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GRADUATE SCHOOL

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A GENERATIVE URBAN CONFIGURATION MODEL

OPTIMIZATION OF SKY VIEW FACTOR AND OPEN SPACES

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MSC IN ARCHITECTURE WITH THESIS

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We certify that, as the jury, we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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ABSTRACT

A GENERATIVE URBAN CONFIGURATION MODEL:
OPTIMIZATION OF SKY VIEW FACTOR AND OPEN SPACES

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Urban morphology has a significant role and a considerable impact on urban climate, thus on global climate change. Urban land use, building density, the presence of open spaces, and the arrangement between building masses and urban voids in an urban area identify the urban fabric.

The high-density urban areas generate an urban heat island (UHI) effect that is not desired. To avoid or minimize UHI effects, the urban design decisions that shape urban fabric have to be thought out more carefully than ever before. It is vital to minimize UHI effects and provide energy efficiency for the buildings. But before considering energy efficiency on a building scale, it is possible to minimize the urban heat island intensity just with the changes to be applied to the urban form. This study aims to develop a computational model by using the Sky View Factor (SVF) value which is used to calculate the urban heat island intensity and works with it reciprocally. The Sky view Factor also is affected by urban morphology. At the end of the study, it is expected to achieve a tool to assist in deciding the design criteria early in the design process.

Due to the computational methods, designers have a chance to see in advance what kind of outcomes their designs will be. Therefore, this study focuses on creating a computational design method that will be able to provide a sustainable perspective to urban planners and architects in the challenging design decision-making process. The model developed in this study is based on the selection of design criteria to be used on the model, mathematical definition of SVF and UHI intensity calculation, and optimization process.

keywords: urban design, computational design, urban heat island, sky view factor, generative model

ÖZ

ÜRETKEN KENTSEL FORM MODELİ: GÖKYÜZÜ GÖRÜŞ FAKTÖRÜ VE AÇIK ALAN OPTİMİZASYONU

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Kentsel morfoloji, kentsel iklim, dolayısıyla küresel iklim değişikliği üzerinde önemli bir role ve etkiye sahiptir. Bir kentsel alanda, kentsel arazi kullanımı, yapı yoğunluğu, açık alanlar ve yapı kütleleri ile kentsel boşluklar arasındaki düzenleme kentsel dokuyu belirlemektedir. Yüksek yapı yoğunluğuna sahip kentsel alanlar, arzu edilmeyen kentsel ısı adalarının (KIA) oluşmasına sebep olur. Kentsel ısı adası etkilerinden kaçınmak veya bu etkileri en aza indirmek için, kentsel dokuyu şekillendiren kentsel tasarım kararları alınırken hiç olmadığı kadar dikkatli düşünülmelidir. Kentsel ısı adası etkilerinin en aza indirilmesi ve binalarda enerji verimliliğinin sağlanması hayati önem taşımaktadır. Ancak, enerji verimliliğini bina ölçeğinde sağlamaya çalışmadan önce, kentsel form üzerinde yapılacak değişikliklerle kentsel ısı adası yoğumluğunu minimize etmek mümkündür. Bu çalışma, kent morfolojisinden etkilenen ve kentsel ısı adası yoğunluğunu hesaplamada kullanılan gökyüzü görme faktörünü kullanarak hesaplamalı tasarım yöntemi geliştirmeyi amaçlamaktadır.

Hesaplamalı yöntemler sayesinde, tasarımcılar tasarımlarının ne tür sonuçlar doğurabileceğini önceden görebilme şansına sahiptirler. Bu çalışma, tasarım sürecinde oldukça zorlayıcı olan karar verme aşamasında, tasarımcılara sürdürülebilirlik yönünden bir bakış açısı kazandırmayı amaçlayan bir hesaplamalı tasarım modeli oluşturmayı amaçlamaktadır. Bu çalışma kapsamında geliştirilecek olan model, modelde kullanılacak tasarım kriterlerinin belirlenmesi, gökyüzünü görme faktörü ve kentsel ısı adası yoğunluğu hesaplamalarının matematiksel olarak tanımlanması ve optimizasyon sürecinden oluşmaktadır.

