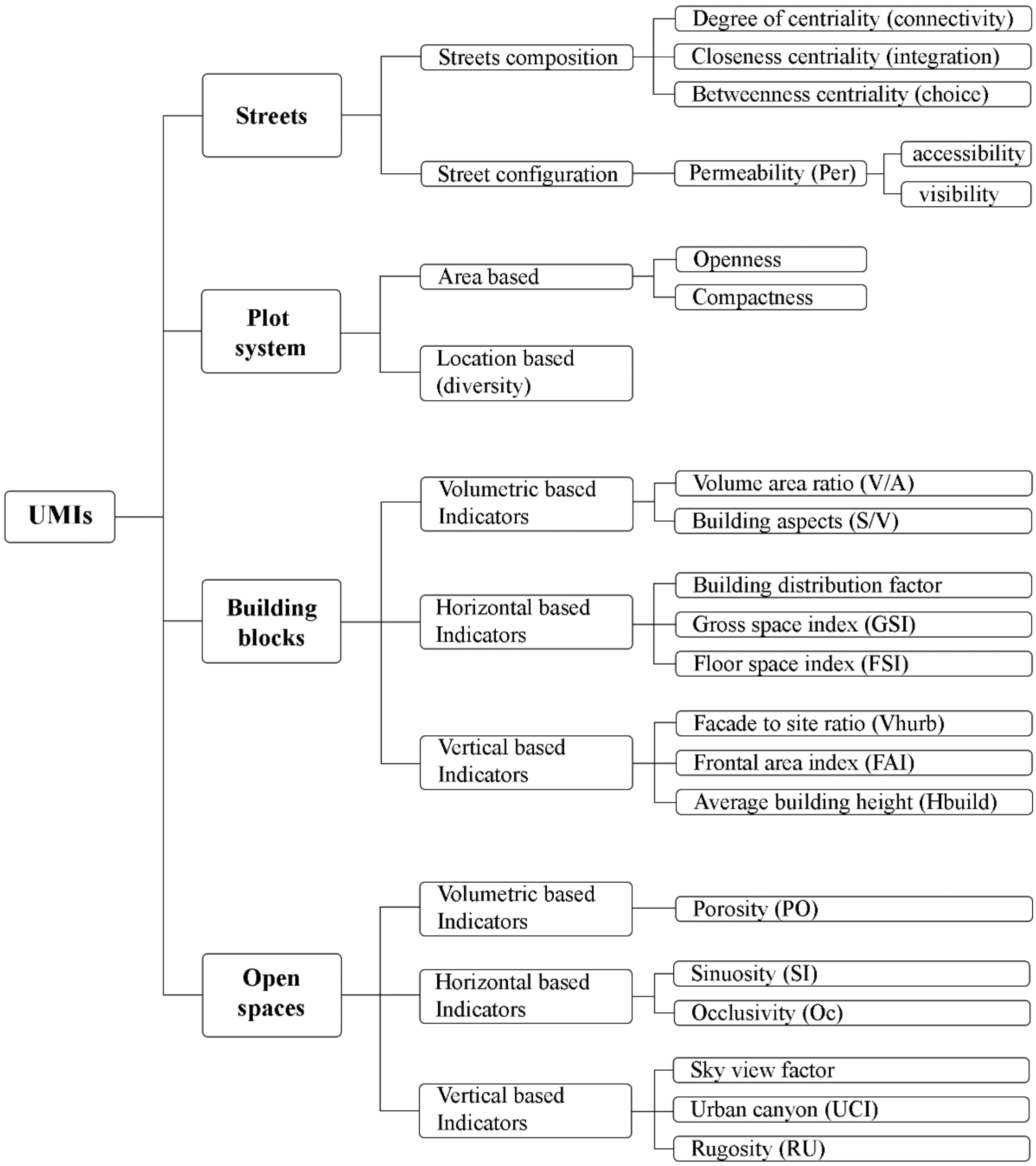

Figure 2. UMIs Classification [26].

2.6.1 Street indicators S(UMI's)

SUMIs are organized by the composition and configuration way of representing streets [26]. For this thesis, only simple street morphological indicators are conduced, such as street length, width and area.

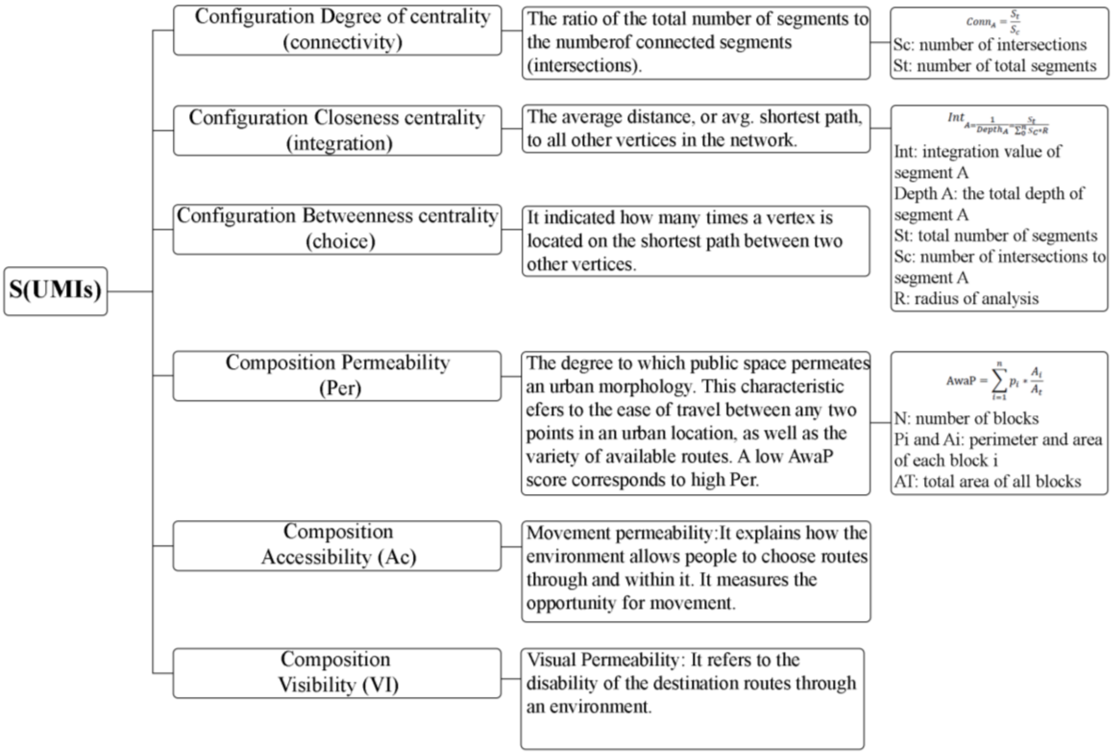

Figure 3. List of Street indicators [26].

2.6.2 Plot indicators P(UMI's)

Plot indicators were developed from the theoretical examination presented by Bobkova *et al.* [33], who evaluated the structures using configurational and geometric criteria like amount and diversity of available plots, as well as geometric terms like openness and compactness.

In relation to this thesis, the plots are studied only from their primitive morphological indicators such as width, length and area.

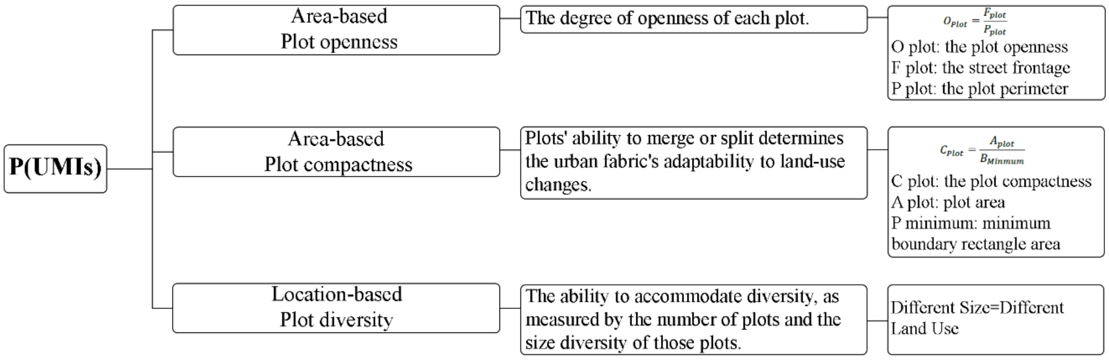

Figure 4. List of plot indicators [26].

2.6.3 Building indicators B(UMI's)

This research by Bobkova *et al.* [31] proposes a series of metrics aimed at capturing different aspects of building morphology. These metrics or also known as indicators serve as quantifiable parameters that can be used to assess and compare the characteristics of buildings in different urban contexts.

There are not many studies that focus on building-level indicators, with most studies focusing on aggregated indicators at a higher-level zone [31]. Nonetheless, in order to calculate aggregated indicators or derivates, the building-level indicators should be calculated first [31].

Almost all these indicators are self-explanatory, while a few require further explanation. The minimum bounding box (MBR) of the building footprint is used to calculate three indicators: length, width, and area [31]. In addition, the shape of the footprint is parameterized by four indicators: shape complexity, shape compactness and number of vertices [31]. All of these indicators and more are illustrated in *Figure 5*. In relation with this this thesis, a similar set of building level indicators are calculated.

The study by Elzeni *et al.* [26] provides other derivative indicators that are organized into three distinct categorizations for building indicators, including the horizontal, vertical, and volumetric approaches, all of which are influenced by the height of the building. These indicators are all explained with their respective definitions and formulas in *Figure 6*.

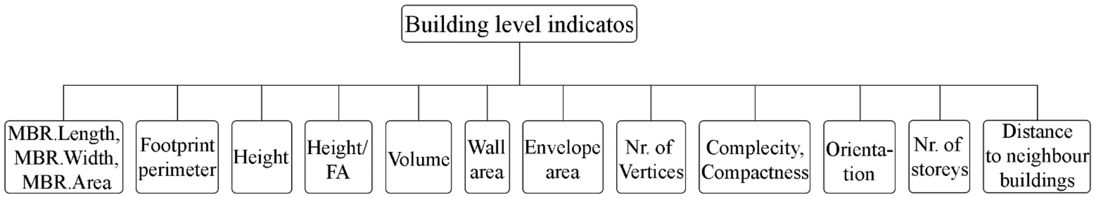

Figure 5. List of building level indicators [32].

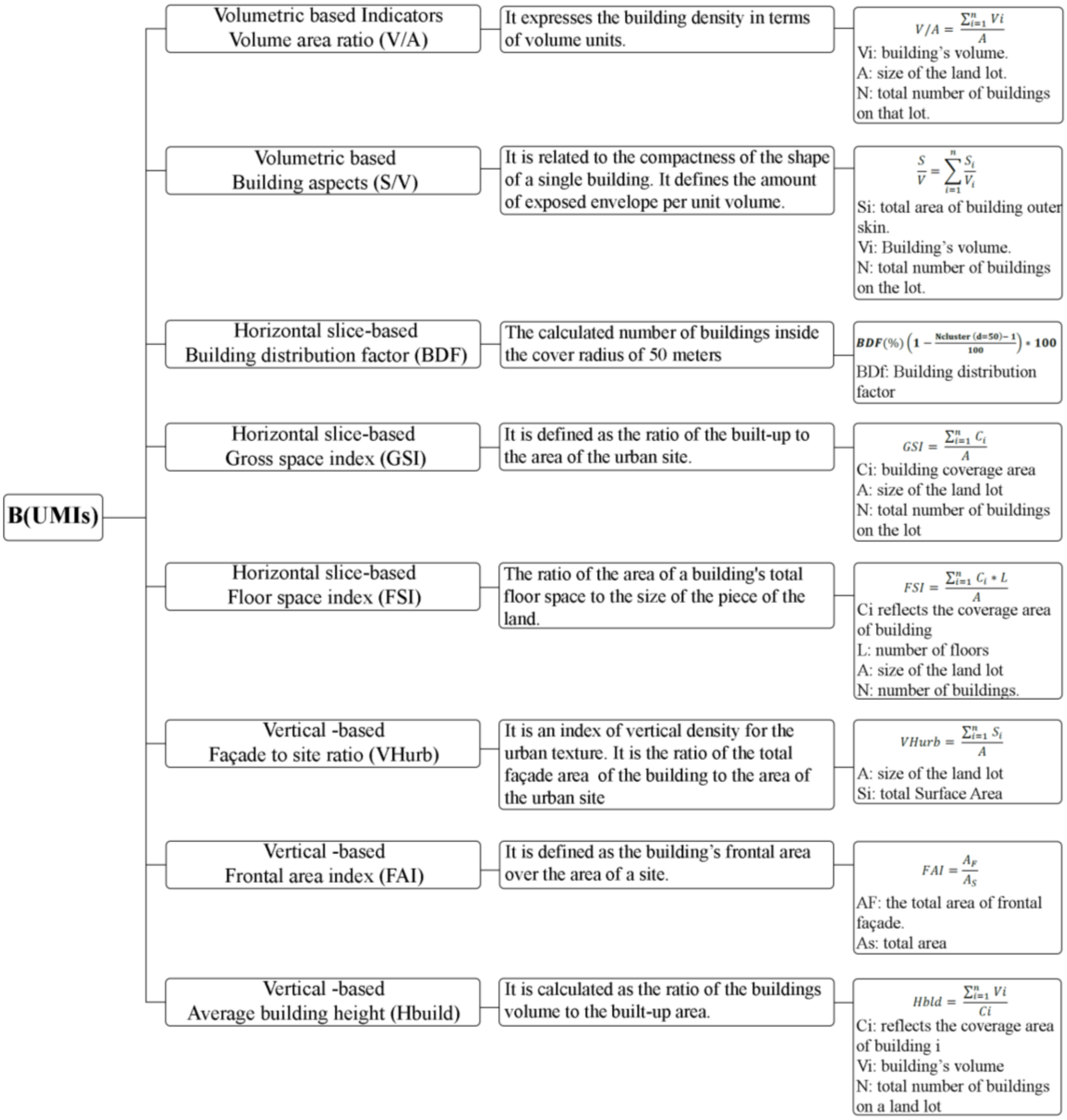

Figure 6. List of building indicators [26].

2.6.4 Open space indicators O(UMI's)

The research by Elzeni *et al.* [26] classifies the open space indicators horizontally, vertically and volumetrically. The open space indicators are illustrated in *Figure 7*. For this thesis, the open area is studied based on its size and ratio to the total urban and built area.

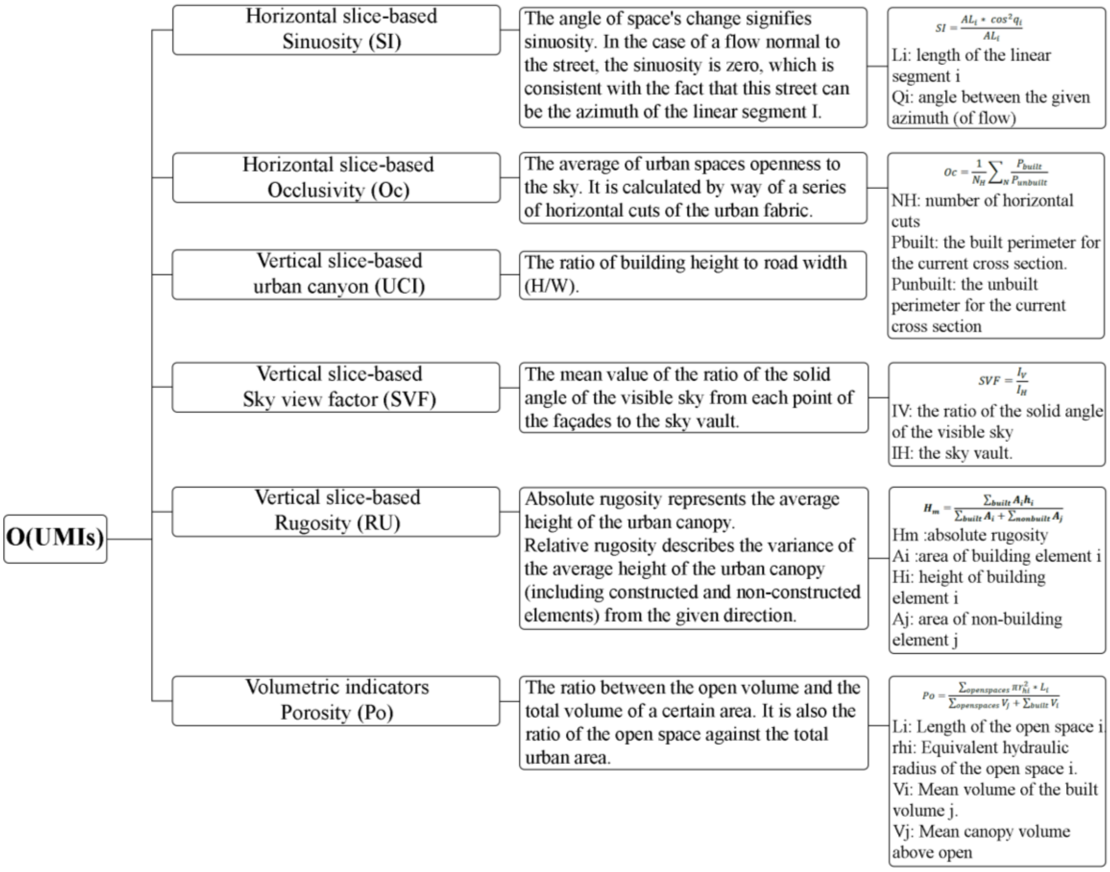

Figure 7. List of open space indicators [26].

2.7 Generative Urban Design

Generative design is increasingly gaining prominence in the realm of computer-aided architecture design (CAAD) methodologies for urban design. This is due to its numerous benefits, such as the ability to manage the complexity of projects, optimize for specific criteria, and offer a dynamic model for real-time adaptation [34]. The process of generative design uses a number of technologies, including parametric design software for modelling the solution space, simulation software for metric evaluation of each design possibility, and optimization solvers such as the Genetic Algorithm (GA) for automated search of the design space to identify the most optimal designs [35]. However, computational optimization techniques for urban design have been restricted in comparison to architecture, primarily due to heightened complexity and computation demands [36]. The most commonly used tools today for generative urban design modelling, optimization as well as for deriving metrics are Grasshopper, Urbano, DeCodingspaces toolboxes, CityMetrics tools etc [37].

2.8 Related Studies

In order to establish the context of this research, numerous previously related studies were analyzed. From the analyzed papers it was noted that many authors had different perspectives of optimization when applying urban generative design, while other authors focused merely on the generative process by creating simplified urban models that can be used on further analysis.

This paper by Huang *et al.* [38] implements the principles of Transit-Oriented Developments (TODs) which are predicted by four principles: walkability, transit accessibility, density, and diversity. The authors construct two models: a contextual model and an activity-based model. The contextual model analyzes the existing built environment and conducts both quantitative and qualitative analysis. The activity-based model includes metadata creation, combining the contextual model and metadata, and conducting trip-sending simulation for quantitative analysis. After developing the framework, the authors then implement it by selecting a case study and produce multiple proposals *Figure 8*. It is the first study to propose a comprehensive framework that uses TODs as optimization or as an evaluation approach in urban design decision making.

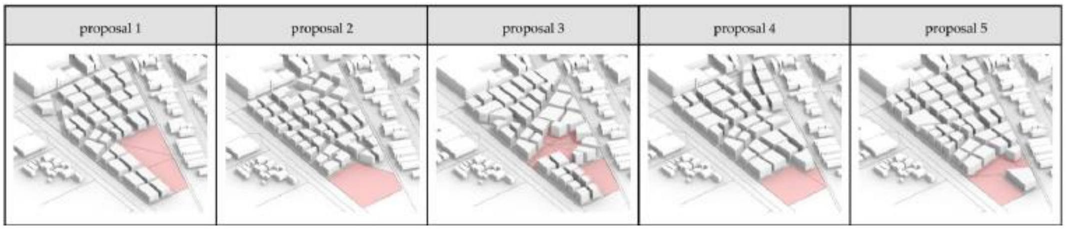

Figure 8. Generated urban design proposals that reflect the public spaces [38]

This study by Zhang & Schnabel [39] presents a methodology for urban design modelling that consists of three primary steps. OpenStreetMap (OSM) data is first linked with the Elk plug-in in order to construct a parametric model in Grasshopper (Gh) as the initial phase. The second step focuses on modelling form-based regulation using the transect matrix and regulation parameter group *Figure 9*. The transect matrix classifies zones and provides a foundation for form-based regulations, whereas the regulation group controls parameters such as depth, width, ceiling height, number of floors, and building height. Using these parameters, Rhino software generates a base map of building coverage surfaces. The third stage is the generation of object-oriented models at the street and neighborhood scale. The authors use the Galapagos plug-in to encourage pedestrian activity paths, with the intention of creating a walkable urban environment.

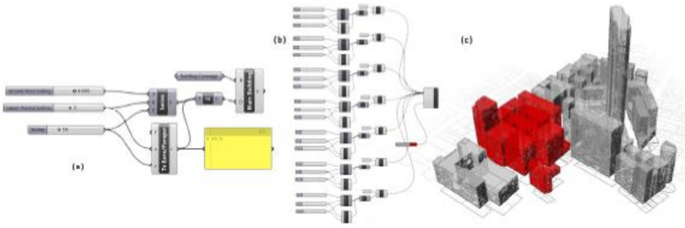

Figure 9. Form based regulation modelling [39]

Other studies by Lima *et al.* [37] and Rakha & Reinhart [3] also uses generative design to optimize urban design for improved transit accessibility and walkability.

This paper by Ameijde & Song [40] uses various criteria of evaluation such as: sunlight exposure in the open spaces, the total FAR of the plot, the geometry of the blocks, their ability to accommodate larger or smaller areas and open spaces' accessibility. The workflow of this study is illustrated in *Figure 10*.

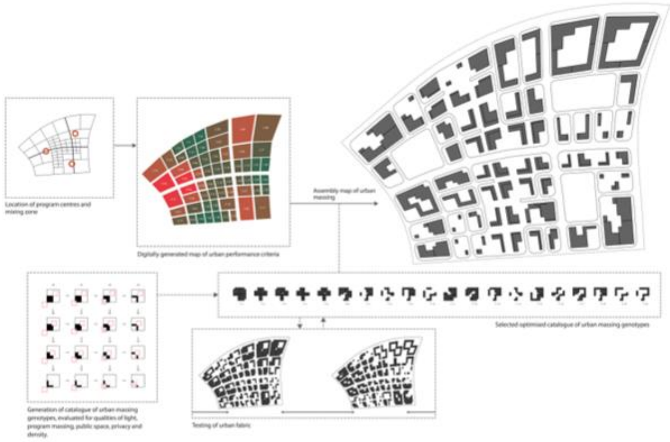

Figure 10. Workflow diagram [40]

In all of the above papers there is no dedicated evaluation or analysis on public space. Huang [38] states that it is difficult to take decisions on PS and that the shape and size of PS is influenced by a variety of factors which need to be studied further in future research. Besides TODs, walkability or the accessibility of open spaces, many other authors use different aspects of optimization such as financial goals, energy performance, environmental performance etc.

This paper by Nagy *et al.* [35] proposes a method for generative urban design that integrates financial and energy goals using a rule-based shape grammar approach. It is also applied in a selected neighborhood area which is that of Alkmaar, Netherlands. The authors of the study selected two primary objectives to evaluate the efficacy of each design, namely, the optimization of the developer's financial gains and the optimization of the amount of solar energy harvested by the building's rooftops. The approach uses a cost-benefit analysis and energy simulation to determine the optimal layout that achieves the financial and energy goals. The steps of the development of the generative model are illustrated in *Figure 11*.