Anahtar Kelimeler: kentsel tasarım, hesaplamalı tasarım yöntemi, kentsel ısı adası, gökyüzü görüş faktörü, üretken model

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Elif Hazal OKUR
İzmir, 2022

TEXT OF OATH

I declare and honestly confirm that my study, titled “A GENERATIVE URBAN CONFIGURATION MODEL: OPTIMIZATION OF SKY VIEW FACTOR AND OPEN SPACES” and presented as a Master’s Thesis, has been written without applying to any assistance inconsistent with scientific ethics and traditions. I declare, to the best of my knowledge and belief, that all content and ideas drawn directly or indirectly from external sources are indicated in the text and listed in the list of references.

Elif Hazal OKUR
Signature

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13.05.2022

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SYMBOLS AND ABBREVIATIONS

ABBREVIATIONS:

UHI	Urban Heat Island
SVF	Sky View Factor
EA	Evolutionary Algorithm
FAR	Floor Area Ratio
BCR	Building Coverage Ratio
Hmax	Maximum Height of the Building
SPEA	Strength Pareto Evolutionary Algorithm

SYMBOLS:

L*	Net long-wave radiative flux density
Q_H / Q_E	Sensible and latent heat flux densities
ΔQ_S	Surface heat flux density
Q^*	Net all-wave radiation flux density (W/m^2)
Q_F	Anthropogenic heat flux density due to combustion (W/m^2)
Q_H	Turbulent flux density of sensible heat (W/m^2)
Q_E	Turbulent flux density of latent heat (W/m^2)
ΔQ_S	Net heat (energy) storage (W/m^2)
ΔQ_A	Net heat advection (W/m^2)
ψ	Sky View Factor value
$\Delta Tu-r$ (max)	Urban Heat Island intensity

CHAPTER 1
INTRODUCTION

1.1. Definition of the Research Problem

Industrialization and rapid urbanization since the 19th century have brought many globally critical issues with it and among these issues, one of the most important of these is rapid population growth. This population growth has affected water and air pollution, increased energy consumption, triggered environmental pollution, and climate change, all of these reasons have made crucial impacts on human health and the environment. Primarily, after the oil embargo occurred in 1973, this energy crisis led the world to think about the ‘’conservation of energy’’ and following that, the ‘’sustainability’’ concept has appeared in Brundtland Report (Bermejo et al., 2010). Since then, energy efficiency and energy management terms have been highly used in this context. These terms required new design solutions and until today, many design approaches have been improved to optimize the most influential factors on urban climate change.

Researches show that buildings generate %40 of energy consumption worldwide so it has become a global problem of our time (Cao et al., 2016). Because of this energy consumption, urban areas have a higher temperature compared to rural areas, and these metropolitan areas are called ‘’urban heat islands’’. Many studies illustrated that the urban heat island phenomenon is one of the most influential factors in urban climate. Urban heat islands increase urban temperature, which affects thermal comfort negatively. Thus, cooling emerges as a necessity, especially in hot-climate countries. So, it is worth mentioning that this phenomenon significantly has an impact on energy consumption and climate change.

Due to the problems caused by urban heat islands, and to reduce the energy demand caused by buildings, there are lots of active and passive design strategies that can be applied to projects such as natural ventilation or natural lighting by using renewable energy sources. The studies on analyzing the air temperature difference between urban areas and rural areas have proved the relationship between urban geometry and urban heat island intensity. So, before any method in the meaning of sustainability is applied at a building scale, it is possible to reduce this energy demand even by changing the placements of buildings in an urban layout.

Considering all these reasons, the main research problem for this thesis which becomes one of the main topics for urban planners and architects' agendas, originates from the search for a design solution as an alternative to traditional methods. Through the ease of computational design methods that can be applied to urban development plans, it is aimed to achieve the design alternatives which could be supportive in the decision-making stage of the urban planning process.

In the light of this search, the basic question underlying this thesis: Can we develop an adaptive design tool for the early design stage for both architects and urban planners to understand and avoid the negative sides of urban heat islands, and design more sustainable urban development plans for the future considering urban heat island (UHI) and sky view factor (SVF). So, this aims to create a design tool for the primary design stages by investigating alternative design solutions to optimize urban heat island effects and provide room for future research and studies.

Due to the development of computational design tools, designers have the chance to produce design alternatives to see the outcomes of their designs in the computational environment and improve their designs to gain better solutions. Since simulation-based studies have an essential role in figuring out the problems of an actual area and help gain awareness for future studies, they should be used more to detect problems that may occur and take precautions before the construction of an urban area.

1.2. Aims of the Research

The main aim of this thesis is to develop a computational design method that generates different urban layout forms with different replacements and geometries of buildings to reduce urban heat island intensity. The method varies the building replacements according to the user-defined design constraints. While each design parameter changes, the computational method produces different urban layout configurations during the generation of the model. The design criteria to develop this computational model are defined according to the constraints set by the urban planning regulations. As a result of a developed generative model, it is expected to gain an optimized design solution with minimum urban heat island intensity.

Within the scope of the research area of the study, there will be some questions to be answered essentially. The main research questions can be stated as:

Provided that FAR is constant, to what extent does SVF changes according to the different configurations of buildings on an urban layout?

Is it possible to keep the SVF value as possible as high even though the open spaces in an urban area are decreased? Or is it possible to capture the same SVF value on different open space values?

The study also aims to enable urban designers to be able to see the possible future effects of the design areas within the context of sky view factor and urban heat island correlation, at the early design phase. Therefore, urban designers and architects can manipulate their designs before putting the project into practice, in this way, adverse effects of designs can also be prevented.

1.3. Method of the Research

Urban planning is a quite challenging process in which many design decisions are taken together. Because of the limitations of planning regulations and design criteria that need to be considered, the design process becomes challenging. So, the decision-making process about mass configuration on an urban layout becomes vital for urban designers. Development of such a tool or method to mitigate urban heat island effects, just with the modifications on urban morphology by using computational design tools becomes something important for designers.

The main aim of this research is to develop a computational design tool to achieve an optimized urban form configuration, which is based on achieving the highest SVF possible by applying a multi-objective evolutionary optimization process.

In the second chapter of the thesis, the relationship between urban heat island intensity and the sky view factor has been explained. As can be understood from the fundamental principles and definition of the causes and effects of urban heat islands, a strong correlation between the urban geometry and sky view factor has been formulated. Following that, the studies about the urban geometry and sky view factor regarding reducing urban heat island intensity are examined.

In the third chapter, the computational workflow has been explained with the multi-objective evolutionary algorithm that provides multiple generated urban layouts during the optimization process. The computational design process and grasshopper definition have been explained in steps due to the design objectives.

Grasshopper plug-in of Rhinoceros is used for the definitions of design parameters, and Octopus plug-in of Grasshopper is used for a multi-objective evolutionary algorithm. With the help of these plug-ins, a diverse number of urban form alternatives have been provided by using the optimization tool ‘Octopus’. There are three aims in the model development of the study, the first is to be able to use the developed design tool at the beginning of the design process, second is to see the outcomes of each modification to the design due to the sky view factor, thus urban heat island, and the third aim is to control the input parameters (morphological constraints in the design algorithm) according to outcomes which come from each design alternatives.

According to the regulations of the planning system in Turkey, FAR value, BCR value, and Hmax are the limitations that are used in urban master plans for providing the residential needs that emerge with the increasing population. The FAR value is one of the crucial factors since it is determined according to the predicted construction area that may be needed. The total construction area of an urban block is calculated with the FAR value. If the FAR value remains constant and the building coverage area is decreased, the floor height increases to meet the total construction area within a plot area. Likewise, to enable this mathematical calculation, if the building coverage area is increased, the floor height decreases. The impact of urban open spaces on SVF value is very clear. If urban areas can have more open spaces, the SVF value gets higher. For this reason, rural areas have much lower air temperatures than urban centers.

While the FAR and BCR ratio is steady, the height of the building (floor number), and the building's width and length will be kept at a certain minimum and maximum intervals. The number of the buildings, setback distance, and floor height are to be defined at the beginning of the optimization process. In addition, any size of the site with a flat topography can be applied to the grasshopper definition. The hypothetical site used in this study is assumed to be at sea level, and topographical characteristics have been excluded from the study.