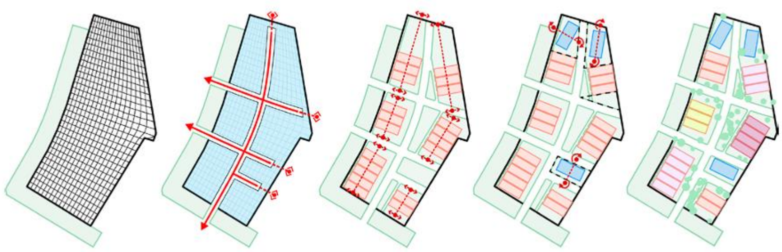

Figure 11. Parametric model generative steps [35]

This paper by Natanian & Thomas [41] also proposes a framework for generative energy-driven urban design that aims to optimize the building's energy performance and demonstrate it on a case study of a residential blocks in Tel Aviv. They use a simplified evaluation metric that considers morphological parameters of the building block such as: compactness, orientation, surface-to-volume ratio, and window-to-wall ratio. The optimization aspect is based on the use of an energy simulation tool that evaluates the energy performance of each design alternative *Figure 12*.

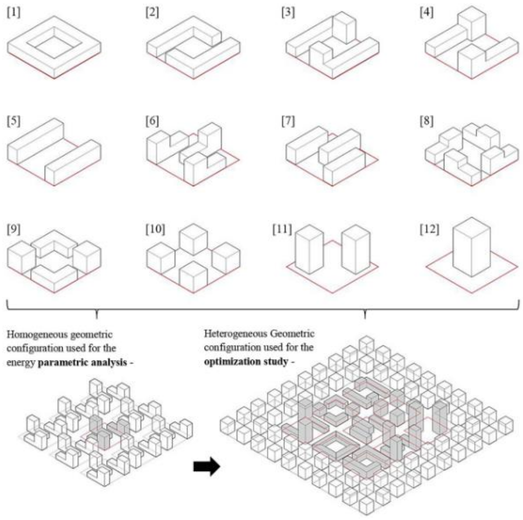

Figure 12. Typologies used for energy parametric analysis and optimization studies [41]

This study by Fink & Koenig [42] presents a workflow for integrated parametric urban design using GH and Rhinoceros 3D software, applied to a master plan in Vienna. The workflow consists of three phases: analysis, synthesis, and optimization *Figure 13*. In the analysis phase, the authors use GIS data and scripting to generate maps of parameters such as solar radiation, noise pollution, and accessibility to public transportation. In the synthesis phase, they use the generated maps as design constraints to create a range of design alternatives. In the optimization phase, the authors use evolutionary algorithms to find the most suitable design solution based on multiple criteria, such as building density, open space ratio, and environmental performance.

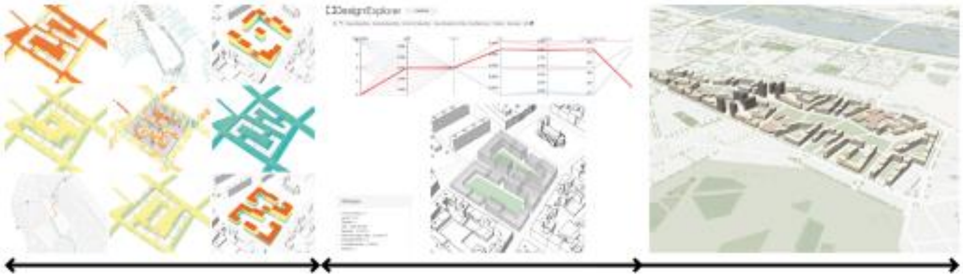

Figure 13. Methodology steps [42]

This study by Shi *et al.* [43] conducts a parametric framework that uses vernacular block typologies and evaluates them in terms of solar energy. The methodology involves indicators such as: width length and depth of the blocks, FAR ratio, site coverage etc. The study is applied in the context of Singapore. The block typologies are developed on Gh by using the Urban Block generator as illustrated in *Figure 14*.

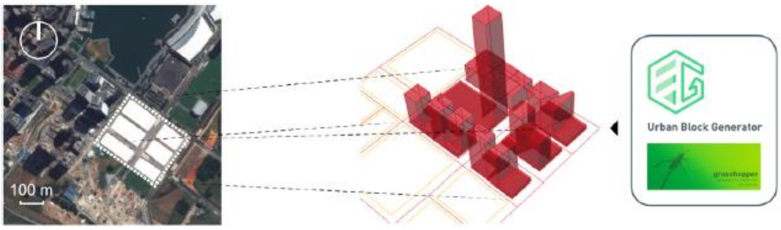

Figure 14. Urban block generator tool [43]

This study by Wang *et al.* [34] develops a framework that uses block morphological analyses and shape grammar platform to create a practical model for the project site. It uses City Engine and morphological rules of CGA language which define the shape grammar that will create the 3D model as illustrated in *Figure 15*. The scope of this study is restricted to the specific location of the project (blocks in Nanjing).

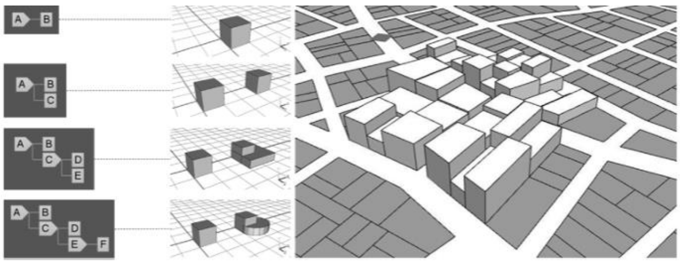

Figure 15. Diagram of tree shape structure and CGA generation process [34]

This study by Ameijde [44] shows how generative tools can help produce differentiation in residential projects at the scale of the urban block as well as at the building scale, to increase the range of lifestyle choices for residents and to stimulate the mixing and collaboration between people of different age groups, social class or cultural background. It does not focus on optimization, but rather on proposing a range of design alternatives that increase visual connectivity. The generated model of this study is illustrated in *Figure 16*.

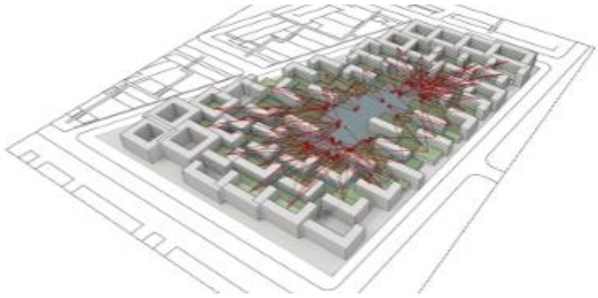

Figure 16. Model with sight lines that increase connectivity [44]

This study by Koenig *et al.* [45] presents a technique for producing urban development schemes that rely solely on computer-aided design. The tool enables the user to generate numerous design scenarios but it does not permit manipulation of the generated scenarios. For developing the scenarios Rhinoceros and GH were used. They first start by creating a road network within a specified region and are then followed up by developing the blocks and plots which are automatically generated based on the road network as showcased in *Figure 17*. The project also takes into account the terrain. The authors state that the research can be fully completed if context data from pre-existing urban scenarios can be implemented in order to create urban layouts that align with the context.

Figure 17. Developed urban plan scenario [45]

From all the related studies, a number of limitations were gathered. Starting with lack of metrics and analysis in public space. None of the papers tackle this aspect in detail.

Another limitation would be that many of the studies focus on developing frameworks and methods for generative urban design but have limited evidence of their effectiveness in practice. Lastly, there is a need for more diverse case studies to test the applicability of these methods across different urban contexts. None of the studies are set in the context of a neighborhood in Tirana, Albania, Southeastern Europe or even Eastern Europe.

CHAPTER 3

METHODOLOGY

3.1 Overall framework and computational tools

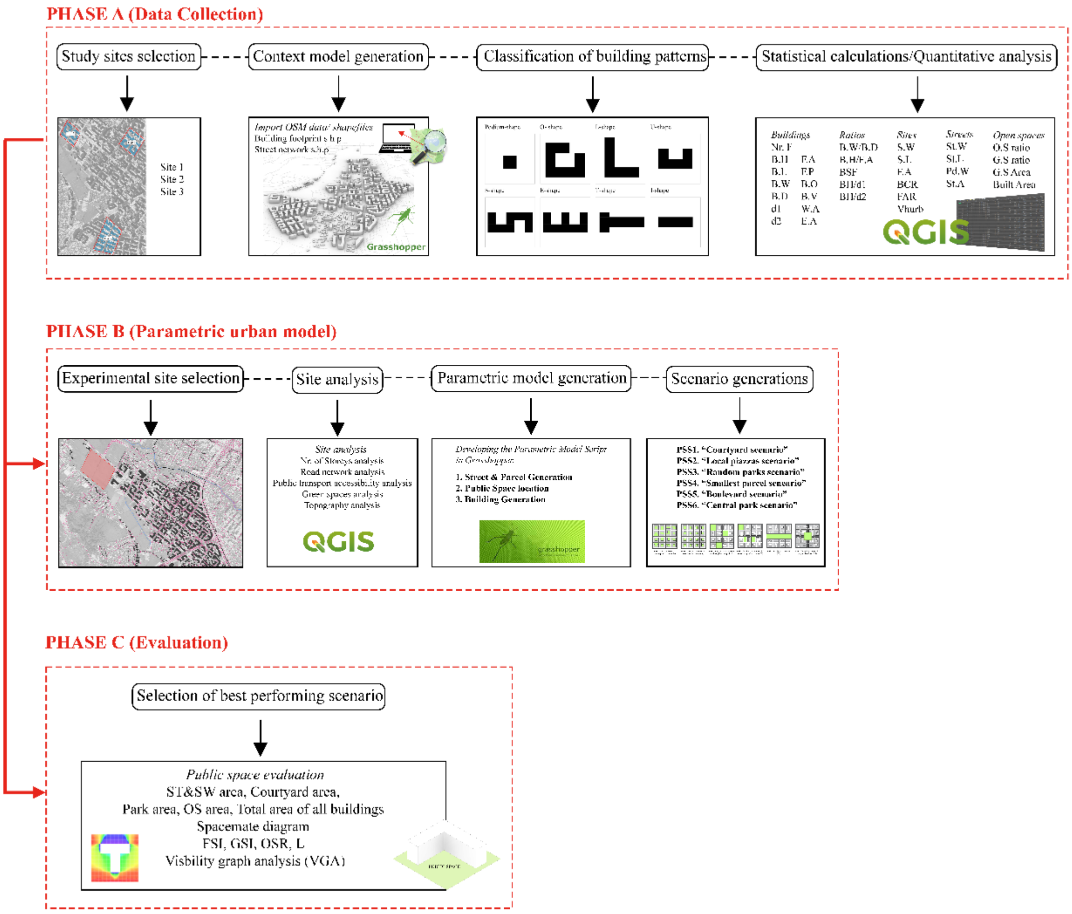

Figure 18. Methodology framework of the research

In this section, we briefly analyze the three phases of the overall framework as well as list the tools that were used to conduct this research. The first phase of the research consists of data collection and geographical mapping from the three selected study sites. The tool that was used for this first step was QGIS which is a Geographic Information System that helps in data management. From OSM (Open Street Map) [46] data the context model of the site was built by using Rhinoceros3D-Grasshopper (GH) and the Urbano plug-in [47]. The Urbano plug-in is not only a useful analytical tool but it can also be used to create a context model by inserting the respective shapefiles into Grasshopper. The following step included classifying the existing building patters of the site. The last step of this phase consists of selecting a set of different morphological indicators in order to conduct the statistical calculations of the study sites. The calculated indicators and the qualitative analysis of the study sites were conducted on QGIS and were later on exported from their respective attribute tables to Excel where a list of averages and derivative indicators were also calculated.

The second phase of the research encompasses building the parametric model. After selecting the experimental site and conducting all the main urban analysis on QGIS the proposed script of the parametric model was built and applied on the selected experimental site. For this phase, GH (Grasshopper) and the DeCodingSpaces Toolbox [48] were used.

The third and last phase of the research consists of evaluating the best-performing scenario in terms of public space. The evaluation phase first consisted of calculating a set of various morphological indicators for each scenario and building the Spacemate diagram by Berghauper & Haupt [49] and well as an area distribution graph in order to visualize the calculations. Visibility analysis on depthMapX [50] were also conducted in order to evaluate the best performing scenario in terms of visibility. The framework as illustrated in *Figure 18* is exemplified for each phase through the utilization of "Astir" as a case study.

3.2 Introduction of the study area

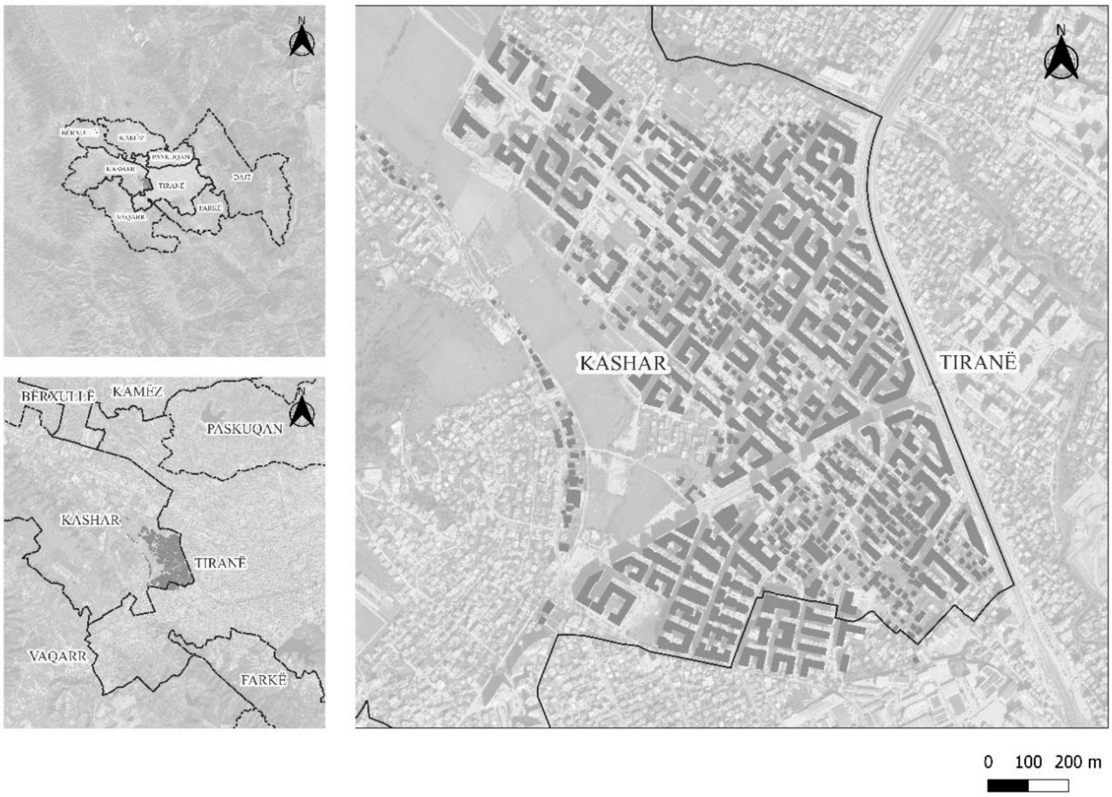

Figure 19. Location of Astir in relation to the city center

The research for this study is applied in a neighborhood located within the boundaries of Tirana's district. The city of Tirana, the capital of Albania between (latitude 41°19'39" N, longitude 19°49'8" E), has witnessed remarkable transformations over the years, making it a captivating case study for urban development. Tirana has undergone major transformations which helped in evolving it from a city of the communist era to a dynamic center of economic growth and architectural innovation.

The city is divided into 11 administrative units [51]. This research is specifically applied in neighborhood Nr.14, commonly known as Astir which is located within the administrative unit of Kashar [51]. The decision behind forming this new neighborhood located on the outskirts of the city center, came from the municipal council in 2018 which consisted in creating three new neighborhoods in Tirana, one of which was that of Astir. The administrative unit of Kashar lies on the northwest part of Tirana's city center between (latitude 41° 19' 11.3988"N, longitude 19° 46' 22.1772"E).

The rapid construction development of Tirana's city center has managed to expand its borders toward its suburban areas, making the administrative unit of Kashar a prime location for residential expansion and commercial ventures. With its proximity to Tirana's central districts and its ease of access to major transportation routes that connect the south and north of Albania, Kashar has attracted major attention as a growing suburban area. The most important businesses of the Albanian economy operate in the area, both in the field of service and production with a number of 3352 businesses [51]. The area is also rich in artificial lakes such as Lake Purezi, Kashari, Gjokaj, and Mzeze. Its relief is hilly-plain, where plain spaces dominate. The fields are flat and low altitude above sea level. The climate is mild and warm with the average annual temperature being 15.8 °C and 1136 mm of precipitation falling annually [52]. It is populated by 37 373 residents and 11 285 families [51].

For a long time, Kashar has become an important center of not only economic but also architectural development. This rapid development along the interurban axis Tirana-Durres in terms of construction, architecture, and urban planning is reflected in the developments that have happened in the Astir from 2007 until now. This neighborhood that was formerly distinguished by expansive agricultural grounds, is now known for its large number of residential complexes. By examining the planning and urban fabric of Astir, urban developers and policymakers can make informed decisions to enhance future urban developments.

3.3 Selection of case study sites

Figure 20. Study sites in relation to the city center

To conduct the necessary calculations of urban morphology indicators, three typical sites with diverse building typologies were carefully selected *Figure 20*. These sites serve as representative examples of different building typologies, enabling a comprehensive analysis of the neighborhood's build environment. By examining these distinct locations, the main goal of the study is to capture the breadth of variations in building forms, densities, and spatial configurations, ultimately providing a full understanding of urban morphology and its influence on the overall urban fabric. Through this selection process, the study endeavors to generate meaningful insights that contribute to informed decision-making and the effective planning and design of future urban developments.

Figure 21. Study site 1 photos

Figure 22. Study site 2 photos

Figure 23. Study site 3 photos

3.4 Context model generation

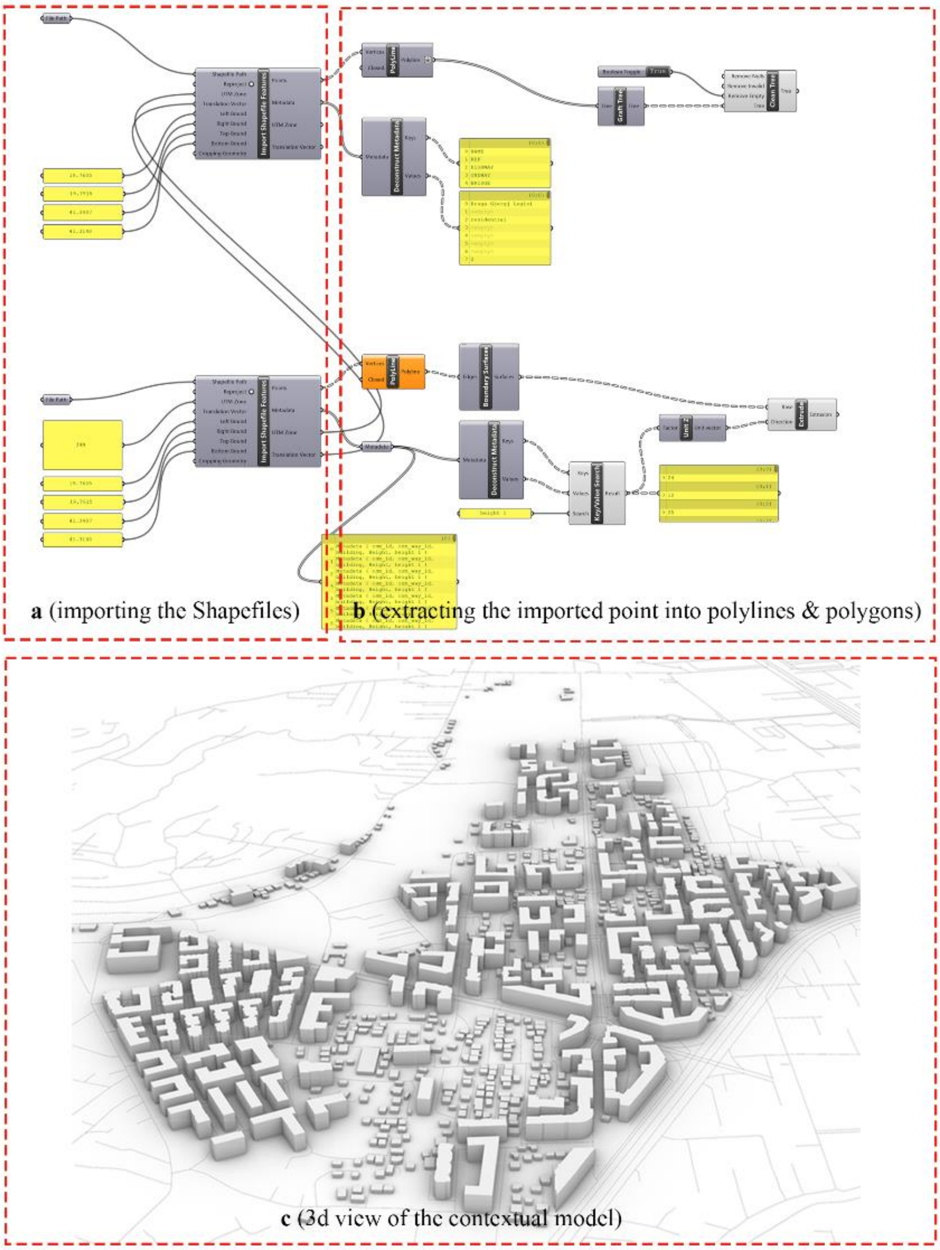

Figure 24. Context model script

Before proposing the next generative design solutions, it is necessary to model the current built environment of the study area. By doing so, it can help designers determine the problems that need to be fixed for future urban developments. The context model also serves as the physical basis on which the generative proposals will be applied on.

To build the existing urban environment of Astir, the Urbano plug-in [47] was used.

The basis data that was used to model the existing built environment was the building footprint shapefile and the street network shapefile from the data collection phase on QGIS. All of the necessary shapefiles are available for download from the OpenStreetMap website [46] or the respective official government websites. The data used for this study was first downloaded from OSM but it was also updated on QGIS with the necessary changes that the site has faced throughout the years. The necessary updates were based on site observations, drone shot photos and satellite imagery.

To import these shapefiles with their according attributes tables, Urbano's Import Shapefile Feature component was used. The first step consisted of connecting the shapefile path, the coordinates of the site, as well as the UTM zone to the component. The following steps consisted of extracting the imported points into polylines for the streets as well as extracting the imported points into polygons for the building's footprint. From the metadata, the height of each building was used to extrude its boundary to its respective height. Each of these steps of the GH script is illustrated in *Figure 24*.

3.5 Statistical calculation

A crucial part of this research phase is the application of statistical calculation from the three case study sites. The calculation includes various measurements and ratios by using UMIs which are based on studies of Elzeni *et al.* [26] and Biljecki & Chow [32]. These UMIs were organized into 5 main lists: Site Morphology Indicators, Parcel Morphology Indicators, Street Morphology Indicators, Building Morphology Indicators and Open Space Morphology Indicators. The graph in *Figure 25* illustrates each category of indicators.

From these measurements and ratios of the Urban Morphology, respective averages for each indicator are collected. This approach ensures that the generative development on the experimental site is based on a thorough understanding of the current urban context, allowing us to build solutions that are responsive and sensitive to the study sites' unique characteristics and challenges.