In the optimization process, it is aimed to maximize the Sky View Factor (SVF) value while providing the building density with the FAR value given by the regulations of the planning system in Turkey. In other words, it is aimed to achieve the optimal urban configuration model by increasing the SVF with a constant FAR value.

Only values that affect urban geometry will be considered as parametric values in this computational model. The values that are considered in this thesis are the intervals of building coverage ratio, floor number, and building locations. Consequently, while urban geometry changes, urban heat island intensity was kept low by obtaining the SVF value as high as possible.

CHAPTER 2

RELATION BETWEEN URBAN HEAT ISLAND INTENSITY AND SKY VIEW FACTOR

Since the main purpose of the thesis is to develop a generic model as a design proposal to reduce urban heat island intensity, in this chapter of the thesis, it will be mentioned that the definition of urban heat island, the formation of these islands, and the main causes of the intensity of urban heat islands. After the definition of the urban heat island phenomenon and the causes of its formation, one of the main causes of this formation which is the sky view factor, and its relationship with urban geometry will be explained. Following that, the main effects of urban heat islands and the studies carried out to reduce urban heat island intensity will be mentioned.

2.1. Definition of Urban Heat Island

Regarding the literature on climate change, there exist numerous risks, challenges, and indisputable consequences if no adequate precautions are being taken. According to Lippiat, one of the most crucial effects of climate change is the construction and the existence of buildings, and buildings generate green gas emissions which have a huge contribution to global warming where they are responsible for 40% of the energy consumption worldwide and 16% of the water used (Lippiatt, 1999).

Each year, the human population keeps increasing, therefore a need for housing and accommodation is in increase coordinately with it too. The increase of urban settlements causes an expansion in the diameter of the city centers, and as a result of this rapid urbanization, the energy amount that buildings generate and operate also increases dramatically in a rapid change. This prominent factor is one of the main reasons for global warming, thus gaining better energy efficiency in buildings is a major objective for energy policy at regional, national and international levels (Pérez-Lombard et al., 2008).

According to Shalaby, the heat generation from urban structures, which absorb solar radiation, and anthropogenic heat sources are the leading causes of urban heat islands (UHI) (Shalaby, 2011). Urban heat islands can be stated as a reflection of global warming, and it represents the air temperature difference between urban and rural areas. Luke Howard was the first researcher who authenticated the air temperature difference between city centers and rural areas by contributing his research (Oke, 1982). Since Howard's studies and observations on air temperature differences and the factors responsible for the urban heat island, many studies have been published worldwide including almost every major city in Europe, North America, and East Asia (I. D. Stewart, 2011).

Howard started his studies by discovering the urban center of London is to be always warmer than the country (rural area), and he claimed that this air temperature difference comes from the reason of urban effects which formalized as ΔTu-r (Parry & Chandler, 1966). Howard deduced that air temperature differences depend on anthropogenic sources, the geometry of urban surfaces which capture the radiation, urban roughness which obstructs the transition of the winds, and the availability of moisture (Parry & Chandler, 1966). Luke Howard describes the urban canopy layer as an effect on air temperature and the canopy layer can be defined as the air that lies below the roof (Mills, 2008). Although, the canopy layer model is implicit in Howard's analysis of London's heat island, and it is developed and systematized formally by Oke in modern literature (I. D. Stewart, 2011). Since Howard's first studies at the beginning of the 19th century, there have been modern investigators like T.J. Chandler, Böhm and Gabl, Oke respectively, and many more, have developed their research on meteorological instruments in cities and also new classification systems for characterizing the urban environment (Iain D. Stewart & Oke, 2006).

2.2. Formation of Urban Heat Island

As mentioned earlier, urbanization, urban sprawl, and population growth are primary reasons for the formation of urban heat islands. The other factors that come with these reasons, such as materials that are used in the built environment, lack of vegetation, urban geometry, urban land use, and anthropogenic heat release, also have a considerable effect on the formation of UHI intensity. The urban heat island phenomenon emerges due to the energy balance between urban and rural areas. However, this energy balance is the difference between energy input (heat uptake from the urban system) and energy output (heat release from the urban system). According to Oke and Cleugh, the city's great heat storage and thermal inertia are presumed to be one of all, even the primary, causes of the urban heat island (Oke & Cleugh, 1987).