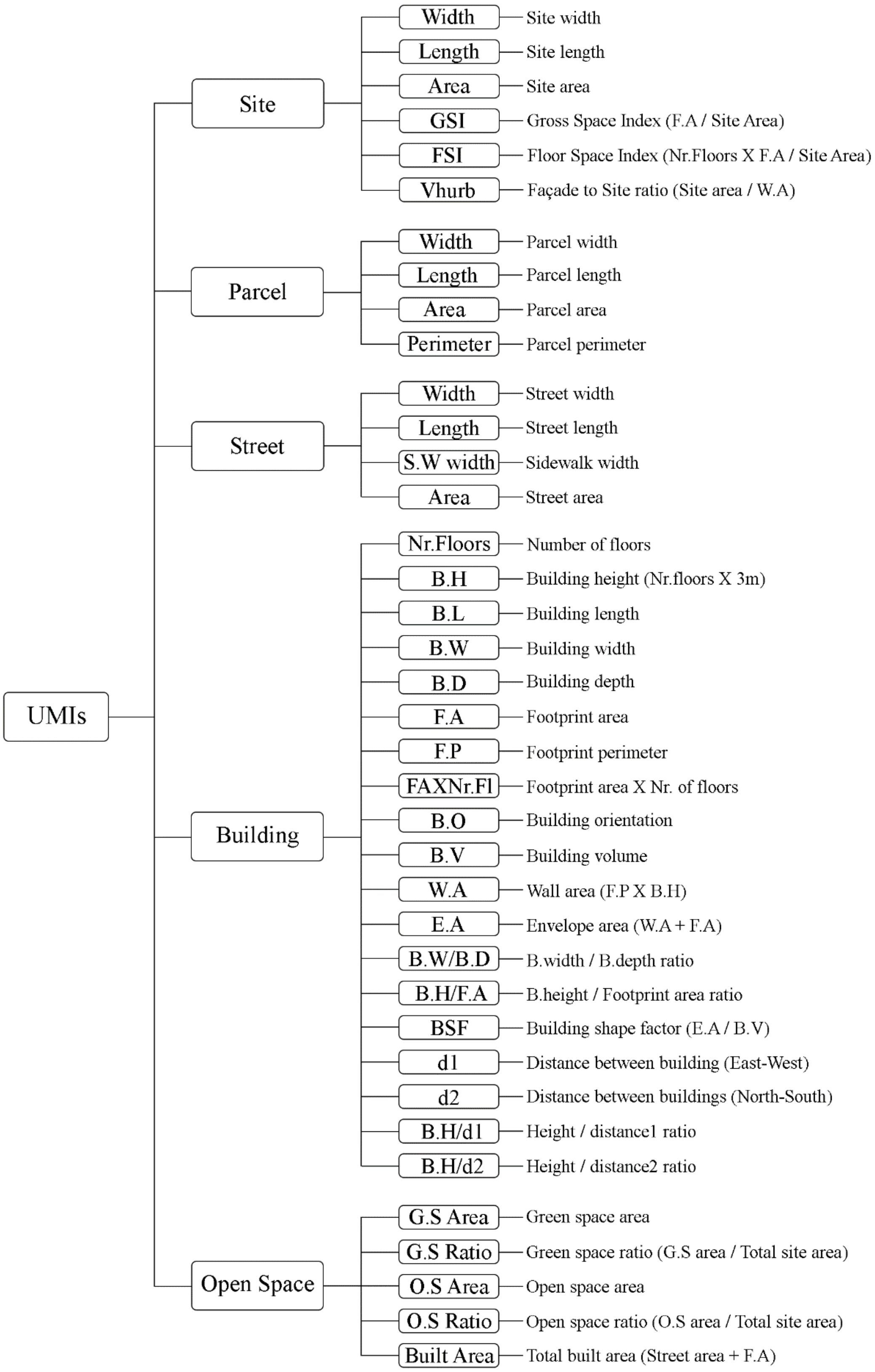

Figure 25. List of the conducted UMIs

3.5.1 Building patterns extraction

Prior to calculating the building morphological indicators an extraction of the most common building patterns in Astir was first realized. These building patterns are a reflection of the surrounding built environment, the master plan, and the local zoning laws. By identifying the most commonly used building patterns, we can predict what is most likely to reoccur in upcoming urban developments of Astir, and also help identify what building patterns that are uncommon to be adapted into the urban area. To help with this process, the current building patterns have been simplified in terms of their shape and each one has been labeled with a respective name in *Figure 26*. The most common building patterns from the case study sites are: Podium shape, O-shape, L-shape, U-shape, S-shape, E-shape, T-shape, and I-shape.

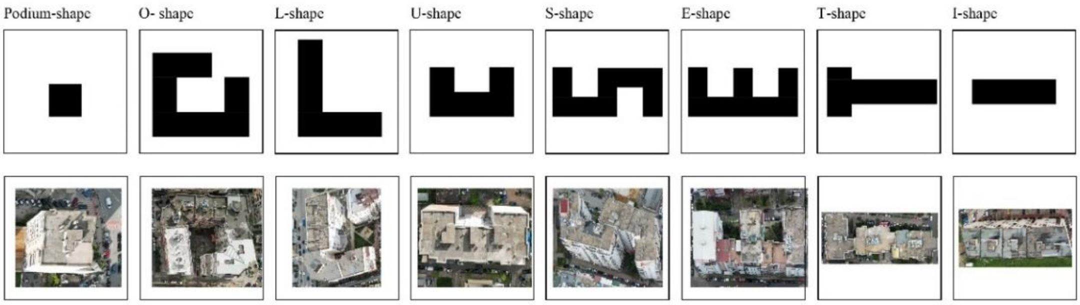

Figure 26. Building patterns

3.5.2 Site statistical calculations

The statistical calculations were conducted on the three study sites that were previously selected *Figure 27*. The site calculations included simple parameters, such as the number of objects located on each site, the length, width and area of the sites. From the building-level statistical indicators other derivative indicators were calculated such as, the GSI, FSI, and Vhurb ratios which are all very common density parameters.

Figure 27. Case study sites illustration

The GSI (Gross space Index) is the ratio between the Footprint Area of the buildings over the Site Area. It is a density indicator that illustrates the relationship between built and unbuilt space.

FSI (Floor Space Index), also known as FAR (Floor Area Ratio) is the ratio of the gross floor area to the urban site area [53]. This ratio reflects the building intensity regardless of programmatic composition [54].

Vhurb (Façade to site ratio) is a vertical density indicator for the urban texture that is measured by the ratio of the building façades area to the urban site area [53].

In *Table 4*, all the site morphological indicators are conducted. The indicators are also graphically explained in *Figure 28*.

Starting with the GSI ratio, from the results Site 1 and Site 2 have the same score, while Site 3 on the other hand appears to have a higher score. From the scores, it is evident that Site 3 is denser than the other two. Based on local planning requirements the footprint of the construction development cannot exceed 45% [55]. In our case the three sites do not exceed this limit, even with the 41% GSI score of Site 3.

From the table, the FSI score of Site 1 is the lowest compared to Site 2 and Site 3, but it still exceeds the proposed 2.5 building intensity by the local planning authority [55]. Site 2 also exceeds the proposed building intensity which is 3. Lastly, for Site 3 there is no data regarding the proposed building intensity, but judging from the score it is still considered high for the area. The results imply that the three case study sites are of high density and have tall extensive buildings.

The Vhurb results for Site 1 are higher than the other two sites suggesting a high proportion of wall coverage compared to the overall site area.

For the experimental site the proposed FSI is 2.2, which suggests that the area will be slightly less dense in future developments [55].

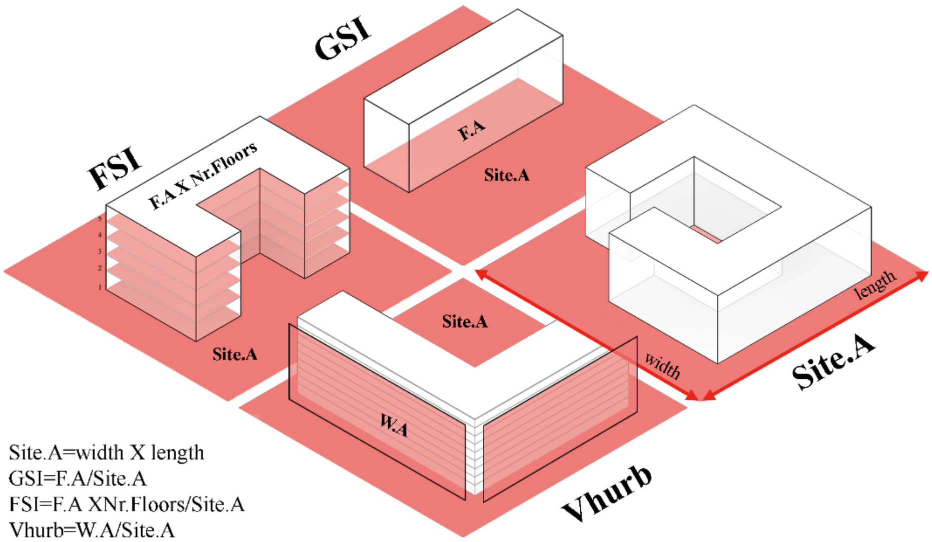

Figure 28. Site morphological indicators

Table 4. Site morphological indicators

Site name	Nr. of objects	Length	Width	Area (m^2)	OS Area	GSI Ratio	FSI Ratio	OSR Ratio	Vhurb Ratio
Site 1	7	200.4	196	38129.2	24371.2	0.36	3.49	0.64	0.70
Site 2	6	190	182	27781.0	17735.2	0.36	3.62	0.64	0.67
Site 3	12	196	194	59836.7	35526.0	0.41	3.60	0.59	0.61
Avg.	8.3	195.5	190.7	41915.6	25877.5	0.38	3.57	0.62	0.66

3.5.3 Parcel statistical calculations

The sites which in many studies are also referred to as zones, areas, or blocks, are composed of different-sized parcels. The parcels in the case of Astir are divided by considering the street network and the buildings' footprints. The division of the parcels is illustrated in *Figure 29*.

Figure 29. Parcel division of the case study sites

The main calculated urban indicators for the parcels are Width, Length, Perimeter, and Area as illustrated in *Figure 30*. For each study site the calculations are shown in *Table 5*.

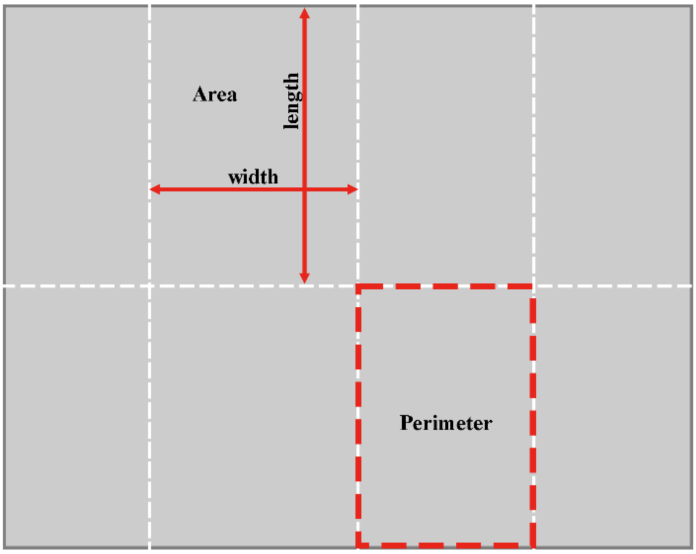

Figure 30. Parcel indicators illustration

Table 5. Parcel morphological indicators for each case study site

Parcel Nr.	**Width (m)**	**Length (m)**	**Perimeter (m)**	**Area (m^2)**
		Site 1		
1	91.6	100	386.90	9330
2	92	97.1	376.57	8823
3	57	198	506.68	10949
4	48.7	58.9	216.91	2888
5	47.6	67	229.83	3183
6	47.5	70.5	236.92	3358
Avg.	64.07	98.58	325.64	6421.83
		Site 2		
1	39.8	89.7	258.05	3427
2	39.8	86.5	251.71	3370
3	89.7	117	414.09	10144
4	86.45	116.7	405.56	9785
Avg.	63.94	102.48	332.35	6681.50
		Site 3		
1	57	98	305.91	5092
2	51.4	110	315.04	5058
3	43.1	96.3	292.09	4670
4	59	102	306.51	4956
5	51	92.1	274.94	4082
6	41.4	104	288.91	4205
7	45	92	277.10	4247
8	50.3	104.02	295.98	4542

9	52	93	290.17	4821
10	46.3	104.4	295.46	4468
11	91	96	369.72	8461
12	60	106	328.30	6044
Avg.	53.96	99.82	303.34	5053.83

A summary table including all the sites, reflects the Min, Max, and Average sizes of the Parcels' width, and length as well as the Min, Max, and Average of the parcel's perimeter, and area. The calculations illustrated in *Table 6*, the minimum parcel width results at 39.8 m, indicating the narrowest parcel, while the maximum width reaches 92 m, representing the widest parcel. On average, the parcels have a width of 60.65 meters. In terms of length, the results include parcels with a minimum length of 58.9 m and a maximum length of 110 m. The average length of the parcels is approximately 100.29 m. Moving on to the perimeter, the smallest value is 216.91 meters, whereas the largest reaches 506.68 m. The average perimeter of the parcels is approximately 320.44 m. Finally, examining the parcel areas, the minimum area is 2,888 m^2, while the maximum area is 10,949 m^2. On average, the parcels have an area of approximately 6,052.39 m^2. These measurements provide valuable insights into the size and dimensions of the parcels.

Table 6. Summary table of Parcels morphological indicators

Summary	**Width (m)**	**Length (m)**	**Perimeter (m)**	**Area (m^2)**
Min.	39.8	58.9	216.91	2888
Max.	92	110	506.68	10949
Avg.	60.65	100.29	320.44	6052.39

Another table was constructed in order to calculate the minimum and maximum parcel area in relation to each building typology, as well as the minimum and maximum GSI ratio for each building typology. From the results of *Table 7*, it is evident that Podium shaped buildings require smaller-sized parcels, while L-shaped and O-shaped building typologies require bigger-sized parcels. From the table, the E-shape, T-shape, and I-shape have the highest GSI score in relation to their parcel area, while the podium shape, U-shape and S-shape have the lowest GSI ratio which indicates that these typologies cover less space from the total site.

Table 7. Parcel Indicators in relation to building typology

Parcel Area	**Podium shape**	**O-shape**	**L-shape**	**U-shape**	**S-shape**	**E-shape**	**T-shape**	**I-shape**
P.A Min	2888	8461	9785	3183	4821	4468	4082	3370
P.A Max	2888	9330	10144	10949	5092	6044	4956	4670
GSI Min	0.2	0.40	0.34	0.28	0.38	0.36	0.36	0.36
GSI Max	0.2	0.45	0.40	0.38	0.39	0.4	0.43	0.51

3.5.4 Street statistical calculations

The street data collected from OpenStreetMap for the case study sites included the name of the street, street typology, the material of the street, street direction, number of lanes and maximum speed. The key street indicators are illustrated in *Figure 32*.

Figure 31. Steet typologies for each site

From the data offered by OSM the streets were grouped into 5 main typologies as illustrated in *Figure 31*.

- Secondary street: it is referred to a street that connects the residential areas to the major primary roads. In our case a street that connects directly to the “Unaza e Re” highway.

- Residential street: it is referred to as the street that connects the residential complex with the secondary street or the primary street. It has lower traffic and speed.
- Living street: it is referred to as a street that prioritizes the needs of pedestrians and provides parcels with connections to residential streets or secondary streets. They are usually located inside the building complexes and have reduced speed limits.
- Service street: it is referred to the street or ramp that leads to the parking of the building complexes.
- Footway street: it is referred to the street that provides accessibility only for pedestrians.

The street morphological indicators were conducted for each case study site and it included the street width, pedestrian width and street length.

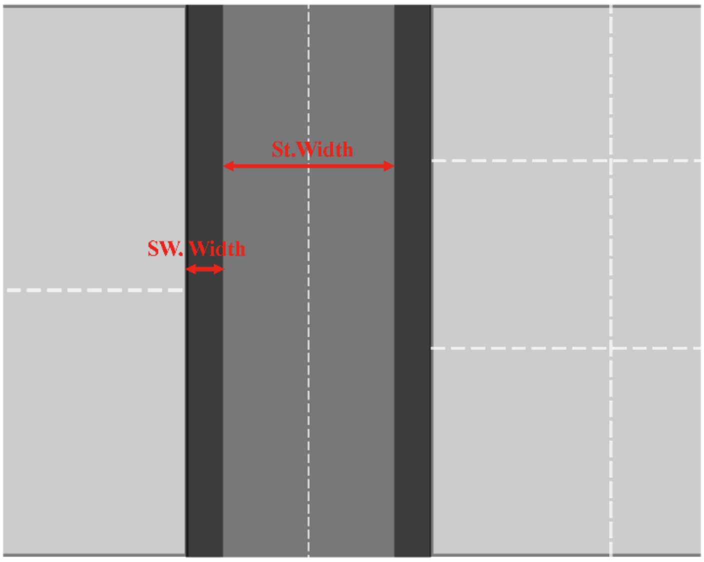

Figure 32. Street indicators illustration

From *Table 8* all the statistical calculations of Site 1 show that the streets of this site are mainly residential, with one lane and a common street width of 3.5m. Most of the streets do not have a sidewalk, but the streets that do, they typically have a width of 2m.

Table 8. Site 1 Street morphological indicators

ST.name	Street typology	Surface material	Direction	Lanes	Max speed (km/h)	ST.Width (m)	ST.Length (m)	SW.Width (m)	ST.Area (m^2)
Site 1									
noname	service	concrete	_	1	0	5	42	0	210
unknown	living	concrete	_	1	0	3	32.7	0	98.1
Mikel Maruli	residential	asphalt	OW	1	35	3.5	193	2	675.5
Henrik Lacaj	residential	asphalt	OW	1	35	3.5	200.1	2	700.4
unknown	residential	asphalt	OW	1	35	3.5	86.6	0	303.1
noname	service	concrete	_	1	0	5.5	29.5	0	162.3
Loni Ligori	residential	asphalt	TWA	4	60	14	201	2.5	2814
Faik Konica	residential	asphalt	TWA	4	60	14	217	2	3038
Henrik Lacaj	living	unpaved	OW	1	30	3.5	160	0	560
Polmonaria	residential	unpaved	TWA	4	40	14	15	2.5	210
Total Sum									8771

The calculations for Site 2 are shown on *Table 9.* Site 2 has a collection of residential and living streets with 1, 2 or 5 lanes and a variety of widths depending on the street typology. The sidewalk width varies from 1.5m to 3m.

Table 9. Site 2 Street morphological parameters

ST.name	Street typology	Surface material	Direction	Lanes	Max speed (km/h)	ST.Width (m)	ST.Length (m)	SW.Width (m)	ST.Area (m^2)
Site 2									
Athanas Tashko	residential	asphalt	TWA	2	35	14	68.8	1.5	963.2
Qemal Stafa	residential	asphalt	OW	1	35	3.5	83	1.5	290.5
unknown	living	asphalt	TWA	2	35	7	86.6	3	606.2
unknown	living	asphalt	TWA	2	35	6	156.4	2	938.4
unknown	living	asphalt	TWA	1	35	5	176.2	3	881
Athanas Tashko	residential	unpaved	TWA	1	35	3.5	89.5	0	313.3
noname	living	concrete	OW	1	0	5	150	0	750
Ismail Qemali	secondary	asphalt	TWA	5	60	10.8	190.8	2	2051

Ismail Qemali	secondary	asphalt	TWA	5	60	10.8	190.8	2	2051
Qemal Stafa	residential	asphalt	TWA	2	35	12	68.3	1.5	819.6
unknown	living	concrete	OW	1	35	3.5	329.6	0	1154
Total Sum									10818

The calculations for Site 3 are shown in *Table 10*. The streets of Site 3 are most commonly residential with 1 or 2 lanes. The street width varies from 3.5m, 5m or more. The sidewalk width is commonly 2m.

Table 10. Site 3 Street morphological indicators

ST.name	**Street typology**	**Surface material**	**Direction**	**Lanes**	**Max speed**	**ST.Width (m)**	**ST.Length (m)**	**SW.Width (m)**	**ST.Area (m^2)**
				Site 3					
Kole Koçi	residential	asphalt	TWA	2	40	5	312	2	1560
unknown	residential	unpaved	OW	1	35	3.5	102.9	2	360.2
unknown	residential	asphalt	OW	1	35	3.5	104.4	2	365.4
unknown	residential	asphalt	OW	1	35	3.5	106.0	2	370.9
unknown	service	unpaved	OW	1	35	3.5	73	2	255.5
noname	service	concrete	_	1	0	4	18.7	0	74.8
unknown	residential	asphalt	OW	1	35	3.5	90.2	2	315.6
Kole Koci	residential	asphalt	OW	1	35	3.5	92.3	2	323.1
unknown	residential	asphalt	OW	1	35	3.5	93	2	325.5
noname	service	concrete	_	1	0	5	25	0	125
unknown	residential	asphalt	OW	1	35	3.5	91.7	2	321.0
noname	service	asphalt	_	1	0	5	23	0	115
Kadri Roshi	residential	asphalt	TWA	4	60	10	237.8	2.5	2378
unknown	residential	concrete	OW	1	35	3.5	105.5	2	369.3
unknown	footway	tiles	_	1	0	2	69	0	138
Joklin Persi	residential	asphalt	TWA	2	35	5	251	2	1255
Tre Dëshmorët	secondary	asphalt	TWA	2	60	7	205	2.5	1435
unknown	service	asphalt	TWA	1	35	3.5	63	0	220.5
Kole Koçi	residential	asphalt	OW	1	35	3.5	300	2	1050
Kole Koçi	residential	asphalt	OW	1	35	3.5	89.2	2	312.2
Total Sum									11670

Based on the calculations above, it is evident that each street typology had different number of lanes, a specified maximum speed, and different street and sidewalk widths. *Table 11* illustrates the average result of these indicators for each specific street typology. Secondary streets are characterized by 2 to 5 lanes, allowing for higher traffic capacity. Residential streets typically have 1 to 4 lanes, indicating a lower volume of vehicles. Living streets also have 1 to 4 lanes, prioritizing pedestrian and cyclist-friendly environments. Footway streets, designed primarily for pedestrians, have a single lane, while service streets, used for building access and service purposes, also have a single lane. The maximum speed limit for secondary, residential, and living streets is 60 km/h, while service streets have a lower speed limit of 35 km/h. This data regarding the speed limit is derived from OSM and may have some inaccuracies. The average widths of these streets vary, with secondary streets being the widest at 9.5 m, followed by residential streets with an average of 5.9 m, living streets at an average of 5 m, and service streets at an average of 4.5m.

Table 11. Summary table of Average Street morphology indicators

Street Indicators	**Secondary Street**	**Residential Street**	**Living Street**	**Footway Street**	**Service Street**
Lanes	2 to 5	1 to 4	1 to 4	1	1
Max.Speed	60	60	60	_	35
Avg.Width	9.5	5.9	5	2	4.5
Avg.SW.Width	2.16	1.91	2.7	_	_

3.5.5 Buildings statistical calculations

Figure 33. Building typologies distribution

The first BUMIs to be conducted were the width, length and depth indicators. They were measured according to each typology as shown in *Figure 34*.

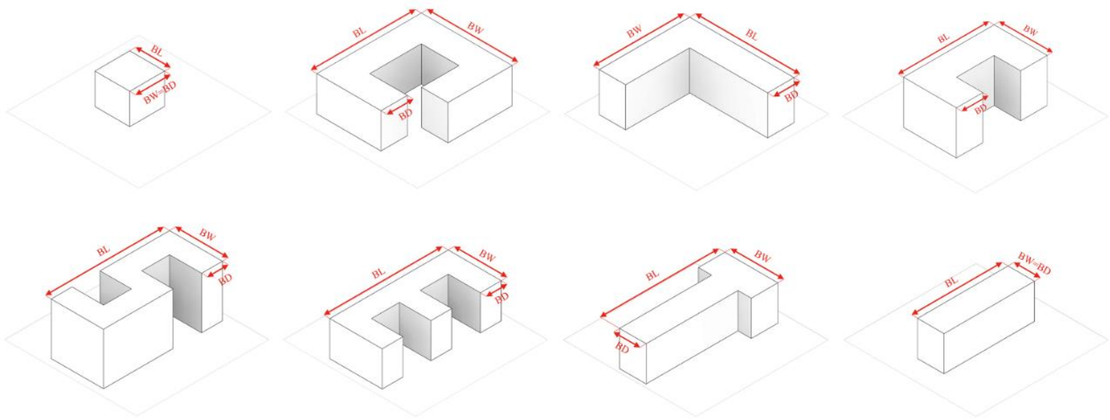

Figure 34. Width, Length, Depth for each building typology.