Energy Input = Energy Output + Energy Storage

For most natural systems, energy balance is explained as the energy input and energy output equation. However, the situation is only valid if values are integrated over a long period such as a year, for shorter periods, the energy balance turns into an equation where the energy input equals the sum of energy output and energy storage (Amaral et al., 2013).

Oke, in 1981, formulized the rural surface energy balance;

$L^* = QH + QE + \Delta QS$

L^* = net long-wave radiative flux density

QH and QE = sensible and latent heat flux densities

ΔQS = Surface heat flux density,

On some occasions, for instance, near calm and cloudless weather conditions when the surface layer is stably stratified the turbulent terms QH and QE become negligible (Oke, 1981). So, net all wave-radiation (L^*) becomes equal with the surface heat flux density (ΔQS).

$L^* = \Delta QS$

The literature on the formation of urban heat islands suggests that to be able to understand energy balance, it is necessary to understand such features as the thermodynamic behavior of air, surface temperature, and the dynamics of local airflow (Oke, 1988).

The equation below is used to explain the energy balance.

$Q^* + QF = QH + QE + \Delta QS + \Delta QA$

Where:

Q^* = Net all-wave radiation flux density (W/m2)

QF = Anthropogenic heat flux density due to combustion (W/m2)

Q_H = Turbulent flux density of sensible heat (W/m^2)

Q_E = Turbulent flux density of latent heat (W/m^2)

ΔQ_S = Net heat (energy) storage (W/m^2) – rate per unit volume (per unit horizontal area)

ΔQ_A = Net heat advection (W/m^2) / net energy (sensible and latent) advection; rate per unit volume (per unit horizontal area)

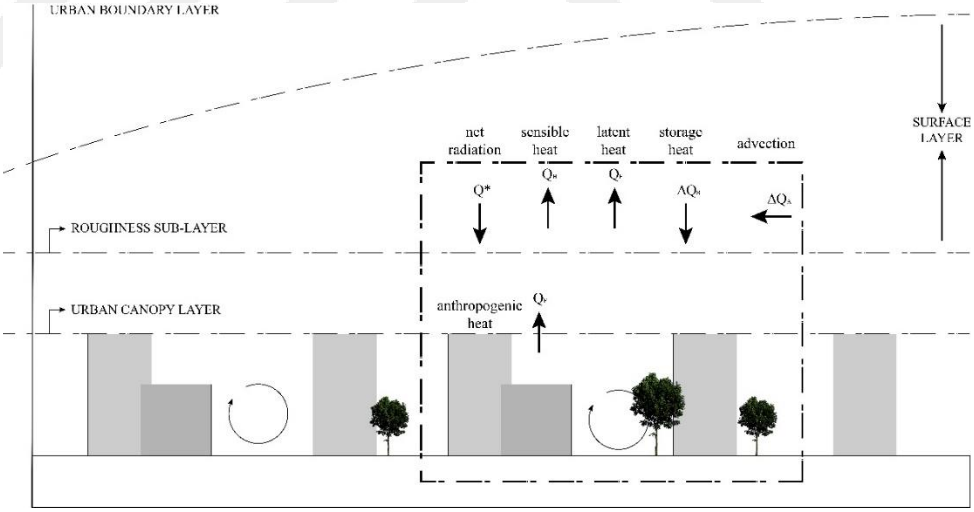


Figure 2.1. Urban Surface Energy Balance Components (Erell et al., Urban Microclimate, 2011)

In the schematic description of an urban energy balance shown above, the arrows pointing inwards represent energy gain, that is to say, heat uptake, and the arrows pointing outwards represent energy loss, in other words, heat release from the system.

2.3. Causes of Urban Heat Island

Many predominant factors like anthropogenic heat release, thermal properties of urban surfaces, absence of vegetation areas and open spaces, the reflection of sunlight, urban canyons, and more, help to contribute to the formation of urban heat islands. In addition, the increase in population growth, transportation, mobility, and artificial heat due to urbanization has significantly affected urban heat island formation. This urbanization effect can significantly influence local and regional climate by changing land-use patterns and thus surface radiation and energy balance (Wu, 2008). According to Landsberg (1981), two factors cause the temperature difference between urban and rural areas. The first reason for the temperature difference between urban and rural areas is artificial surfaces absorb the sun’s heat so that buildings and pavement form canyons to trap reflected heat, whereas the second is that building materials cannot dissipate this heat (Landsberg, 1981).

Urbanization alters the radiative properties of both the surface and the atmosphere, whereas the building materials introduce a wider range of surface emissivity than is typical for undeveloped areas. Consequently, the urban heat island raises the temperature of the surface and the atmosphere (Oke, 1988). Due to the heat load, demand for energy increases; to cool buildings and increase human comfort, and to achieve that, air conditioning systems are used, which generates a massive level of heat (Grimmond, 2007). Each 1°C increase in temperature increases energy demand in cities by 2-4% and 5-10% of the total electricity demand is spent to cool buildings only to compensate for the increase of 0.5-3°C in temperature (Akbari et al., 2001). The previously mentioned demands are caused by urbanization, and their effects contribute to urban heat island intensity (Akbari et al., 2001).

One of the most compelling reasons that affect climate change is the intensity of heatwaves loaded in an urban area, and it is urgent to decrease the urban heat island intensity. Luke Howard, who first recognizes the effects of urban areas on urban climatology, and is known for addressing the air temperature differences between urban and rural areas, defines the reasons for these temperature differences as follows;

- Anthropogenic heat sources that cause the rise in air temperature,
- The urban geometry and urban surfaces that captures and traps radiation and obstruct free radiation to the sky,
- The negative impact of ‘urban roughness’ on the passage of summer winds,
- The amount of moisture required for evaporation; (Mills, 2008).

2.3.1. Urban Geometry

Many direct and indirect factors that cause urban heat islands have been studied conducted through the years. Urban geometry, which is strongly linked to this phenomenon has been proved by many studies as, the leading one. Several studies demonstrate that morphological modifications on land use have an impact on urban heat island intensity. However, apart from the precautions taken on the building scale, urban scale morphology has a priority that must be considered.

According to Oke’s hypothesis (1976), two different layers cause urban heat island formation produced by urbanization. The first layer is the urban canopy layer, which acts microscale and consists of the air contained between urban roughness elements, and buildings (Oke, 1976). Urban surface units consist of geometric combinations of horizontal and vertical surfaces repeating throughout the urban area, and these units define the urban canopy (Nunez & Oke, 1977). These units can be defined as urban canyons, and in geometric terms, urban canyons can be described as the height/width (H/W) ratio (also known as an aspect ratio) of the space between adjacent buildings (Strømann-Andersen & Sattrup, 2011).

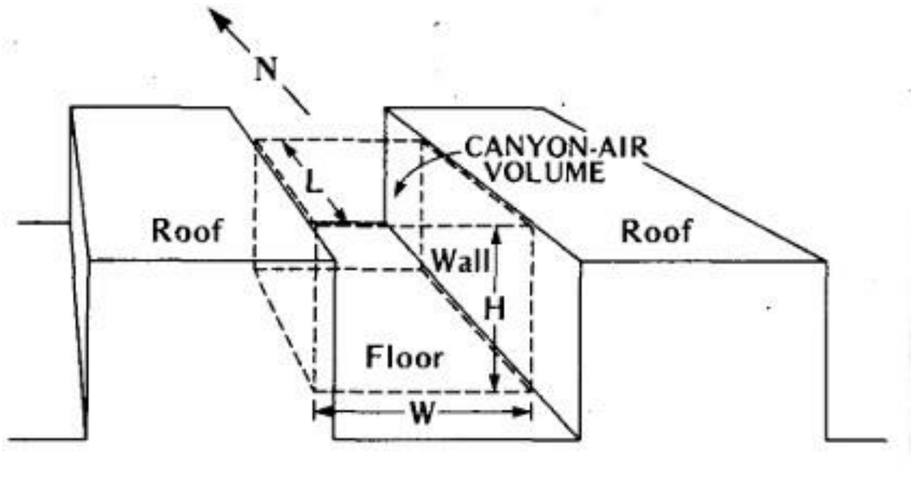


Figure 2.2. The Energy Balance of an Urban Canyon, (Nunez & Oke, 1977)

The experiments show that canyon geometry is a definite variable, especially in the formation of nocturnal urban heat islands, due to its role in regulating longwave radiation (Oke, 1981). Therefore, it is possible to say that urban canyons have an obvious relation to the energy performance of buildings. Urban canyons are shaped by buildings orientation, spaces between buildings, street width, building height, the footprint of a building, and the form of a building.