The gathered calculations for each building continue with other derivative indicators such as building height, footprint area, footprint perimeter and building orientation *Figure 35*. More indicators and ratios include building volume, wall area, envelope area, width/depth ratio, height/ footprint area ratio, building shape factor, distances between building, and height over distances ratios *Figure 36*.

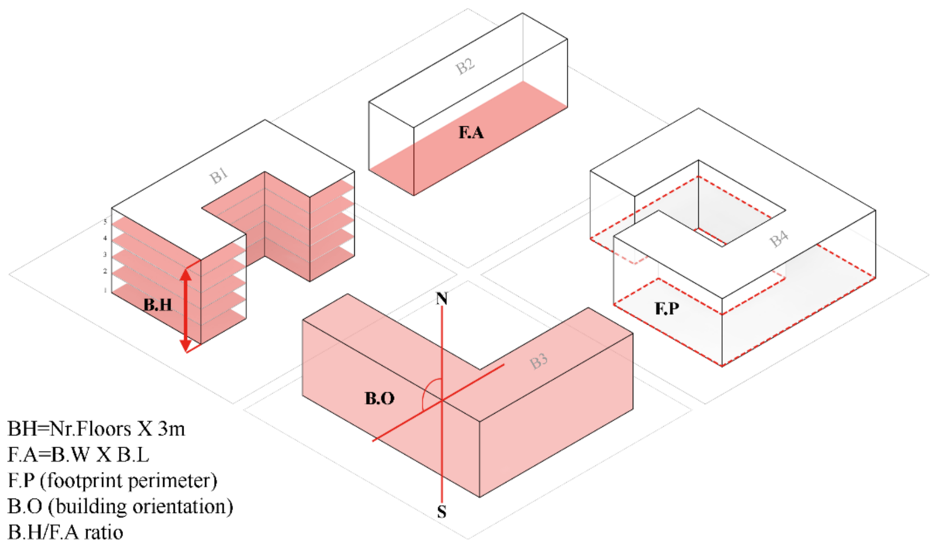

Figure 35. Building Urban Morphology Indicators 1

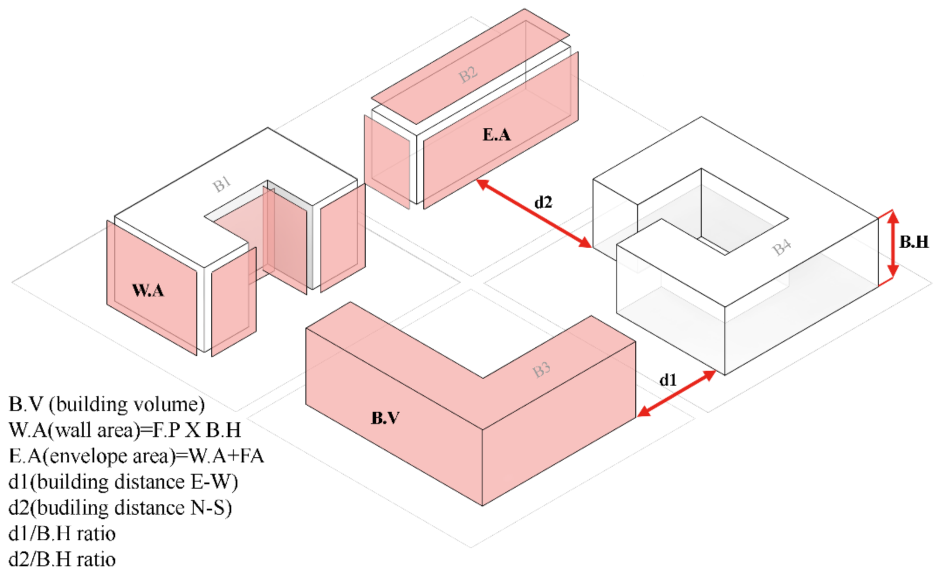

Figure 36. Building Urban Morphology Indicators 2

The indicators for each building are illustrated in their respective table according to their site. (see APPENDIX A for the full calculations on the building indicators for each respective study site)

From the BUMIs for each respective building, a summary table was created in order to illustrate the average BUMI's for each specific building pattern *Table 12*.

Table 12. Summary table of the Averages of Building morphology indicators.

Avg. Indicators								
Typology	**Podium - shape**	**U-shape**	**O-shape**	**L-shape**	**I-shape**	**S-shape**	**T-shape**	**E-shape**
Nr. Floors	9	10.8	8.7	10	9.5	9	9	8.5
B.H (m)	28	33.4	27	31	29.5	28	28	26.5
B.L (m)	21	72	78	73.8	76.7	76.8	84.1	84.5
B.W (m)	22	28.2	70.3	55.8	24	35.3	35.5	33.5
B.D (m)	22	16.8	19.8	20	24	15.5	18.8	16.5
F.A (m^2)	447	1509	3701	1847	1729	1905	1745	1966
F.P (m)	85	224	433	246	199	326	282	300
F.A X Nr.Fl (m^2)	4025	15839	32154	18468	16222	17145	15701	16801
B.O (°)	53.2	54.1	52.9	49.5	55.2	56.9	60.8	66
B.V (m^3)	12521	49000	100164	57251	50396	53340	48848	52367
Wall area (m^2)	2370	7337	11680	7636	5844	9138	7901	7947
Envelope area (m^2)	2817	8845	15381	9483	7573	11043	9645	9912
B.W/B.D Ratio	1	1.69	3.5	2.8	1	2.3	1.9	2.0
B.H/F.A Ratio	0.1	0.03	0.01	0.02	0.02	0.01	0.02	0.01
BSF (E.A/B.V) Ratio	0.2	0.18	0.15	0.2	0.15	0.2	0.2	0.2
d1 (m)	20.6	19.1	22.35	21.5	20.2	19	19.2	20.5
d2 (m)	30	24.3	19	22.0	21.2	18.4	12.3	20.8
B.H/d1 Ratio	1.4	1.8	1.26	1.5	1.5	1.5	1.5	1.3
B.H/d2 Ratio	0.9	1.4	1.5	1.4	1.4	1.5	2.5	1.3

From *Table 12* it is evident that different building typologies reflect different results from the calculated indicators. The number of floors is similar in almost all eight building typologies with an average of 8.5 to 10.8 floors. Another indicator that is almost similar in all the building typologies is the depth which varies from an average of 15.5m to 24m.

A study by Moughtin [56] finds that the optimal height to width ratio for public spaces is between 1:1 and 1:3, therefore from the table if we were to compare B.H and d1 it is evident that none of the building typologies fall into this optimal ratio, resulting with unsatisfactory open or public spaces.

3.5.6 Open space statistical calculations

The statistical calculations for the open space included the amount of Built area (Sum of streets and building footprint), the amount of Open space (OS) area and the amount of Green space area. From these areas ratios of Green space, Open space and Build space were calculated. Each respective ratio was measured by the calculated area of the open, green and built area over the total site area.

A comparative analysis of green space ratios across different sites indicates that Site 2 displays the highest green space ratio, while Site 1 demonstrates the lowest green space ratio.

Figure 37. Green space typologies and percentages

The green space analysis of the sites first also included a categorization of the current green spaces that each site possessed as illustrated in *Figure 37*.

The categorized green spaces for all three sites are:

- Green courtyard: green space that is partially enclosed by buildings.
- Planting beds: it referred to as particular areas in an outdoor space where plants, flowers or trees are grown on purpose, they are usually placed alongside building frontages.

• Pocket Park: it refers to a small park that is accessible to the public.

• Roadside Verge: it refers to the strip of greenery that usually runs alongside roads or highways.

• Urban wasteland: it is referred to an area where semi-natural vegetation has grown and it is not maintained

A comparative analysis of OS ratios reveals that Site 1 and Site 2 display the highest proportion of open space *Table 13*. As a result, from all the three sites there's very little green space and a high built ratio.

Table 13. Open Space Morphological indicators

Green space typology	**Site area (m^2)**	**Built area (m^2)**	**Open area (m^2)**	**Green space area (m^2)**	**Green space ratio**	**OSR ratio**	**Build area ratio**
			Site 1				
Urban wasteland				1464.69			
Planting beds				152.10			
Sum.	38129.19	22529.25	24371.24	1616.79	0.04	0.64	0.59
			Site 2				
Green courtyard				283.95			
Pocket park				562.60			
Roadside verge				237.98			
Planting beds				2270.93			
Sum.	27781.04	20863.81	17735.18	3355.46	0.12	0.64	0.75
			Site 3				
Planting beds				2560.63			
Green courtyard				621.70			
Sum.	59836.68	35980.46	35526.05	3182.33	0.05	0.59	0.60
Average	**41915.63**	**26457.84**	**25877.49**	**2718.19**	**0.06**	**0.62**	**0.65**

This portion of the analysis categorizes the architectural typologies that facilitate the development of open space. The typologies identified within the context of the three case study sites comprise of six distinct forms, namely the O-shape (enclosed courtyard), Double L-shape (enclosed courtyard), U-shape (semi-opened square courtyard), S-shape (double courtyard), E-shape (double courtyard), and I-shape (open courtyard). Each of these typologies is illustrated in *Figure 38*.

The BCR and OSR were calculated for the typologies that provide open space, as presented in *Figure 38*.

From *Table 14* the typologies with the lowest building coverage appears to be the U-shape typology (33%) and the Double L-shape typology (37%). The low BCR ratio also indicates that these two typologies also facilitate the most amount of open space.

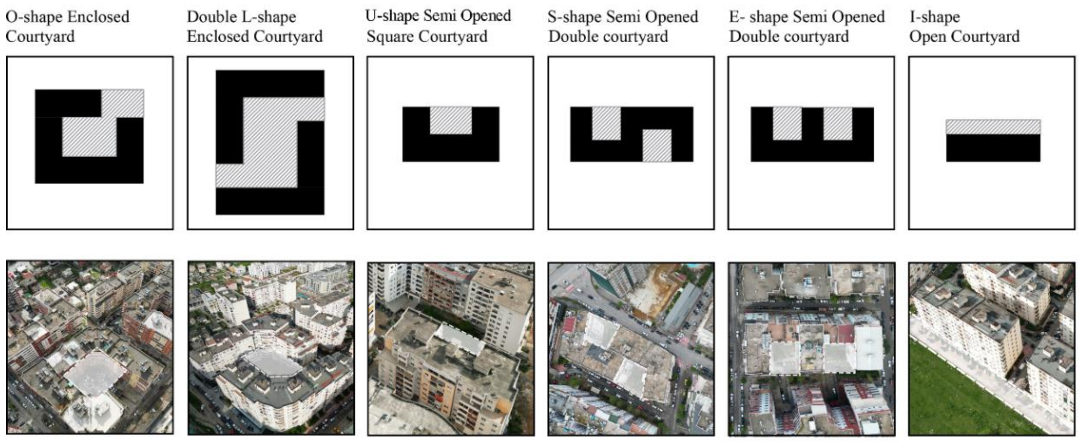

Figure 38. Open space typologies

Table 14. BCR & OSR for open space typologies

Indicators	O-shape	Double L-shape	U-shape	S-shape	E-shape	I shape
Avg. BCR	42%	37%	33%	38%	38%	43%
Avg. OSR	58%	63%	67%	62%	62%	57%

CHAPTER 4

PARAMETRIC MODEL

4.1 Experimental site selection

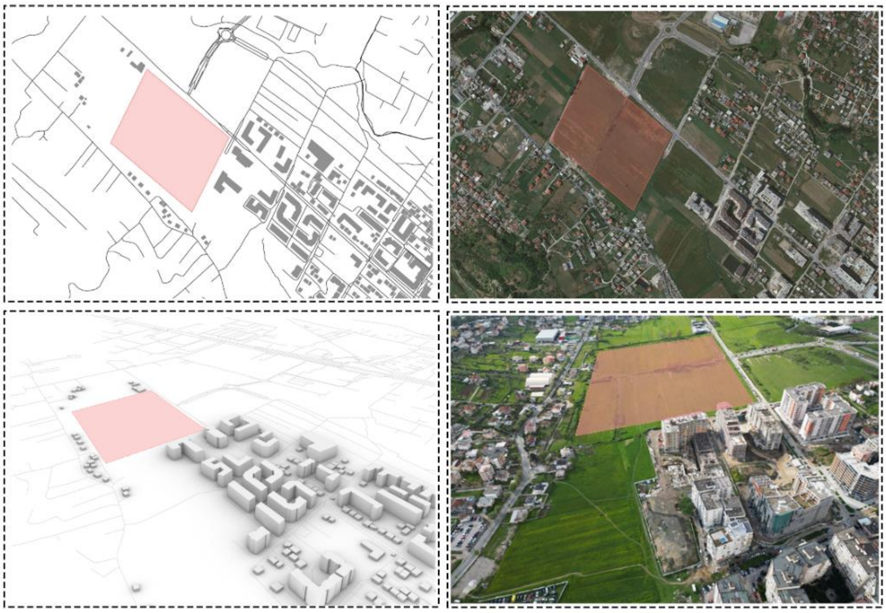

Figure 39. Experimental site location

In this research's generative design phase, selecting the experimental site is a crucial step. In order to select the ideal experimental site for the generative proposals and to make sure that the chosen selection will successfully carry out the research goals, some key selection criteria were applied. First, the location needed to be an empty piece of ground that could serve as a blank canvas for the generated proposals. Additionally, proximity to the three study sites was a key consideration, enabling easy access for data collection and analysis. The crucial criterion for the site's location was its relation to the future urban projects planned for the Astir area. The selected site, upon meeting the aforementioned criteria, presents a complementary initial step for the following stages of the methodology.

4.2 Site analysis

A thorough urban analysis was carried out as part of this study's methodology to gain a holistic understanding of the chosen experimental site and its connection to the broader neighborhood of Astir. This analysis encompassed both a close-up scale of 1:2500 focused specifically on the experimental site and a large scale of 1:10000 of the entire neighborhood. The experimental site was analyzed at a close-up scale to understand its unique features, limitations, and how it fits into its immediate surroundings. In addition, the larger-scale analysis provided a wider perspective, allowing for an investigation of the site's relationship to the whole neighborhood. This dual-scale approach of the conducted urban analysis provides a solid foundation for the generative design phase of the study.

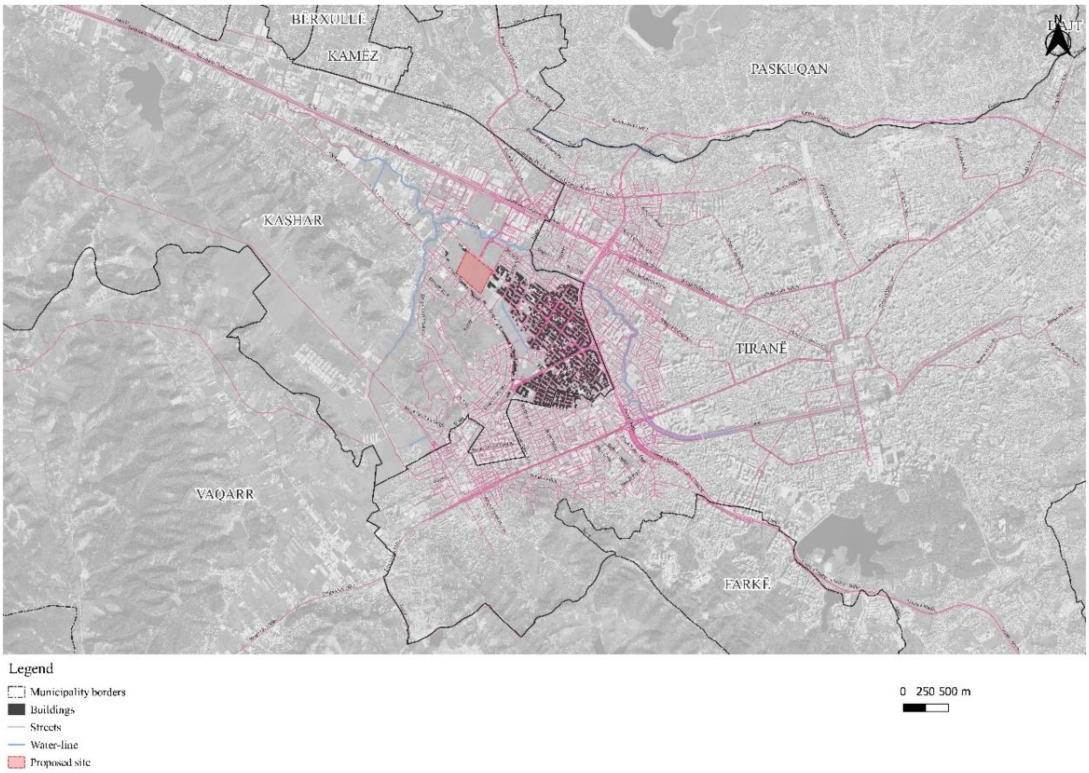

Figure 40. Masterplan of the experimental site in relation to the city center of Tirana

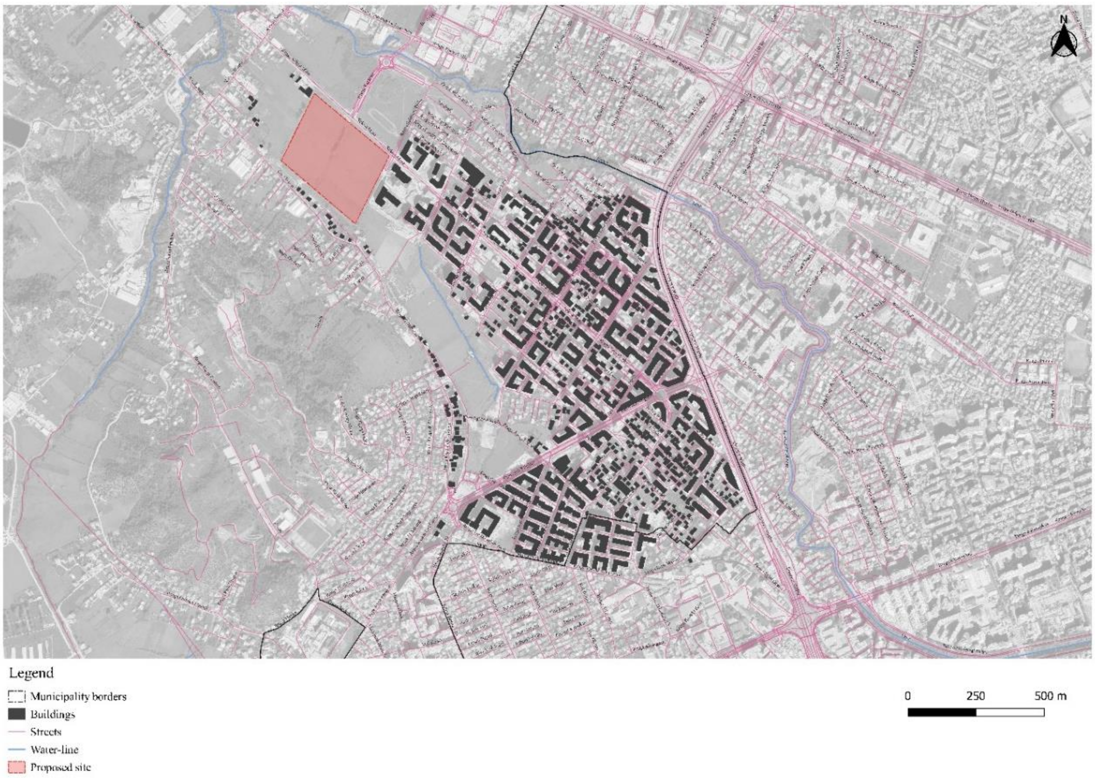

Figure 41. Masterplan of the neighborhood of Astir with the experimental site SC 1:10000

4.2.1 Building height analysis

From the building height analysis at a scale of 1:10000, it resulted that the most common number of floors is between 8 to 10 floors. It is also quite evident that throughout the whole neighborhood, there is a large number of settlements that have a low number of floors from 1 to 3 floors. The building floor analysis also indicated that close to the selected experimental site, the existing buildings on its East are around 9 to 10 floors, and on the contrary, the buildings on its West are lower settlements from 1 to 3 floors.

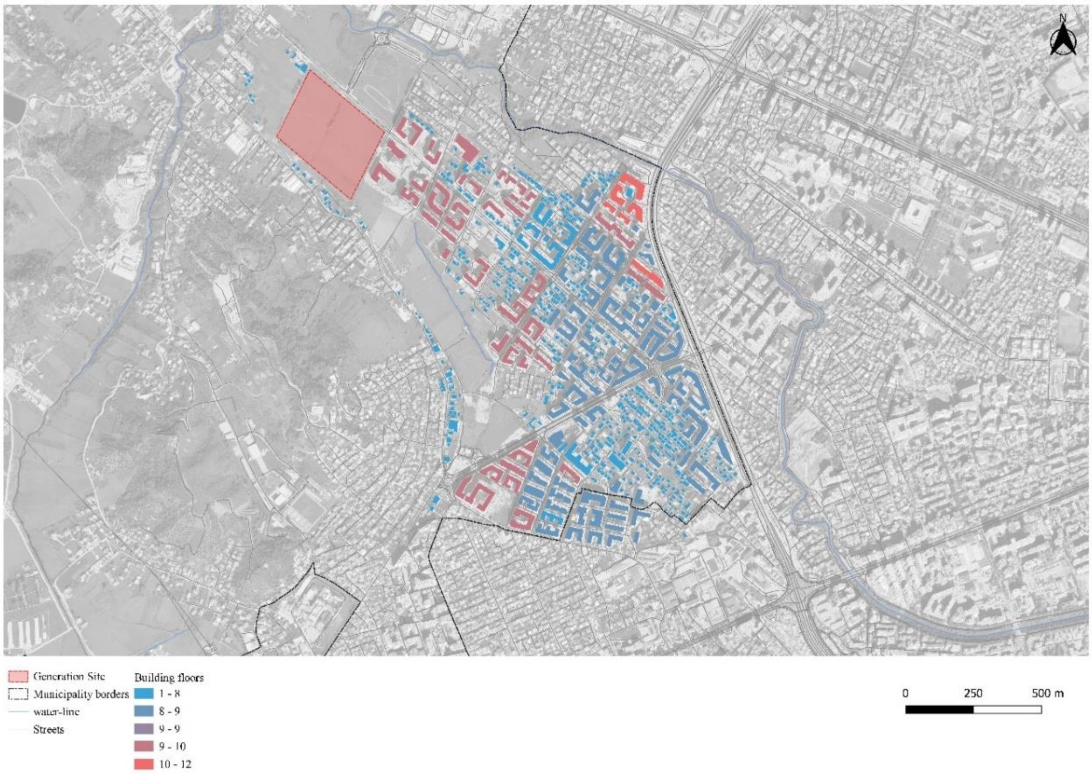

Figure 42. Building height analysis SC 1:10000

4.2.2 Road network analysis

The road network analysis demonstrates the connectivity of the selected renewal site to the surrounding neighborhood through a network of primary and secondary roads. These well-established road systems ensure convenient access within the neighborhood, promoting a sense of integration and accessibility. In addition, the site enjoys a strategic advantage by being connected to the "Unaza e Madhe" highway, a major transportation artery that facilitates easy access to both the northern and southern regions of Albania. From the scale of 1:2500 of the network analysis, it was evident that there are multiple secondary and residential roads that could serve as guides from the street generation of the experimental site.