The second layer is the urban boundary layer, and the urban boundary layer is acted at the mesoscale, it is situated right above the urban canopy layer and interacts with the atmosphere (Oke, 1976).

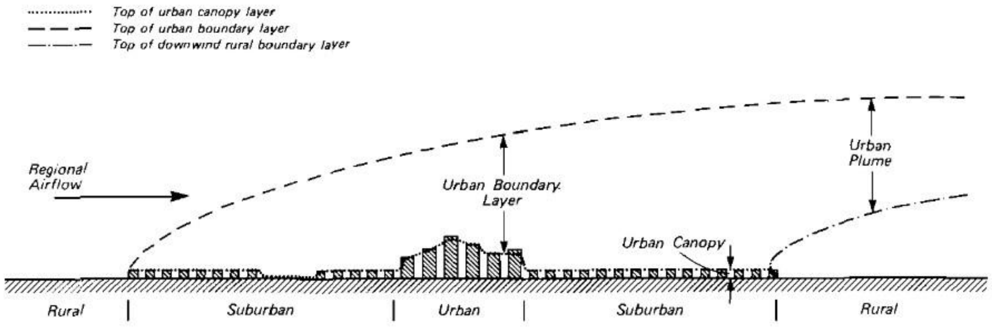


Figure 2.3. The distinction between canopy and boundary-layer urban heat islands (Oke,1976)

As seen in the figure above, the urban canopy layer is located between buildings and is limited by height. Observations on urban heat islands are based on the measurements made within the layer below the urban canopy layer (Tzavali et al., 2015). Because of the limitation formed by buildings, the climate and air circulation in the urban canopy layer are affected by buildings' orientation and geometry, surface materials, and thermal properties. On the other hand, the urban boundary layer positions itself between the upper boundary of the urban canopy layer and the curve, which starts on the urban surface (x=0) and moves towards the atmosphere with the effect of regional airflow.

An urban form consists of urban canyons, and they are characterized by three domains that affect the urban climate. These domains are the aspect ratio, the canyon's axis orientation, and the SVF (Bakarman & Chang, 2015).

2.3.1.1. Aspect Ratio

Due to the number of buildings in the city centers, there is a significant air temperature difference between urban areas and rural areas. The anthropogenic heat released by the building surfaces increases the air temperature and contributes to outdoor and indoor thermal comfort. The urban heat island phenomenon is due to the intense heat accumulation caused by these building intensities, whereas one of the primary reasons for the formation of urban heat islands in the urban forms is shaped by urban forms.

Aspect ratio is the ratio of the height of a canyon building to the width of its street canyon. Besides urban canyon surfaces, researchers argue, that the aspect ratio is one of the most effective parameters that directly contribute to urban air temperature, hence energy efficiency and energy consumption.

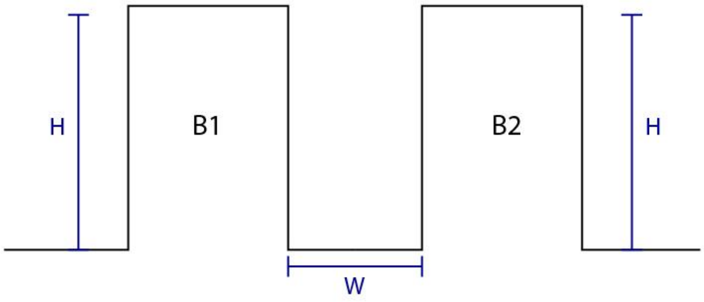


Figure 2.4. Aspect Ratio 1

In the situation where building 1 (B1) and building 2 (B2) heights are even (H1 = H2), the aspect ratio will be;