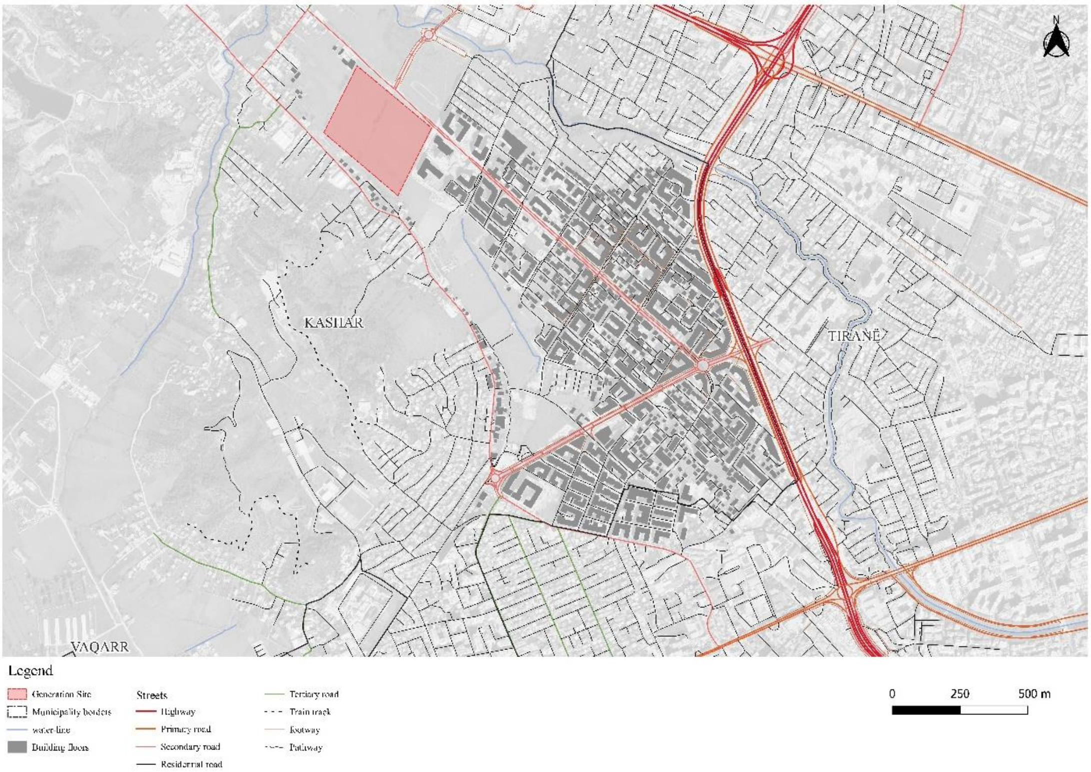

Figure 43. Road network analysis SC 1:10000

Figure 44. Road network analysis SC 1:2500

4.2.3 Public transport accessibility analysis

Following the road network analyses, a public transport accessibility analysis was also conducted. The analyses were accomplished by building three isochrones with radiuses of 100m, 300m, and 400m around each bus stop located in the neighborhood of Astir. From this analysis, it was noted that the selected experimental site is well connected by public transport with the rest of the neighborhood.

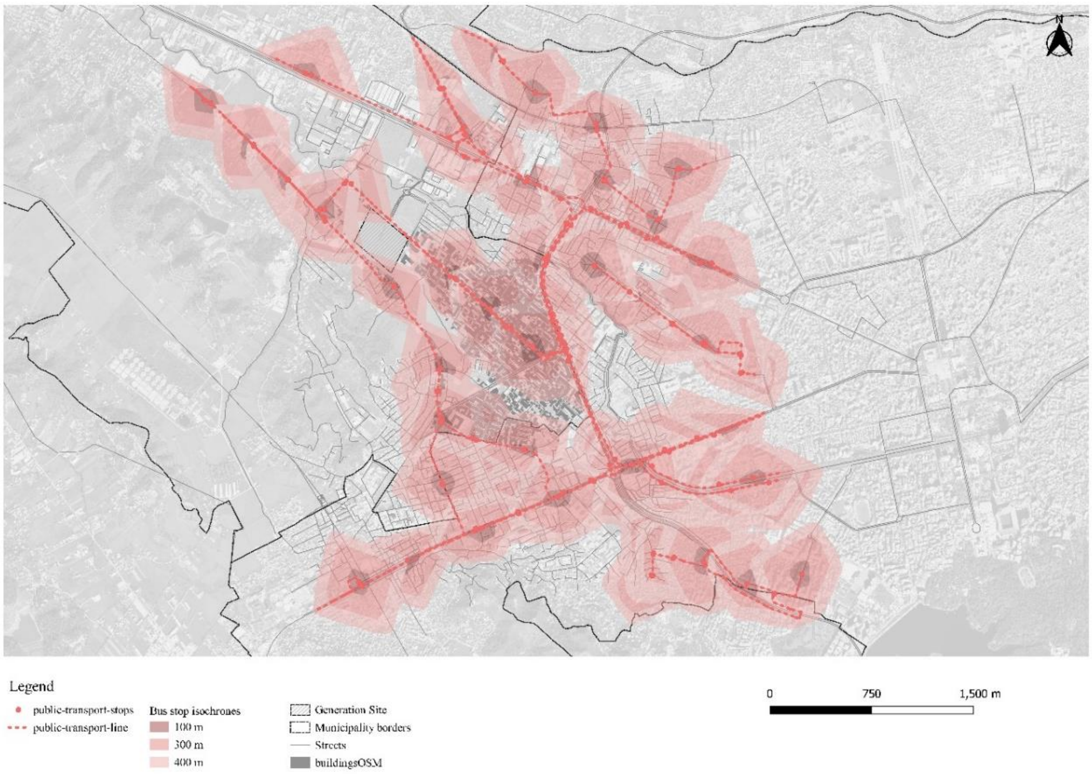

Figure 45. Public transport accessibility analysis SC 1:20000

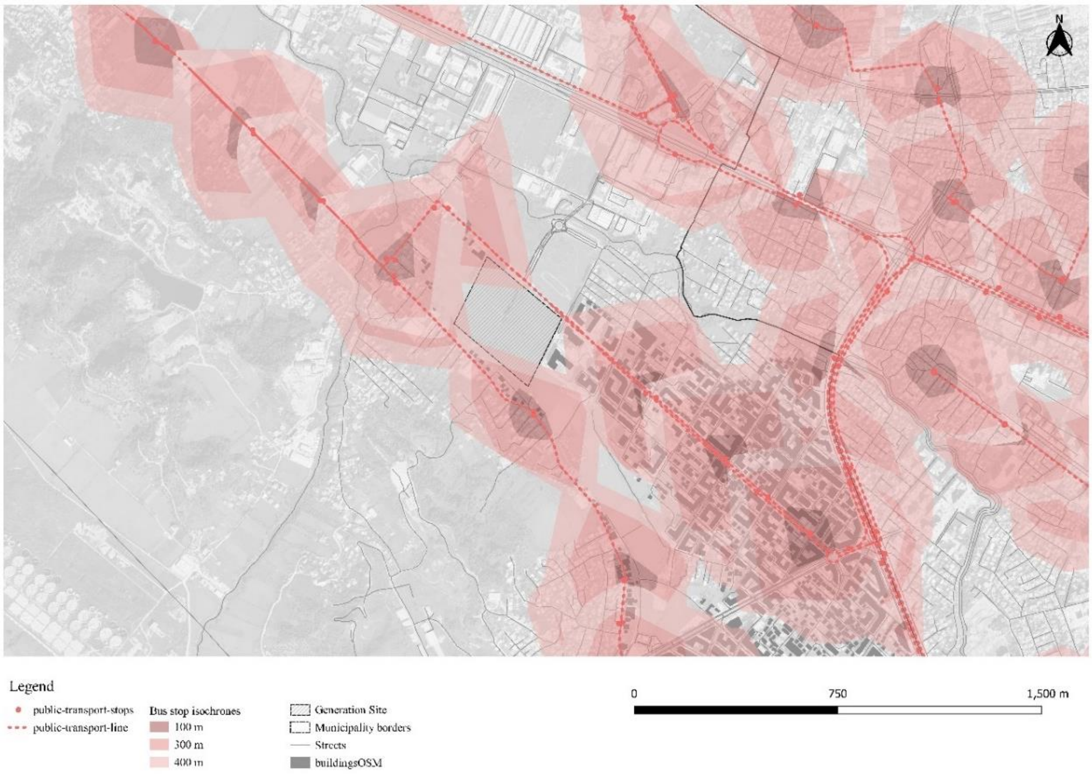

Figure 46. Public transport accessibility analysis SC 1:10000

4.2.4 Greenery analysis

The greenery analyses were realized from data imported from OSM. The analyses indicated that on the West side of Astir, the land is greener since there are not as many construction developments as there are on the East side of the neighborhood. The land of the experimental site is Meadowland which consists of only grass. On the contrary, the East side of Astir has little to almost no greenery due to the dense construction of residential building.

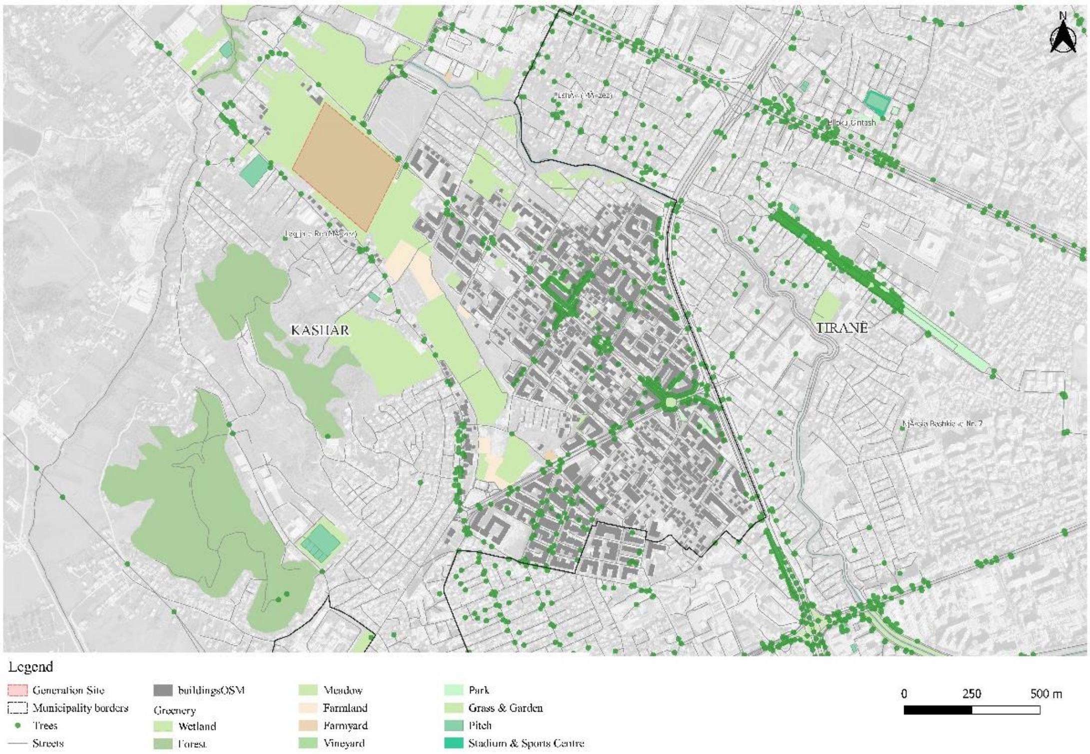

Figure 47. Greenery analysis SC 1:10000

Figure 48. Greenery analysis SC 1:2500

4.2.5 Topography analysis

For the topography analyses the shapefiles were requested and collected from the government webpage [55]. It is noticeable from the analyses that in the South-Western part of the neighborhood the relief is hilly-plain and the area where the experimental site is located is a flat field.

Figure 49. 3D topography analysis SC 1:10000

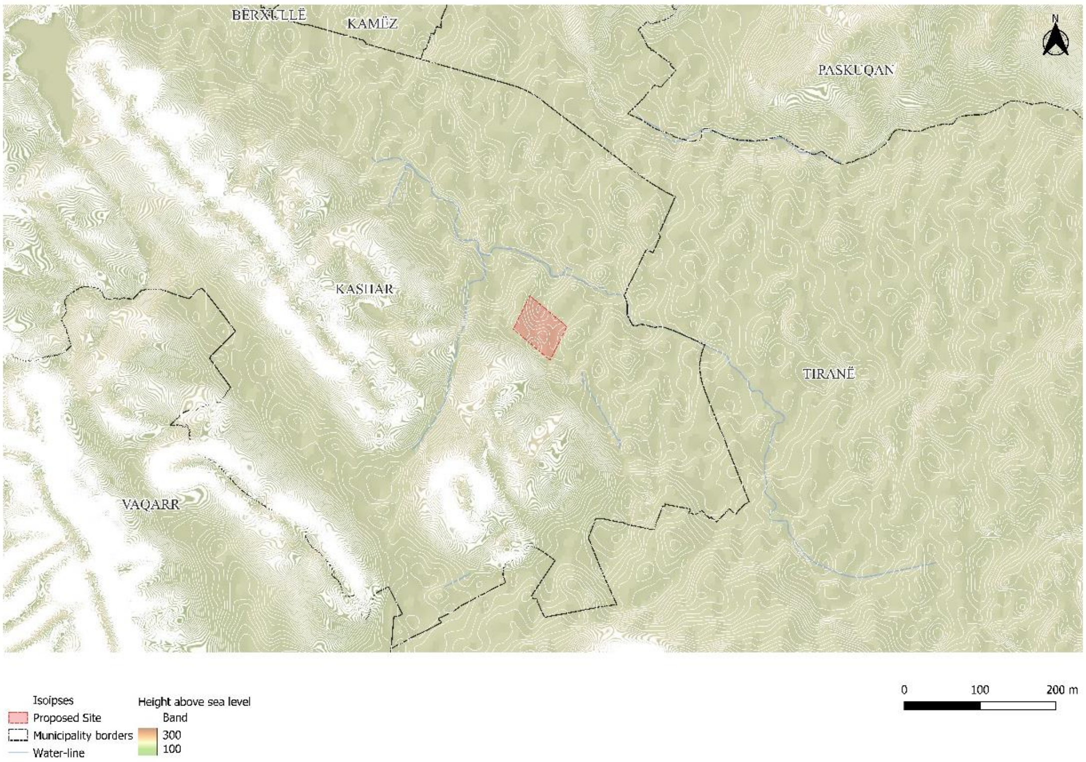

Figure 50. Isoipse analysis SC 1:20000

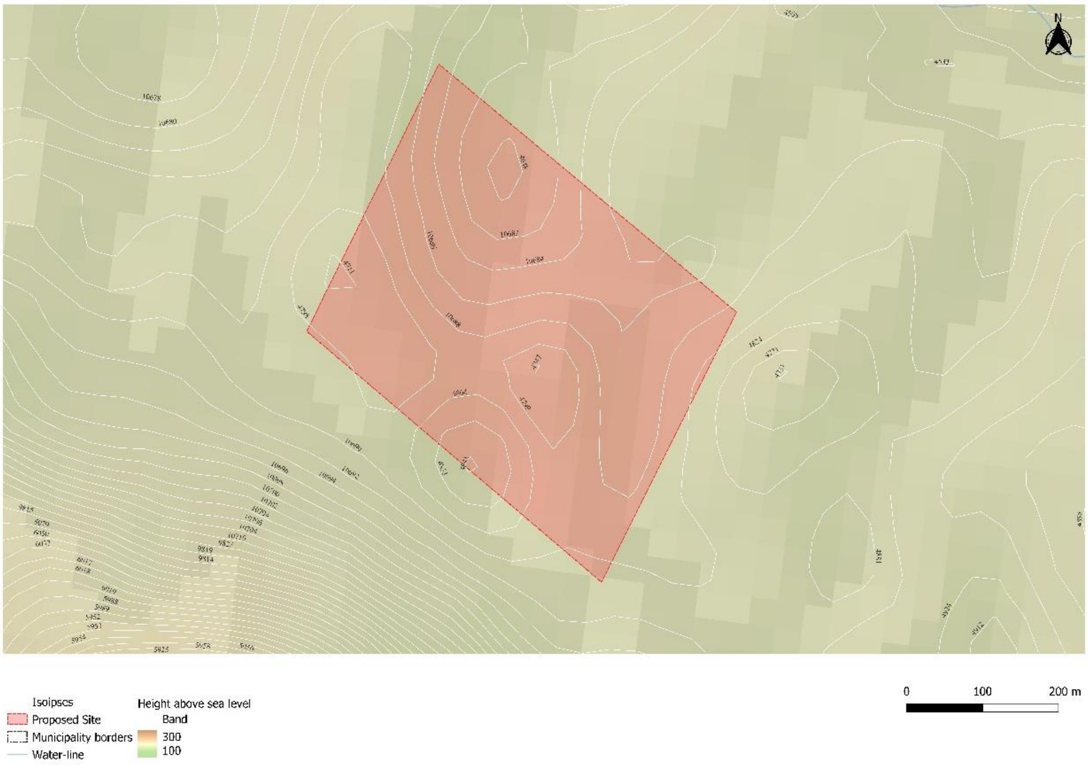

Figure 51. Isoipse analysis SC 1:2500

4.3 Parametric model development

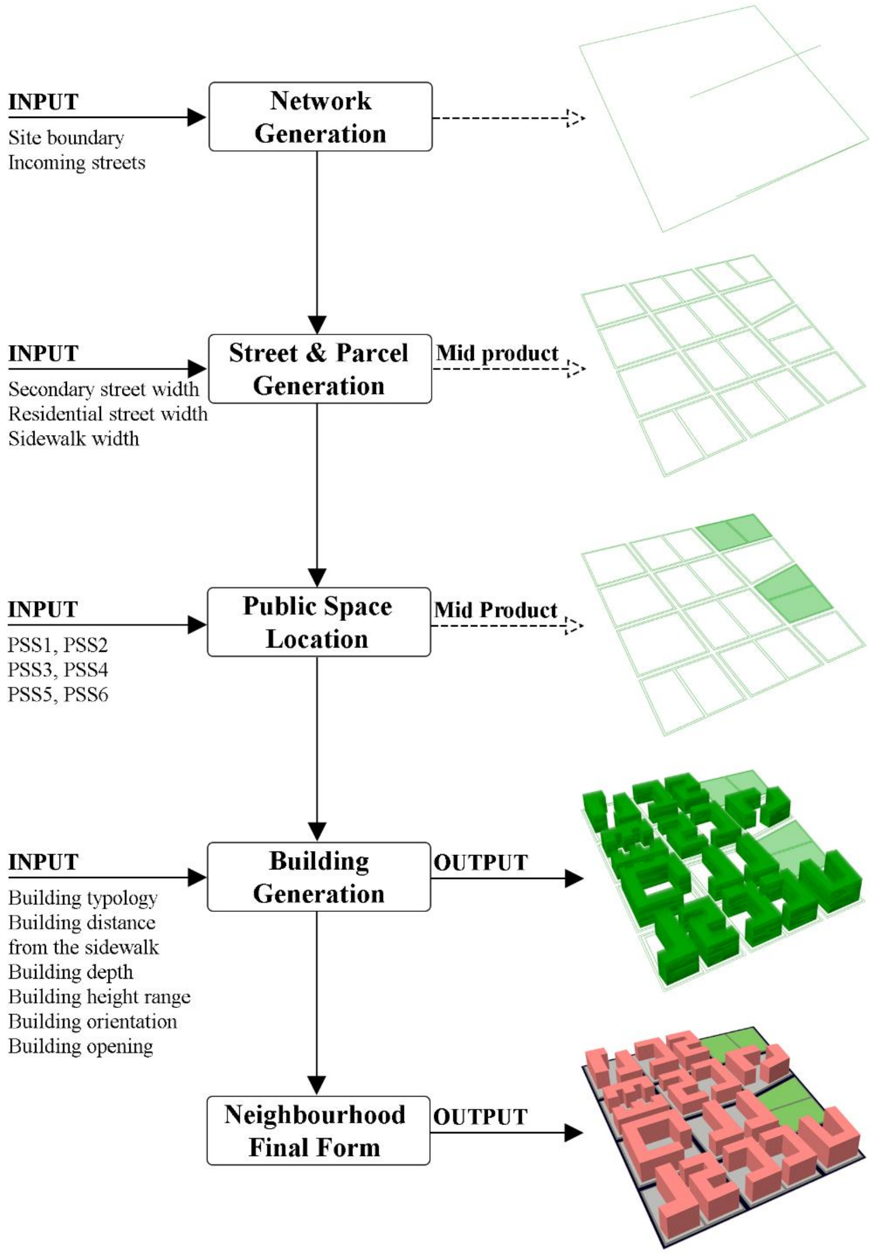

Figure 52. Parametric model framework

The first step of developing the parametric model begins by defining the site boundary and incorporating the existing incoming streets. The subsequent crucial step involves constructing the street network. This phase encompasses the parallelization of the site which was conducted by using the Decoding spaces toolbox [48]. This phase also includes various inputs such as the width of secondary streets, the width of the residential street and the width of the sidewalk. In the case of our site, secondary and residential streets are constructed in relation to the street categorization from the context. The generated street network is therefore connected to the existing main street of the site. Another significant step involves determining the location of the public space within the model. Each scenario is carefully modelled parametrically and serves as an input for the overall generated model. The following step involves, the generation of building footprints which are based on existing building typologies. This step incorporates inputs such as building depth, the distance of the building from the sidewalk, a range of building heights, building orientation and building openings. Ultimately, these steps culminate in the production of the final built form of the parametrically generated neighborhood as illustrated in *Figure 52*.

4.3.1 Street & Parcel generation

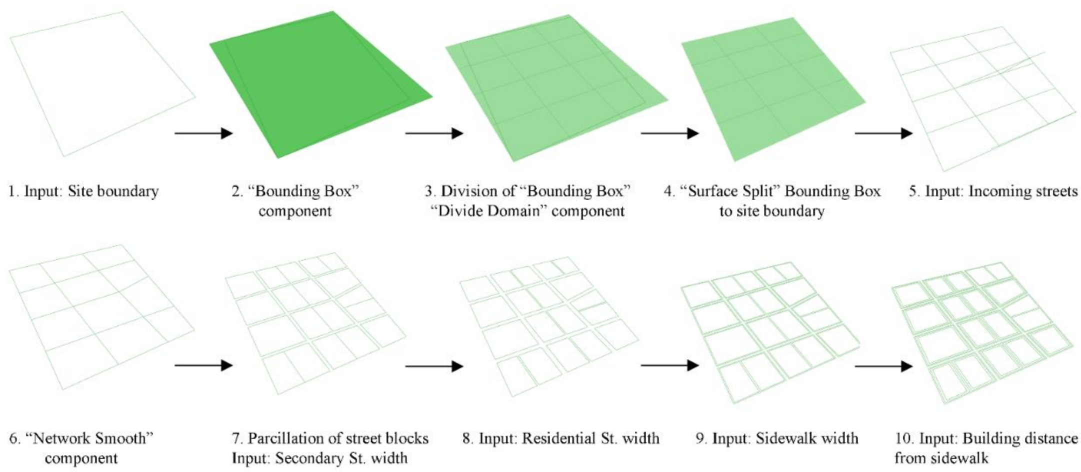

Figure 53. Street & Parcel generation process

The street generation process starts by first assigning the site boundary of the experimental site. Then the "Bounding Box" component is used to create a large rectangle surface on the site. The other main step consists of dividing the surface into potential street blocks. To do so the "Divide Domain" component is used. The domain is divided into squares with an average width of 80m. The "Isotrim" component is then used to trim the surface of the "Bounding Box" with these squares from the previous step. Then by using the "Surface Split" component the whole "Bounding Box" surface is trimmed to the boundary of the experimental site.

The already constructed grid needs to be oriented so that it aligns with the site boundary. The last step involves connecting the grid with two incoming streets from the existing context. To do so, the "Network Smooth" component from the DeCodingSpaces library was used. (see APPENDIX B, *Figure 63* for the street and parcel generation script)
The "Parcel" component from the DeCodingSpaces library [48] was also used to create parcellations of street blocks and to help assign the street width for the secondary and residential streets. To assign the sidewalk width a simple "Offset Curve" component was used. The same component was also used to assign the buildings distance from the sidewalk. (see APPENDIX B, *Figure 64* for the parcellation step, street and sidewalk width and building distance from the sidewalk script)
The average width of the streets, the average width of the sidewalk, the average width of the parcels and the existing incoming streets were all data assigned for the street generation phase from the "Data Collection Phase" of the methodology. The assigned inputs can be changed to any different value apart from the already set values that reflect the context data collected from the first phase of the methodology.

4.3.2 Building footprint generation

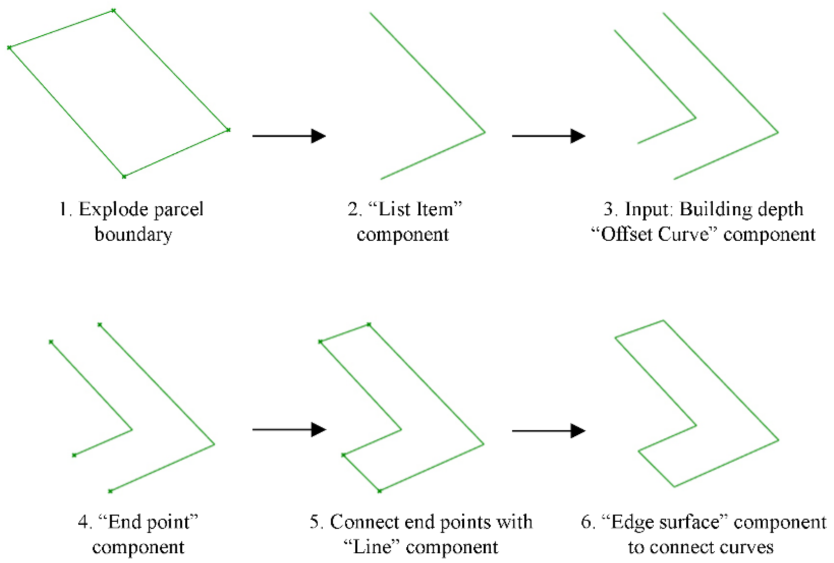

Figure 54. Building footprint generation

The building typologies used for the footprint generation are the ones that were previously extracted from the existing context. The typologies include: O-shape, S-shape, E-shape, L-shape, I-shape and U-shape. Each of the typologies have a similar way of generation. The first step includes using the “Explode” component which explodes the borders of the parcel. The second step involves the “List Item” component which is used in order to select the necessary segments of the parcel that would help form the building footprint shape. After selecting the segments which vary in accordance to the building typology, the selected segments or curves are then joined by using the “Join Curves” component. The following step is offsetting the curves with the “Offset Curve” component. The last step involves joining the previous segments and the offset ones. To do so, various components can be used like “Ruled Surface” component or “Edge Surface” component. (see APPENDIX B, *Figure 65*, *Figure 66*, *Figure 67*, *Figure 68*, *Figure 69*, *Figure 70* for each building typology script)

4.3.3 Building height generation

For the building heights, the method that was used consisted of extruding the buildings randomly or according to the location of a point. By using the point, the buildings located closest to the point automatically have the lowest number of floors and on the contrary the buildings located furthest from the point have the highest number of floors. The range of the number of floors is 8 to 13. This already set range of floors can be set to any number. In case the range is 6 to 10 the building will have a lower FSI ratio. (see APPENDIX B, *Figure 71* for the Building height generation script)

4.4 Development of the scenarios

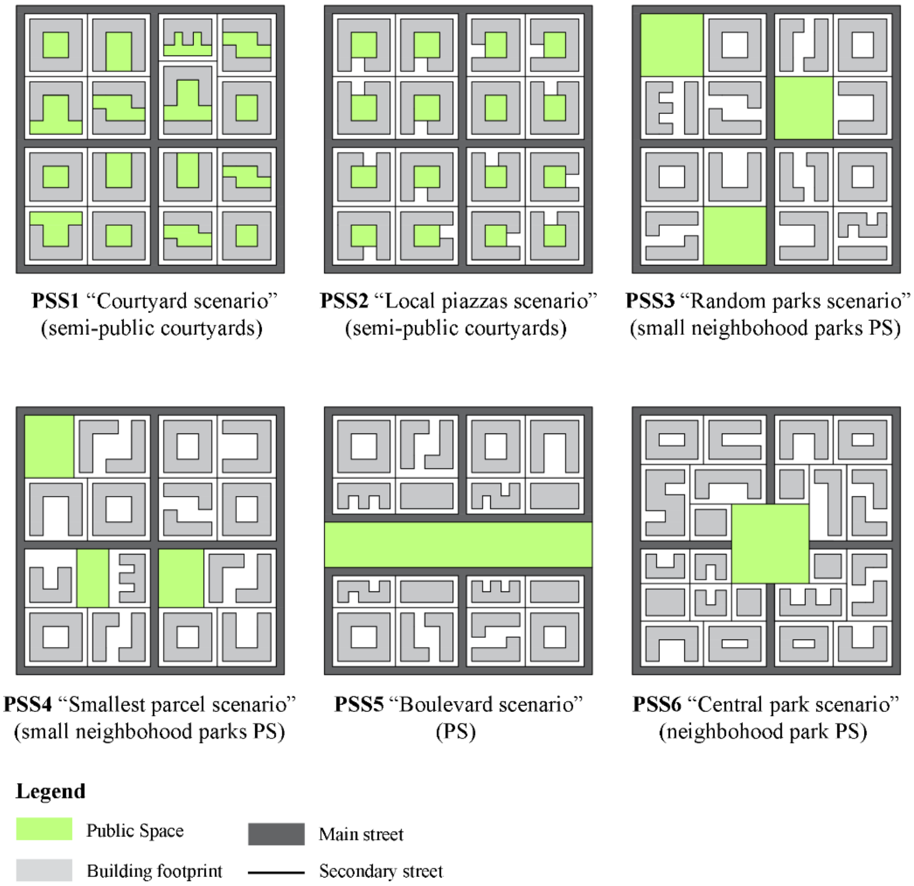

Figure 55. Public space scenarios (PSS)

In order to develop diverse and dynamic public spaces in urban plans, five distinct scenarios that embody different characteristics were developed. Each scenario is elaborated below:

PSS1: "Courtyard scenario," reimagines the idea of shared public space by putting more emphasis on the presence of semi-public courtyards rather than a centralized public space. In this scenario, public interaction takes place in these semi-public spaces within each residential building.

PSS2: "Local piazzas scenario," is created by an assortment of O-shaped building typologies that form semi-public courtyards. The entrances of the buildings are randomly assigned in order to fosters a sense of diversity.

PSS3: "Random parks scenario," introduces little neighborhood parks that are scattered across the urban environment by a random input.

PSS4: "Smallest parcel scenario," presents a way of distributing similar neighborhood parks like the ones from the PSS3 scenario. In this case, the parks are distributed by the smallest parcel rule, which directly turns small plots of land that are insufficient to build on into little parks. This way the scenario makes use of underutilized small parcels.

PSS5: "Boulevard scenario," presents a large boulevard as the main common public space. This scenario aims to create a lively and busy street for different cultural and recreational events.

PSS6: "Central Park scenario," establishes the city's hub as the main public space. It intends to become the community's focal point which can host different activities.

Through the development and evaluation of these different scenarios, the thesis aims to offer insightful information regarding the implementation of public space in urban planning.

4.4.1 Scenario generation

The process of generating the scenarios encompasses all the key steps that the whole general parametric model consists of. These steps include street and parcel generation, building footprint generation, and building height generation. In order to develop all 6 scenario some small steps were added to the general script.

PSS1 and PSS2 do not require any special component. They both reflect the exact steps of the general parametric model. An additional emphasis was made on the generated public space through the allocation of green surfaces to indicate the presence of courtyards.

PSS3 is constructed by utilizing the “Random Reduce” component, which randomly reduces the pre-developed parcels. The inputs of the component include the number of parks and a number connected with the seed of the component to help locate these parks randomly. (see APPENDIX B, *Figure 72* for the “Random parks scenario” script)

PSS4 is developed by assigning a mathematical component that will help turn the parcels with the smallest area into parks. By using the “Larger Than” component the parcels that are larger than the number that is connected with the component are the parcels where the buildings will be located and on the contrary, the parcels that are smaller than the assigned number will be assigned as small neighborhood parks. (see, APPENDIX B Figure 73 for the “Smallest parcel scenario” script)

PSS5 is developed by splitting the surface of the experimental site with the curve that represents the boulevard. The curve is set first in Rhino and is then offset by 15m on both sides. The location of the curve and the width can be changed accordingly. (see APPENDIX B, *Figure 74* for the “Boulevard scenario” script)

PSS6 is established by initially selecting one of the parcels as the central park. In this scenario, the chosen parcel is positioned near the center of the site using the “List Item” component. (see APPENDIX B, *Figure 75* for the “Central park scenario” script)

All of the parametrically developed scenarios are illustrated in *Figure 56*. Their relation to the surrounding context is illustrated in *Figure 57*.

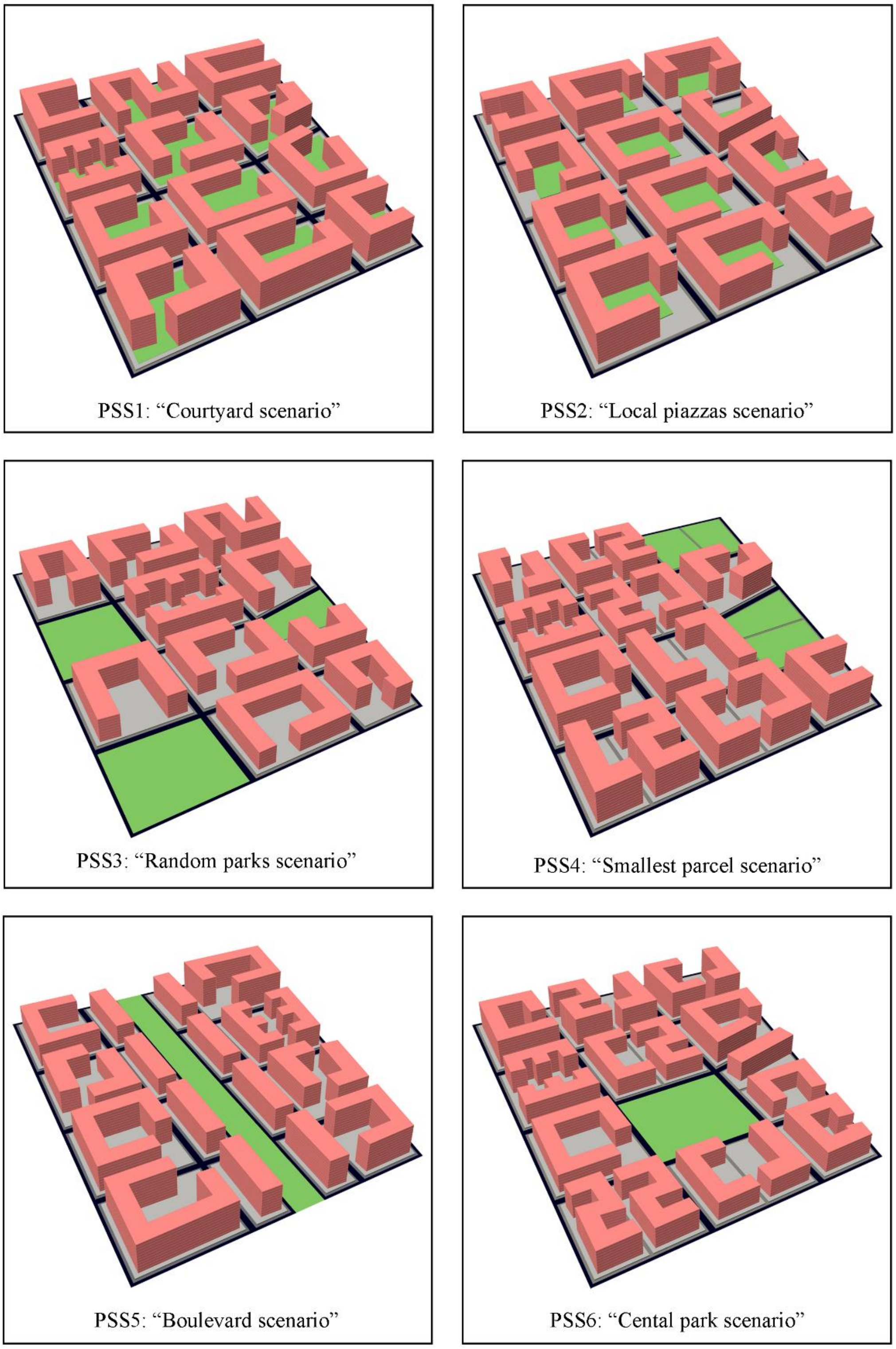

Figure 56. The parametrically generated PSSs

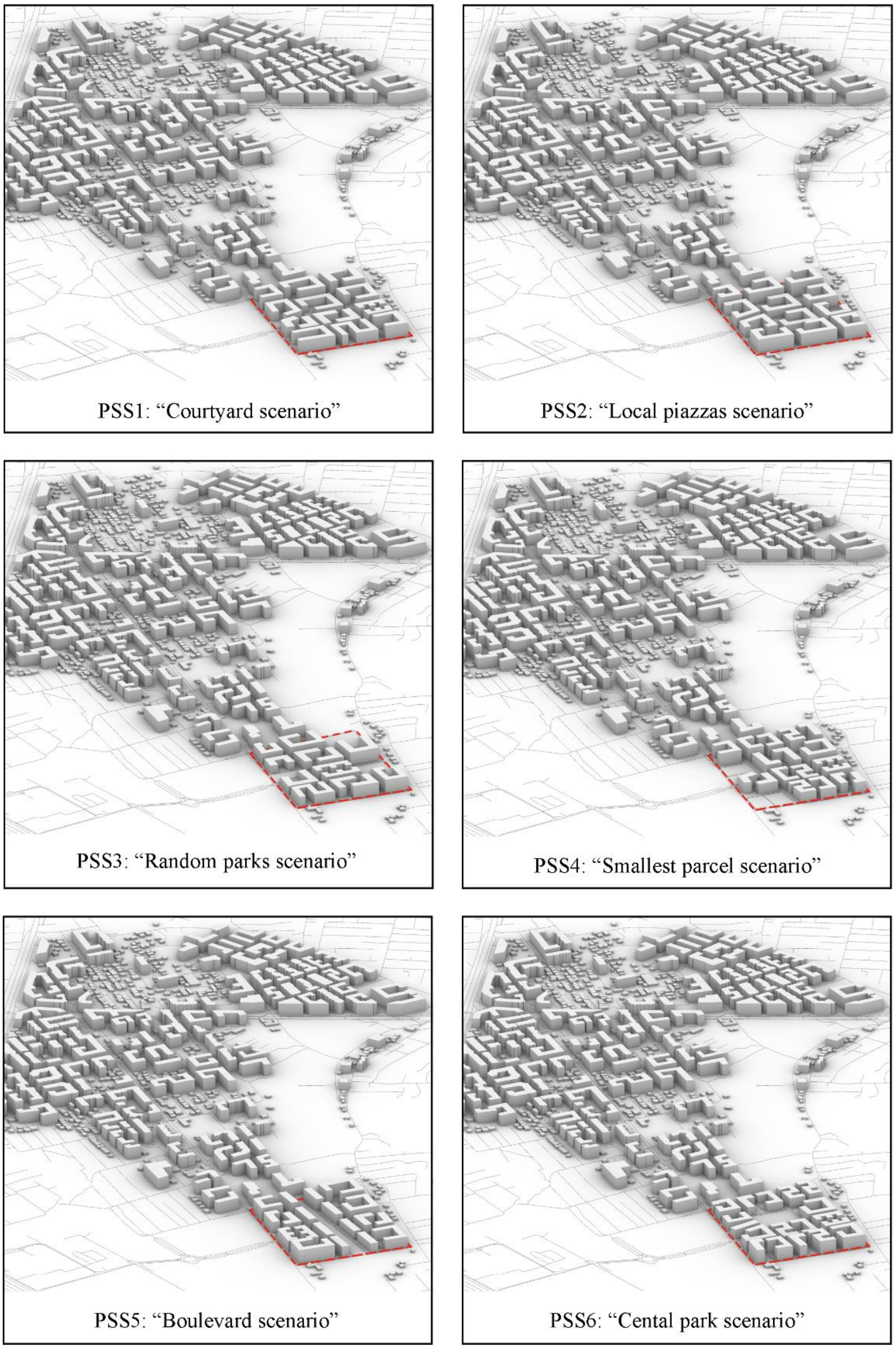

Figure 57. The parametrically generated PSSs in the context model

CHAPTER 5

EVALUATION

5.1 Overview

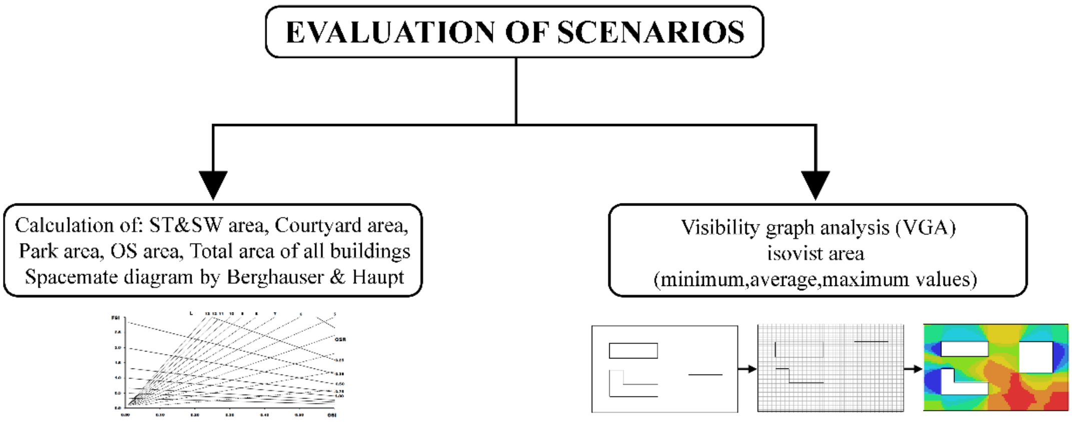

Figure 58. Evaluation process diagram

The evaluation of public spaces is an extensive process that involves diverse methods. Several authors, including Carmona [10], have identified various features that can evaluate and enhance public spaces. The key ones among them are diversity, engagement, sociability, equilibrium, and resilience.

Other methods of evaluation include the public space index (PSI) [57]. This method is considered the most reliable and it includes forty factors focusing on inclusiveness, meaningful activities, comfort, safety and pleasurability. While this method is very well-established and reliable, it requires a lot of time for evaluators to conduct observations [38]. As a result, numerous urban planners agree that the presence of open spaces has a positive impact on the quality of housing projects, making it more desirable to have open spaces than to not have them [38].

Fortunately, there are alternative approaches that can quickly and effectively evaluate public space. One such method is visibility analysis, which employs isovists to quantify the visual experience of open spaces [58]. An isovist refers to the area or volume of space visible from a specific point, providing insights into the visual-spatial qualities of the built environment [59].

The isovist includes many different parameters such as the perimeter, the area, compactness and occlusivity [60]. The isovist area quantifies the area that is visually accessible from a particular point [60]. Meanwhile, the compactness illustrates the correlation between area and perimeter. It helps to show how complex or compact the field of view is [60]. On the other hand, occlusivity refers to the degree of openness within the visual field. In spaces with a lot of physical boundaries, occlusivity is low [60].

For this study, the isovist field is used as a key method of evaluation since it helps to evaluate the total plan of each public space scenario from more than one viewpoint. The properties of the isovist field include the minimum, maximum and average values, and standard deviation of the frequency [60]. The minimum, maximum and average values are the most universally used properties of isovists, therefore this study will only include these three properties. The areas of the isovist field that are closer to the blue colour have low occlusivity, meanwhile areas of the isovist field with bright yellow colour showcases high occlusivity.

Another noteworthy methodology, introduced by Berghauser & Haupt [49], uses four indicators to measure built density: FSI, GSI, OSR and number of floors (L). From these four indicators, the OSR which is also known as spaciousness is a key indicator in providing insights into the utilization of unbuilt areas. By combining these variables, the Spacemate diagram is constructed, offering a holistic representation of urban forms that individual variables fail to capture.

The Y axis on the diagram represents the FSI, which indicates the area's density. The GSI is placed on the X axis and represents the construction's density. The OSR and number of floors are used to divide the chart into zones [49]. The formulas for calculating each indicator are: FSI = gross floor area/site area; GSI = building footprint/ site area; OSR = (site area-built area)/site area; L= gross floor area/ built area [49]. The formulas for each indicator are also illustrated in *Figure 28*. The graph in *Figure 59* illustrates the construction and interpretation of the Spacemate diagram.

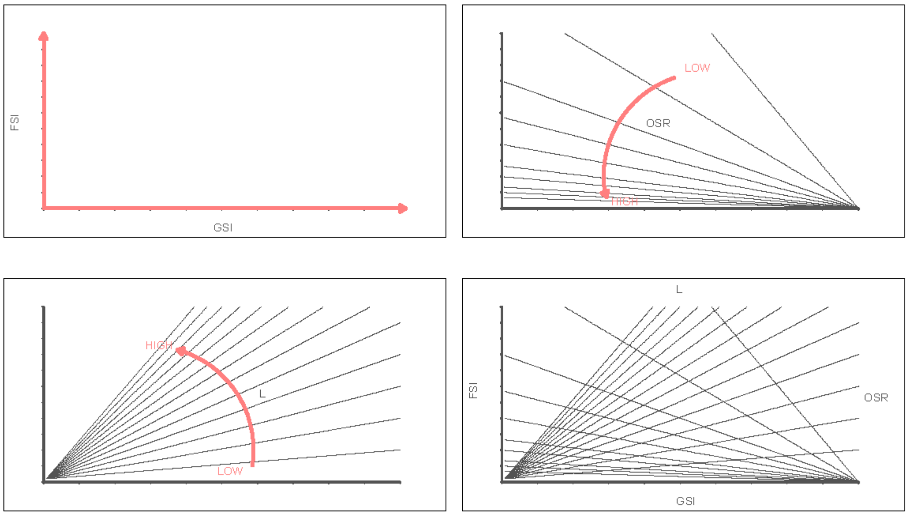

Figure 59. Spacemate diagram interpretation [61], adopted by author

In relation to this thesis, in order to evaluate the five parametrically generated scenarios from the perspective of public spaces a set of indicators are calculated for each scenario. These indicators include FSI, GSI, OSR, ST (street) &SW (sidewalk) area, Courtyard area, Park area, Open space area and total area of all buildings. From these calculations of the GSI, FSI and OSR the Spacemate diagram for each scenario is constructed, showcasing their respective performance. Furthermore, the visibility analysis employing isovists is conducted with depthmapX [50]. Ultimately, the scenario that performs the best in relation to these public space indicators is selected.

5.2 Calculation of evaluation indicators

The calculated indicators for the evaluation phase of the methodology included GSI, FSI and OSR ratios. These ratios were calculated directly from the Gh developed model and a small script in order to calculate each of the them was developed. (see APPENDIX B, *Figure 76* for the GSI, FSI and OSR ratio calculation script).

The evaluation phase also included the calculation of the total area occupied by all building footprints and the total area of open space. Additionally, it considered calculations such as street and sidewalk area, courtyard area, park area, and their respective ratios in relation to the total open space area. All of these calculated metrics are illustrated in *Table 15*. By incorporating these metrics, a comprehensive assessment of the urban environment's spatial characteristics and the distribution of gross space was achieved.

Furthermore, a graph was generated to visually represent the distribution of each respective area and its contribution to the total gross space of the site *Figure 60*. By incorporating visual representations alongside the calculated indicators, a comprehensive understanding of the site's spatial composition and the significance of each area in determining the total gross space is facilitated.

Table 15. Evaluation indicators for each scenario

Scenario	**PSS1**	**PSS2**	**PSS3**	**PSS4**	**PSS5**	**PSS6**
Image						
GSI Ratio	0.38	0.34	0.31	0.32	0.34	0.35
FSI Ratio	4.08	3.69	3.21	3.49	3.57	3.42
OSR Ratio	0.62	0.66	0.69	0.68	0.66	0.65
ST&SW Area (m^2)	24919	24938	22801.7	26999	27378.1	25674
ST& SW Area to OS Ratio	0.34	0.32	0.28	0.35	0.35	0.33
Courtyard Area (m^2)	49335	53297	37003	38667	39713	40663
Courtyard to OS Ratio	0.66	0.68	0.45	0.50	0.50	0.53
Park Area (m^2)	–	–	22062	14816	11737	10556
Park Area to OS Ratio	–	–	0.27	0.19	0.15	0.14
OS Area (m^2)	74254	78235	81883	77913	78828	76893

Total Area of all buildings (m^2)	44888	40907	37275	38660	40314	42249

From *Table 15* the GSI Ratio ranges from 0.31 to 0.38. PSS1 has the highest GSI ratio (0.38), indicating that it is denser than the other scenarios. On the other hand, PSS3 has the lowest GSI ratio indicating that it is less dense than the other five scenarios. Based on the local planning requirements the footprint of the construction development cannot exceed 45% [55]. All six scenarios do not exceed this limit.

The FSI Ratio ranges from 3.21 to 4.08. PSS1 has the highest FSI ratio (4.08), indicating that it has a high building intensity compared to the local planning requirements which suggests that the proposed FSI ratio for the area is 2.2 and the buildings cannot be higher than 9 floors [55]. From the context, the buildings already exceed this requirement. In order to change this FSI ratio, you can simply change the range of floors that are already assigned in the building height generation script. All of the scenarios have a high FSI ratio with the lowest one being PSS3 which has a FSI score of 3.21.

OSR Ratio ranges from 0.62 to 0.69. PSS3 has the highest OSR ratio (0.69), indicating a larger proportion of open space compared to the total area while, PSS1 has the lowest OSR ratio (0.62), suggesting a relatively smaller proportion of open space.

Street and Sidewalk (ST&SW) Area ranges from 22,801.73 m^2 to 27,378.05 m^2. PSS5 has the highest ST&SW area (27,378.05 m^2), indicating a larger extent of street and sidewalk coverage, while PSS3 has the lowest ST&SW area (22,801.73 m^2), suggesting a relatively smaller coverage of streets and sidewalks.

Courtyard Area ranges from 37,003 m^2 to 53,297 m^2. PSS2 has the highest courtyard area (53,297 m^2), indicating a larger extent of courtyard spaces, while PSS3 has the lowest courtyard area (37,003 m^2), suggesting a relatively smaller coverage of courtyards.

Park area varies across different scenarios and they are not specified for scenarios PSS1 and PSS2 since they only provide courtyard spaces. Alternatively, scenarios PSS3, PSS4, PSS5 and PSS6 include park areas ranging from 10,556 m^2 to 22,062 m^2. PSS3 has the most park space in relation to the total open space.

Open Space (OS) Area ranges from 74,254 m^2 to 81,883 m^2. PSS3 has the highest OS area (81,883 m^2), indicating a larger overall open space while, PSS1 has the lowest OS area (74,254 m^2), suggesting a relatively smaller overall open space.

Total area of all building's ranges from 37,275 m^2 to 44,888 m^2. PSS1 has the highest total area of all buildings (44,888 m^2) while Scenario PSS3 has the lowest total area of all buildings (37,275 m^2). This is also reflected in the GSI ratio.

From these calculations, different scenarios perform better for various metrics, however, PSS3 performs relatively better compared to the other scenarios in terms of the GSI ratio, FSI ratio, OSR ratio, Park area, and OS area.

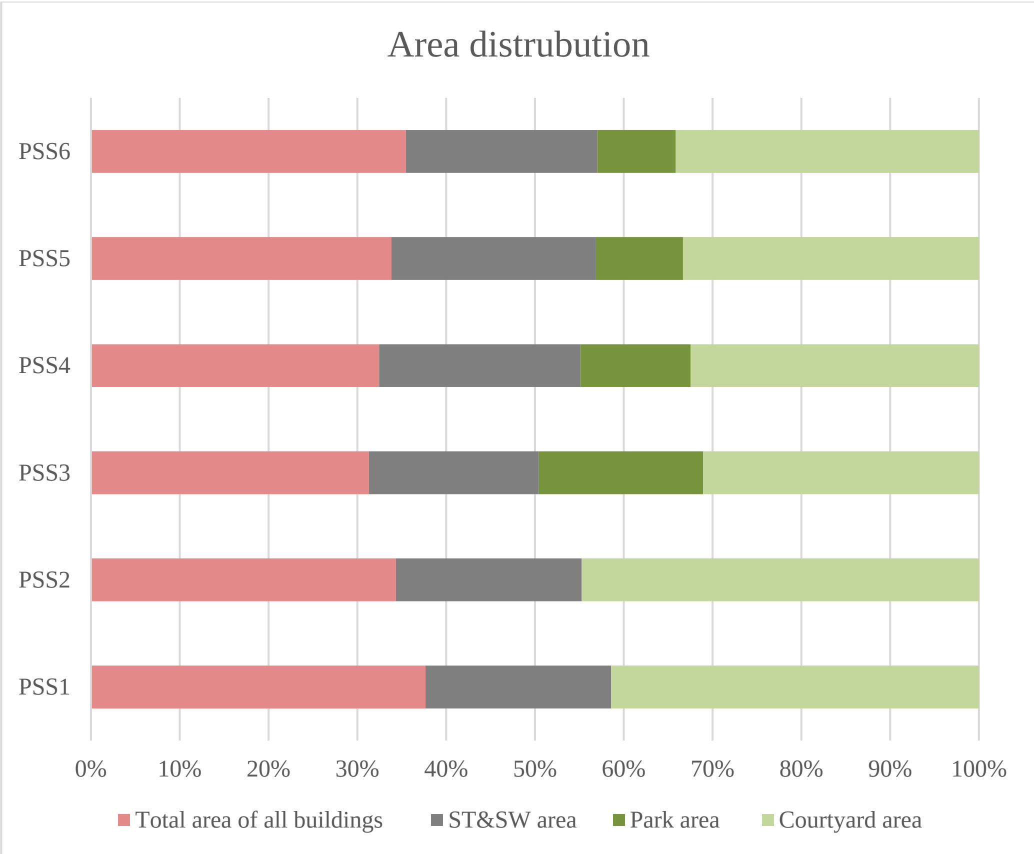

Figure 60. Area distribution graph

The data presented in *Figure 60* highlights the distribution of the total area of all buildings, street and sidewalk area, park area, and courtyard area. All of the above areas constitute the total area of site (119142 m^2). Among all the scenarios, PSS1 stands out with the most built environment. Additionally, PSS1 and PSS6 demonstrate notable street and sidewalk areas, suggesting a significant emphasis on pedestrian access and circulation. In relation to the park area distribution, PSS3 features a substantial park area alongside a sizable courtyard area, showcasing a focus on green spaces and outdoor recreational areas. Overall, the graph provides valuable insights into the spatial distribution and composition of the scenarios, aiding in the evaluation and understanding of their respective urban environments.

The calculations of FSI, GSI and OSR from *Table 15*, are represented graphically by constructing the Spacemate diagram [49]. The diagram illustrates the effect of the growth in built form and open space reduction for all six public space scenarios *Figure 61*.

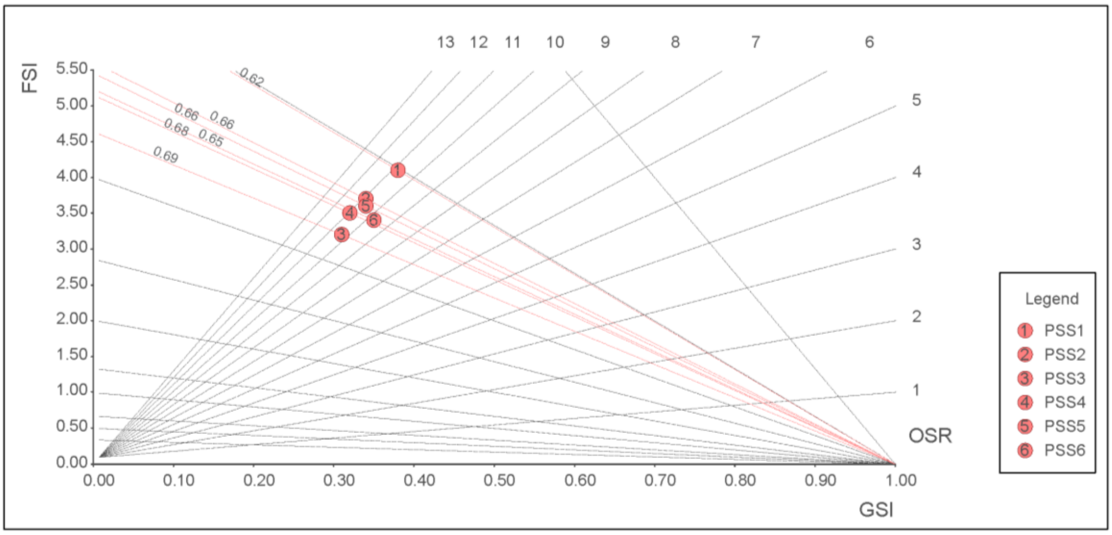

Figure 61. Spacemate diagram by Berghauser & Haupt [49], adopted by author

All the scenarios have their respective fingerprint in the Spacemate diagram. However, a common feature among almost all scenarios is their high FSI score, primarily influenced by the input of the floor range from the context, ranging from 8 to 13 floors. Analyzing the diagram, it reveals that PSS1 has the highest intensity and built area, hence resulting in the least amount of open space. From this analysis, it appears that PSS1 is the worst-performing scenario.

From the diagram PSS2, PSS5 and PSS6 all have similar results in terms of FSI, GSI and OSR while PSS3 and PSS4 are the only two scenarios with the most amount of open space. PSS3 has the lowest built intensity and the least amount of built space, which automatically indicates that it also has the least amount of reduced open space. Based on its position on the diagram PSS3 appears to be the best-performing scenario.

5.3 Visibility graph analysis

The calculated isovist area data helps provide insights into the spatial characteristics of the public space scenarios, highlighting the range, average, and extremes of visibility within each scenario.

Table 16. Minimum, Average and Maximum Isovist area

	Isovist area		
Scenario	**Minimum**	**Average**	**Maximum**
PSS1	367.1	5732.4	17002.6
PSS2	703.9	7358.1	20597.5
PSS3	766.3	11654.6	25356.8
PSS4	737.0	9711.6	23922.2
PSS5	801.5	11734.1	28837.1
PSS6	483.8	11197.5	29206.2

Table 16 and *Figure 62* make it clear that the isovist area exhibits noticeable changes between the various scenarios. The minimum and maximum values indicate the range of isovist areas observed within all six scenarios.

For example, in PSS1, the isovist area ranges from 367.05 (minimum) to 17002.6 (maximum), indicating low occlusivity.

Secondly, the average isovist area provides an overall measure of the typical size of visible space within the scenarios. In this case, the average isovist area is approximately 9176.23. This value gives an indication of the average extent of visibility within public spaces. From the analysis, PSS1 performs the lowest in comparison to the other scenarios.

From the table, it is worth noting that PSS5 and PSS6 have relatively higher isovist areas compared to the other scenarios, both in terms of average and maximum values. Among all six scenarios, it resulted that PSS6 demonstrates a notable advantage in providing enhanced visual accessibility within its layout. This indicates that PSS6 offers a greater extent of visible space compared to the other scenarios, indicating high occlusivity. PSS6 offers a potentially more open and expansive public space, allowing for improved observation and visual engagement.

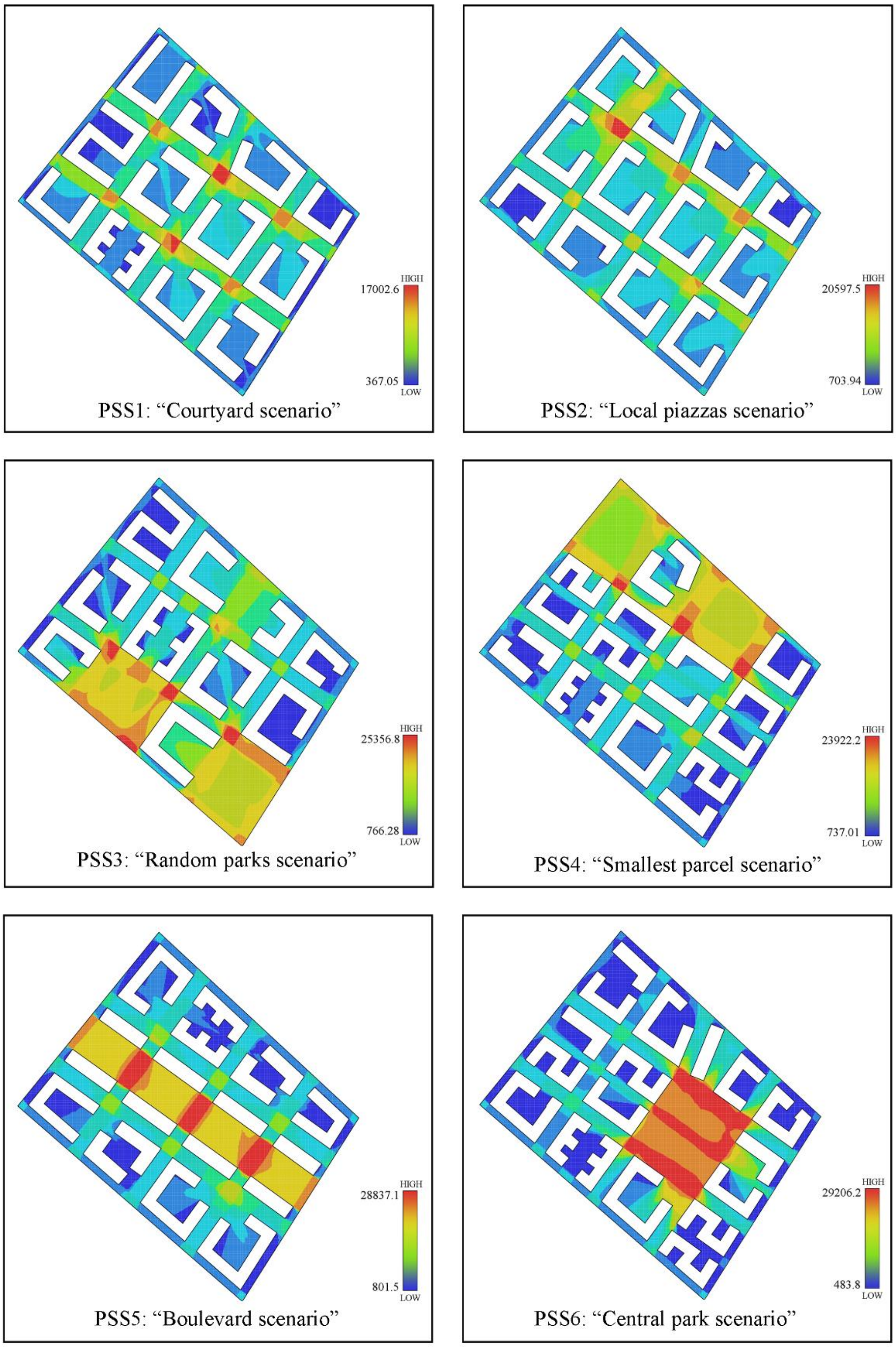

Figure 62. Visibility graph analysis (VGA)

CHAPTER 6

DISCUSSION

This chapter offers some introspective reflections on how the research was conducted. The first part of the discussion will highlight the findings from the evaluation phase of the study while the second part of the discussion will give insights regarding the strength and weaknesses of the developed framework and also showcase its relation and differences with other similar studies.

6.1 The selection of the best-performing scenario

The evaluation phase of the methodology included multiple criteria when assessing the performance of different scenarios from the perspective of public space.

It incorporated the following evaluation criteria: GSI ratio, FSI ratio, OSR ratio, the total area of all buildings, ST&SW area, Courtyard area, Park area and their respective ratios to the open space area. The comparisons for each scenario were also visually illustrated by the constructed Spacemate diagram and the area distribution graph. Another important aspect of the evaluation was the visibility analysis, which involved comparing the isovist areas of all six scenarios. The paper by Schneider & Koenig [60] uses the isovist area in order to evaluate the visual properties of open spaces and states that the use of isovist areas helps assess different spatial qualities and can also serve as a single criterion for evaluation and also

Based on the overall indicators, PSS3 performed the best with the lowest GSI and FSI ratios, as well as the highest OSR ratio. However, when considering the visibility analysis, PSS3 ranked third in terms of the isovist average and maximum values, with PSS6 outperforming it in terms of isovist analysis. Although PSS6 excelled in terms of visibility, it had relatively higher GSI and FSI ratios compared to PSS3. PSS5 also exhibited higher GSI and FSI ratios compared to PSS3 but performed the second best in terms of visibility.

To determine the best-performing scenario, it is important to also consider the municipal regulations. All scenarios complied with the standard GSI ratio, which was up to 45% [55]. However, all scenarios exceeded the assigned FSI score of 2.5, according to local planning regulations [55]. Since the scenarios surpassed this score but adhered to the GSI regulation, the isovist area and OSR ratio played crucial roles in determining the best-performing scenario.

PSS6 demonstrated the best visibility performance, with a maximum isovist value of 29206.2 and a relatively good score of OSR (0.65). Although it did not have the highest OSR ratio like PSS3 (which scored 0.69), the higher visibility score of PSS6 highlighted the importance of quality open spaces over their size. The slightly lower OSR value in PSS6 in comparison to PSS3, it indicates that the site was utilized efficiently to achieve a satisfactory balance between the built area and high-quality open space in terms of visibility. As a result, PSS6 is considered the best-performing scenario.

On the other hand, PSS1 emerged as the worst-performing scenario. It had the highest GSI and FSI ratios, the lowest OSR ratio, and no assigned parks. The visibility analysis further confirmed its poor performance, as the average and maximum isovist values of PSS1 were the lowest among all scenarios, primarily due to the absence of a common park. Thus, PSS1 can be considered the worst-performing scenario based on the listed criteria of evaluation.

6.2 Framework strengths and weaknesses

The second phase of the research focuses on the development of the parametric model. Prior to constructing the parametric model, various urban analyses were conducted on the experimental site to gain a deeper understanding of its characteristics.

The parametric model in this study shares similarities with several studies [39], [40], [42], [45], [43] in terms of the parametric generation process and the control parameters such as building dimensions, ceiling height, number of floors, and street width.

Equivalent to the findings of Koening *et al.* [62], the practice of incorporating the incoming streets from the existing context is a shared approach when generating the street network. However, this study offers additional control parameters including sidewalk width, building distance from the sidewalk, building openings, orientation, and various building typologies that reflect the current context of the site. This diversity of control parameters and building typologies is a notable strength of the framework.

Another strong aspect of the generative framework is the inclusion of different scenarios for locating public spaces within the urban plan. While other studies mentioned above also provide alternative scenarios for evaluation or optimization, they do not specifically offer public space scenarios that are distinct in nature. The ability to switch between different scenarios and the control to modify other parameters provides a range of options and flexibility in the design process. However, a weakness of the generated script is that occasionally, when parameters are changed, Grasshopper may introduce inaccuracies that require further adjustments.

Overall, this framework stands out for considering the existing context and analyzing the site's built environment as a fundamental step in the urban design process. It offers various control parameters, diverse building typologies, and multiple pubic space scenarios, allowing for the creation of endless design options. The applicability of the framework in the context of Astir is also a strength of the framework showcasing its applicability in a real case study.

By successfully applying the framework to the context of Astir, its robustness and adaptability are showcased, further enhancing its credibility and potential for implementation in other similar settings.

CHAPTER 7

CONCLUSION

7.1 Conclusions

In this study, the framework of the methodology behind the parametrically generated public space scenarios was planned through three main phases: starting from the data collection and statistical analysis phase, moving through the urban "planning domain" with parametric modelling, and concluding with the evaluation phase where the best-performing scenario in terms of public space is selected.

The findings from the evaluation phase proved that the proportions, size and the quality of the public space in terms of visibility, can all be evaluated by comparing several morphological parameters such as the FSI, GSI and OSR ratios as well as by analyzing the isovist area. Notably, the "Central park scenario" (PSS6) emerged as the best-performing scenario. This outcome as indicated by the Spacemate diagram and the results obtained from the isovist area analysis. The favourable location and size of the central park contributed to this outcome, further emphasizing the importance of location and size in determining the quality of public space.

Conversely, scenarios without dedicated public spaces, like the "Courtyard scenario" (PSS1), performed poorly, emphasizing the value of incorporating central parks for optimized urban planning. However, besides the results from the evaluation phase, it is also important to acknowledge the influence of urban planners and architects in deciding how public spaces are integrated into the planning process. Furthermore, despite the fact that the 3D modelling presented in this thesis is a prototype with simplifications and assumptions, it helps highlight the importance of incorporating public space dimensions in future urban developments. The parametric model phase also contributes to the field of generative design by explaining the generative process in detail and exploring its integration with data collection, local planning regulations, and urban site analysis. In conclusion, this framework demonstrates its applicability through both theoretical construction and practical application in the context of Asitr, which reflects the current urban developments in the city of Tirana.

7.2 Recommendations for future research

The current framework of the methodology has room for improvement, particularly in two key areas. Firstly, the parametrically developed framework could benefit from a more user-friendly interface. By prioritizing user-friendliness, the developed script could become more accessible to a wider range of professionals, enabling their participation in parametric urban planning and enhancing the overall planning process. Secondly, the evaluation phase of the methodology could be expanded to include additional criteria for assessing public spaces. Factors such as accessibility, social interaction, community engagement, and environmental impact could be considered. Furthermore, by incorporating the ratio of the building height to the street width as a morphological metric of evaluation, it can offer further valuable insights. Some studies have already shown that this ratio has a significant influence on the quality of public spaces.

These suggested enhancements, along with other methods for analyzing the configuration and dimensions of public spaces, hold potential for further improvements. By continually advancing and expanding upon these aspects, the methodology can become more comprehensive and efficient in evaluating and optimizing public spaces.

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APPENDIX A

Table 17. Site 1 Building Morphological indicators

Site 1										
Object	**Name**	**Shape Typology**	**Nr. Floors**	**B.H (m)**	**B.L (m)**	**B.W (m)**	**B.D (m)**	**F.A (m^2)**	**F.P (m)**	**F.A X Nr.Floors (m^2)**
B1	Romario	U-shape	12	37	52	24.5	16.5	928.58	155.43	11187.53
B2	Romario	U-shape	12	37	52	24.5	16.5	932.29	160.28	11187.53
B3	Romario	Podium shape	9	28	21	22	22	447.18	84.63	4024.59
B4	Romario	U-shape	10	31	85	32	16	1975.99	260.39	19759.91
B5	Romario	U-shape	10	31	85	32	16	1834.67	260.14	18346.7
B6	Romario	O-shape	9	28	77	71.5	20.5	3698.15	410.72	33283.31
B7	Romario	O-shape	9	28	80	73.9	20.5	3941.10	443.61	35469.86
		Total Sum						13757.95	1775.20	133259.44
		Average	10.14	31.43	64.57	40.06	18.29	1965.42	253.60	19037.06

B.O (°)	**B.V (m^3)**	**Wall area (m^2)**	**Envelope area (m^2)**	**B.W/B.D Ratio**	**B.H/F.A Ratio**	**BSF (E.A/B.V) Ratio**	**d1 (m)**	**d2 (m)**	**B.H/d1 Ratio**	**B.H/d2 Ratio**
54.99	34357.31	5750.98	6679.56	1.48	0.04	0.19	20.10	24.50	1.84	1.51
55.33	34494.88	5930.29	6862.58	1.48	0.04	0.20	15.50	27.00	2.39	1.37
53.23	12520.96	2369.67	2816.85	1.00	0.06	0.22	20.60	30.00	1.36	0.93
57.42	61255.72	8072.00	10047.99	2.00	0.02	0.16	22.60	27.60	1.37	1.12
51.15	56874.77	8064.40	9899.07	2.00	0.02	0.17	_	27.00	_	1.15
55.35	103548.09	11500.13	15198.28	3.49	0.01	0.15	21.00	16.00	1.33	1.75
46.54	110350.69	12421.00	16362.09	3.60	0.01	0.15	23.70	16.00	1.18	1.75
	413402.41	54108.47	67866.42							
53.43	59057.49	7729.78	9695.20	2.15	0.03	0.18	20.58	24.01	1.58	1.37

Table 18. Site 2 Building Morphological indicators

Site 2										
Object	**Name**	**Shape Typology**	**Floors**	**B.H (m)**	**B.L (m)**	**B.W (m)**	**B.D (m)**	**F.A (m^2)**	**F.P (m)**	**F.A X Nr.Floors (m^2)**
B1	Fratari	L-shape	10	31	73	55	20	1410.43	199.93	14104.3
B2	Fratari	L-shape	10	31	78	56.5	20	1996.76	263.79	19967.64
B3	Fratari	L-shape	10	31	70	55	20	1886.15	256.00	18861.51
B4	Fratari	L-shape	10	31	74	56.5	20	2093.82	265.60	20938.21
B5	Fratari	I-shape	10	31	75	20	20	1214.70	174.62	12146.98
B6	Fratari	I-shape	10	31	76.8	20	20	1444.00	187.62	14439.97
		Total Sum						10045.86	1347.54	100458.61
		Average	10	31	74.47	43.83	20	1674.31	224.59	16743.10

B.O (°)	**B.V (m^3)**	**Wall area (m^2)**	**Envelope area (m^2)**	**B.W/B.D Ratio**	**B.H/F.A Ratio**	**BSF (E.A/B.V) Ratio**	**d1 (m)**	**d2 (m)**	**B.H/d1 Ratio**	**B.H/d2 Ratio**
61.47	43723.33	6197.77	7608.20	2.75	0.02	0.17	21.00	26.10	1.48	1.19
37.35	61899.68	8177.37	10174.13	2.83	0.02	0.16	26.00	17.00	1.19	1.82
61.34	58470.68	7935.88	9822.03	2.75	0.02	0.17	17.00	24.00	1.82	1.29
37.97	64908.45	8233.60	10327.42	2.83	0.01	0.16	22.00	21.00	1.41	1.48
52.38	37655.64	5413.13	6627.83	1.00	0.03	0.18	20.10	25.00	1.54	1.24
52.15	44763.91	5816.13	7260.12	1.00	0.02	0.16	24.00	_	1.29	_
	311421.69	41773.86	51819.73							
50.44	51903.62	6962.31	8636.62	2.19	0.02	0.17	21.68	22.62	1.46	1.40

Table 19. Site 3 Building Morphological indicators

Site 3										
Obj.	**Name**	**Shape Typology**	**Floors**	**B.H (m)**	**B.L (m)**	**B.W (m)**	**B.D (m)**	**F.A (m^2)**	**F.P (m)**	**F.A X Nr.Floors (m^2)**
B1		S-shape	9	28	77	35	16.5	1915.25	292.73	17237.28
B2	Condominium	I-shape	9	28	76	27.5	27.5	2075.57	218.43	18680.12
B3	Molla sh.p.k	T-shape	9	28	78	34	16.5	1585.53	243.83	14269.76
B4		I-shape	9	28	79	28.5	28.5	2180.26	215.42	19622.38
B5		S-shape	9	28	76.5	35.5	14.5	1894.73	359.96	17052.53
B6		O-shape	8	25	77	65.5	18.5	3463.69	444.76	27709.52
B7		U-shape	10	31	86	28	19	1871.48	285.99	18714.77
B8		T-shape	9	28	86	36	19.5	1799.63	294.39	16197.90
B9		T-shape	9	28	86.5	36	19.5	1799.77	294.41	16197.90
B10		T-shape	9	28	86	36	19.5	1793.33	296.03	16139.94
B11		E-shape	8	25	83	33	16	1781.48	308.30	14251.8
B12		E-shape	9	28	86	34	17	2149.93	292.34	19349.38
		Total Sum						24310.63	3546.59	215423.28
		Average	8.92	27.75	81.42	35.75	19.38	2025.89	295.55	17951.94

B.V (m^3)	**Wall area (m^2)**	**Envelope area (m^2)**	**B.W/B.D Ratio**	**B.H/F.A Ratio**	**BSF (E.A/B.V) Ratio**	**d1 (m)**	**d2 (m)**	**B.H/d1 Ratio**	**B.H/d2 Ratio**
53627.08	8196.44	10111.69	2.12	0.01	0.19	22.00	20.00	1.27	1.40
58115.93	6116.01	8191.58	1.00	0.01	0.14	17.80	21.00	1.57	1.33
44394.81	6827.27	8412.80	2.06	0.02	0.19	18.80	18.50	1.49	1.51
61047.39	6031.68	8211.94	1.00	0.01	0.13	19.00	17.50	1.47	1.60
53052.30	10078.80	11973.52	2.45	0.01	0.23	16.00	16.80	1.75	1.67
86592.25	11119.03	14582.72	3.54	0.01	0.17	_	25.00	_	1.00
58015.79	8865.66	10737.14	1.47	0.02	0.19	18.00	15.30	1.72	2.03
50389.56	8242.89	10042.52	1.85	0.02	0.20	19.00	9.50	1.47	2.95
50393.48	8243.59	10043.36	1.85	0.02	0.20	20.00	10.00	1.40	2.80
50213.16	8288.87	10082.20	1.85	0.02	0.20	19.00	11.00	1.47	2.55
44536.88	7707.38	9488.85	2.06	0.01	0.21	21.00	16.50	1.19	1.52
60198.07	8185.63	10335.56	2.00	0.01	0.17	20.00	25.00	1.40	1.12
670576.69	97903.24	122213.87							
55881.39	8158.60	10184.49	1.94	0.01	0.18	19.15	17.18	1.47	1.79

APPENDIX B

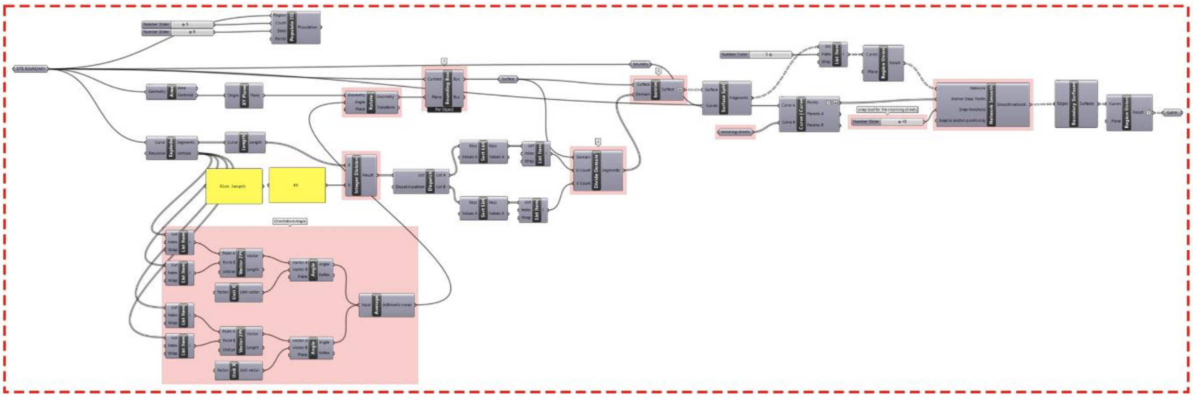

Figure 63. Street and Parcel generation Gh script

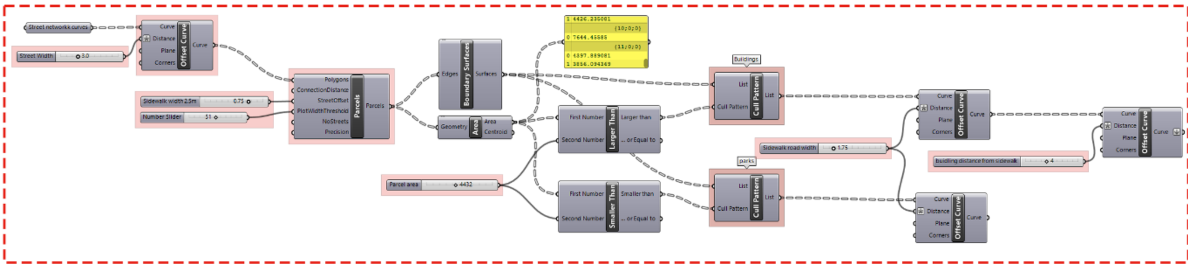

Figure 64. Parcellation step, Street & Sidewalk width, Building distance from sidewalk script

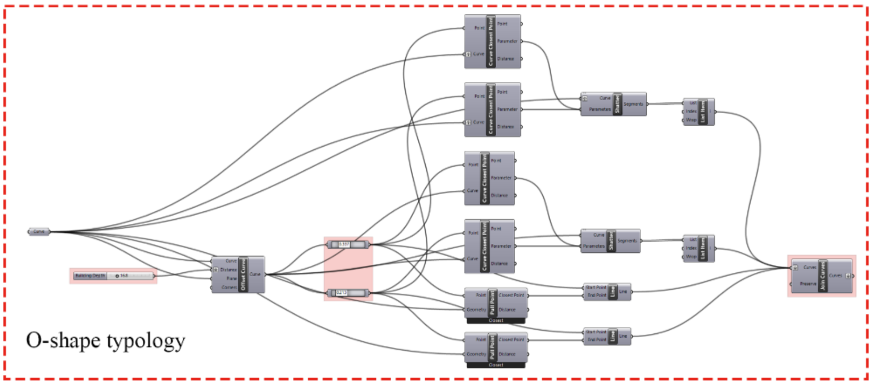

Figure 65. O-shape building typology script

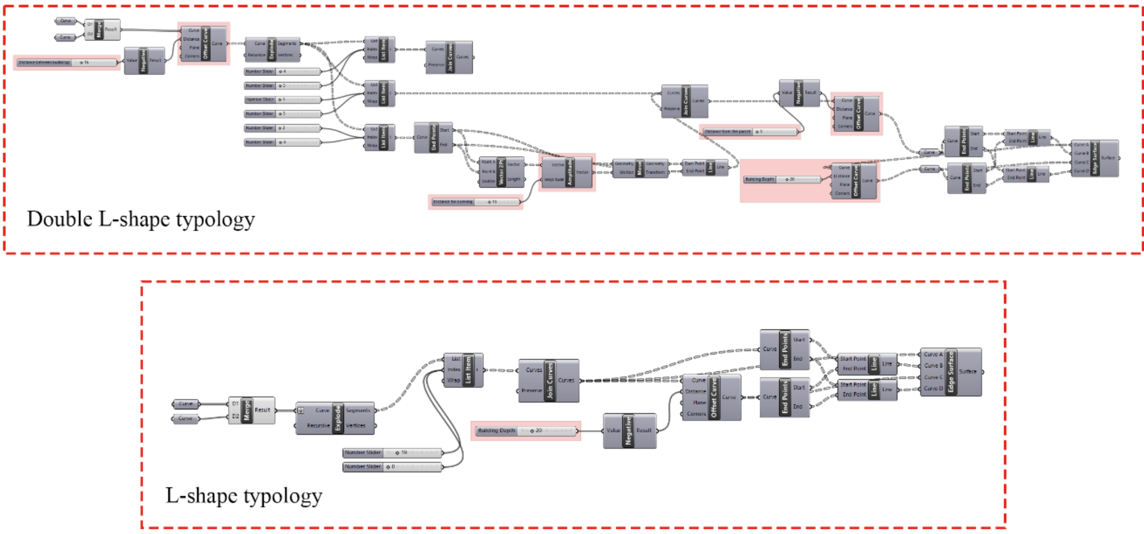

Figure 66. L-shape building typology script

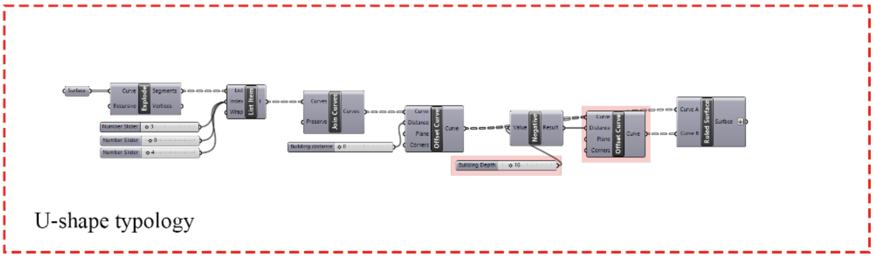

Figure 67. U-shape building typology

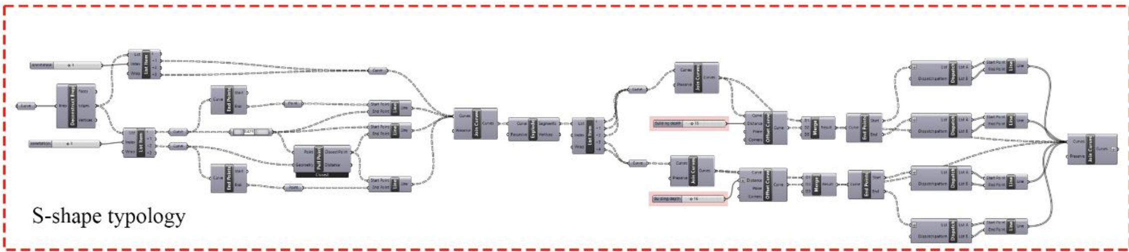

Figure 68. S-shape building typology script

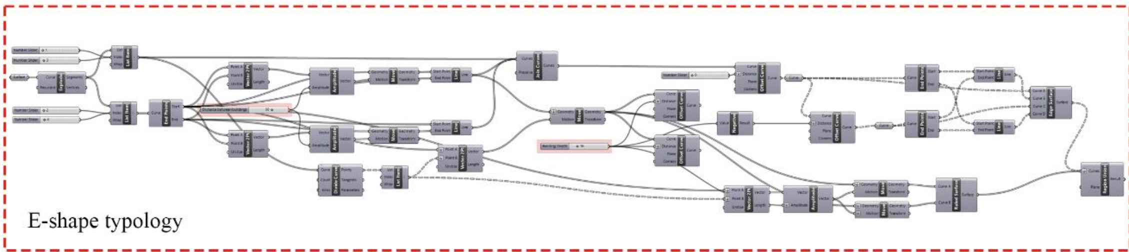

Figure 69. E-shape building typology script

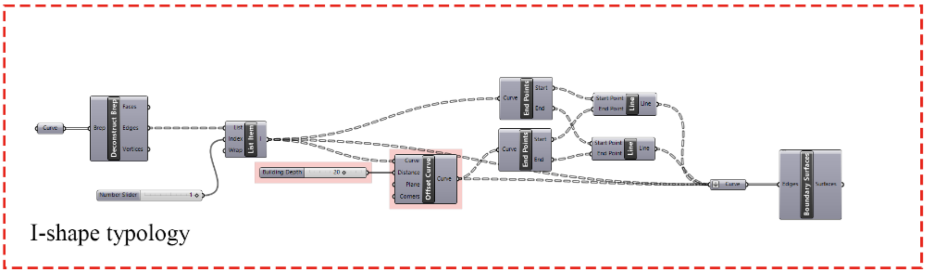

Figure 70. I-shape building typology script

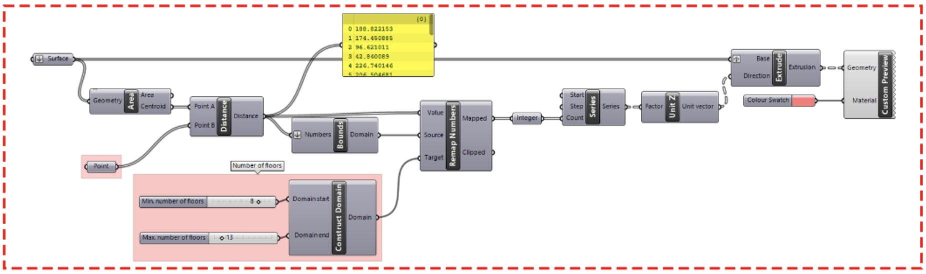

Figure 71. Building height generation script

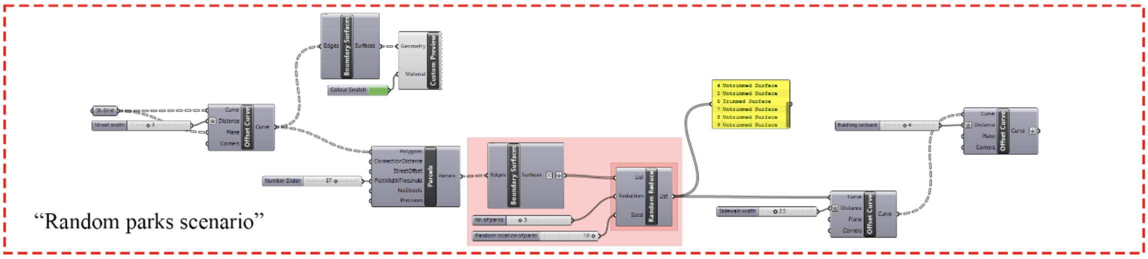

Figure 72. "Random parks scenario" script

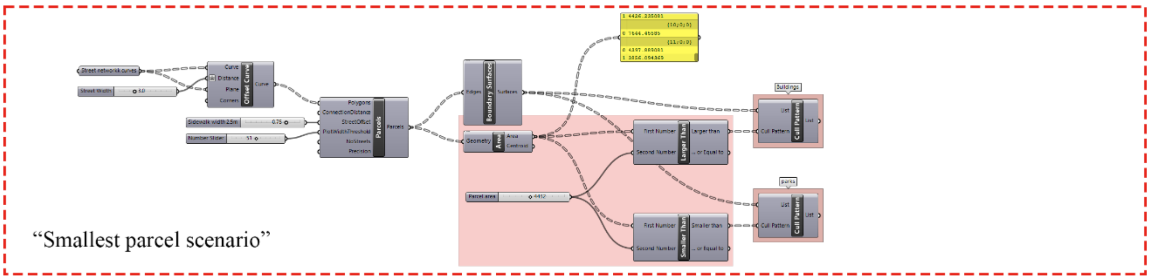

Figure 73. "Smallest parcel scenario" script

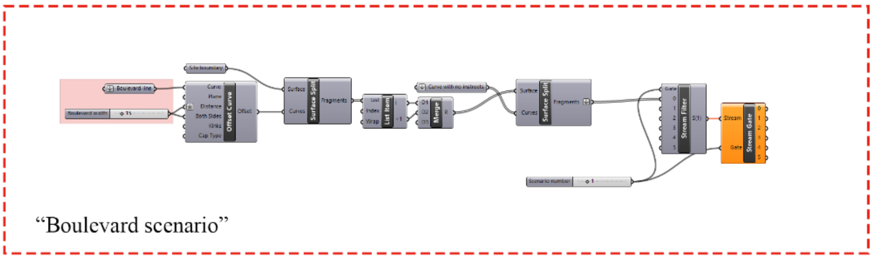

Figure 74. “Boulevard scenario” script

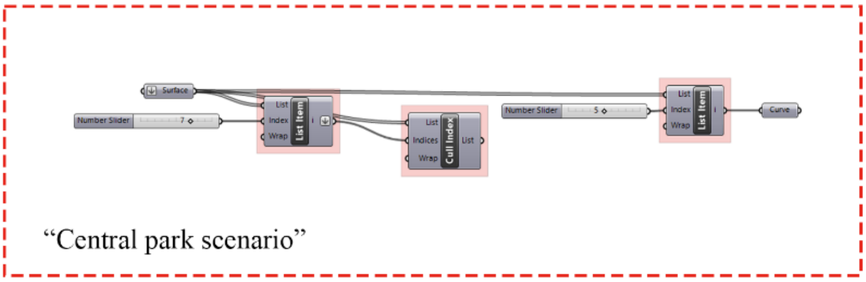

Figure 75. “Central park scenario” script

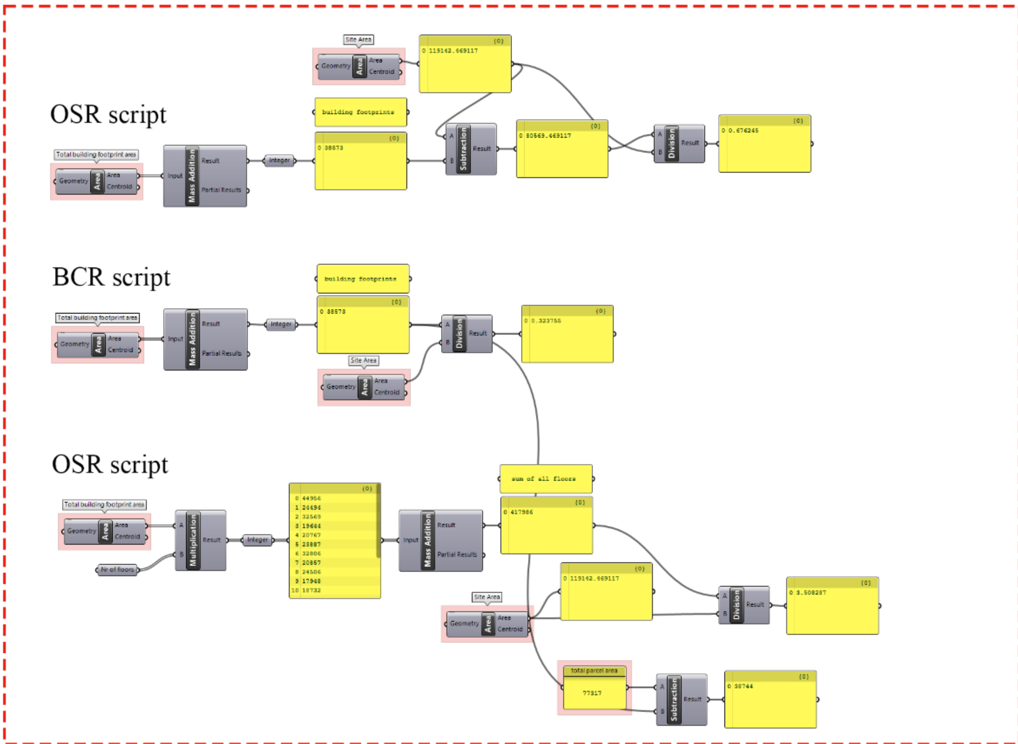

Figure 76. BCR, FSI and OSR calculation script