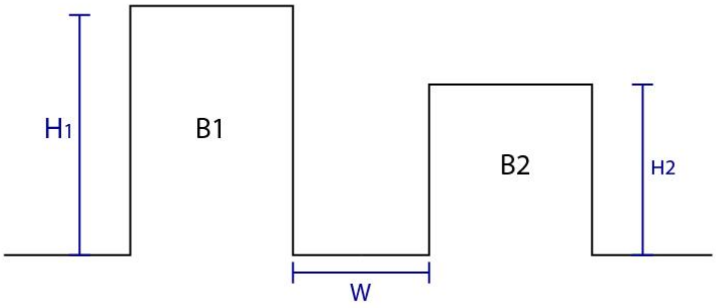


Figure 2.5. Aspect Ratio 2

As above, where the two building's heights are different from each other (H1 ≠ H2), the aspect ratio will be;

$$\frac{(H_1+H_2)\,/\,2}{W}$$

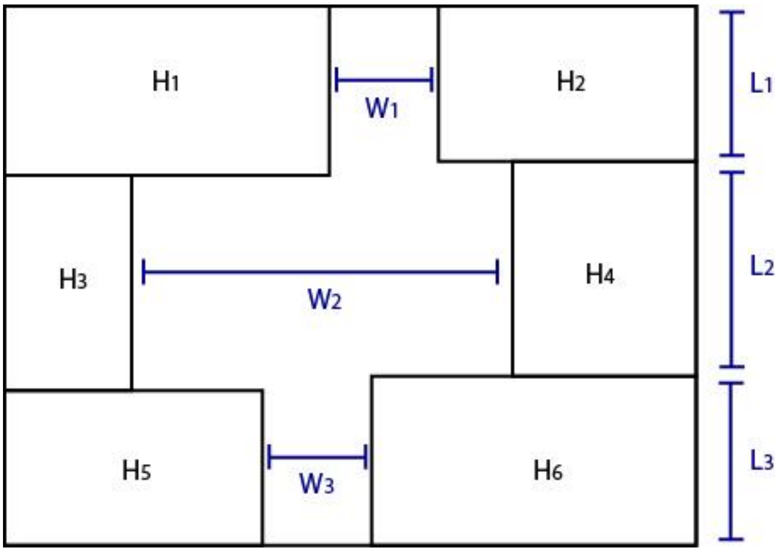


Figure 2.6. Aspect Ratio 3

The aspect ratio clearly describes how the density of urban blocks changes according to their heights and widths of each other and according to the blank spaces left between them. The differentiation in the H/W ratio directly affects urban heat island intensity. According to numerous studies, the aspect ratio has the most significant effect on air temperature and energy fluxes. The building orientation, positioning of the buildings, relative to each other, and height differences of the buildings in the urban canyon differentiate the aspect ratio and affects naturally the energy flow, the movement of air among buildings, and anthropogenic heat generated as a result of the thermal discomfort.

2.3.1.2. Sky View Factor

The sky view factor (SVF) is another factor that has an important influence on the energy performance of buildings and the differentiation of an urban air temperature, in the scope of the relation between urban geometry and urban heat island intensity. Studies show that the sky view factor (SVF) is a parameter that has a cooling effect on urban climate representing an openness of the sky. Also, it is directly related to the H/W ratio and the urban geometry. The factor varies from 0 to 1. As the factor approaches 1, the visibility area of the sky increases and an unobstructed view of the sky is obtained. On another note, considering the studies on mitigating urban heat island intensity while employing the SVF, researchers discussed the alternative ways that the urban layout configuration should be addressed to reduce intensity.

The studies' findings yielded that the urban configuration is an important control and has a significant role in the formation of an urban heat island intensity. Several calculation methods have been developed to calculate SVF values. As input data, some

methods find the SVF value based on fish-eye images or street view images, while some of them use raster or vector data to identify the sky obstacles (Bernard, 2018). The SVF is calculated from any point between buildings by including all obstacles surrounding that point. These obstacles are considered buildings, trees, and anything that could be considered as an input that would affect the sky's visibility.

2.3.2. Effects of Vegetation and Open Spaces

According to the studies that have been made by Rosheidat and Bryan vegetation and the presence of open and green spaces have an essential effect on urban heat island intensity and also the sky view factor. Studies show that one of the most effective factors in mitigating urban heat island intensity is increasing the urban vegetation. Therefore, urban vegetation is a crucial and natural intervention method in minimizing the effects of extra energy stored by construction materials exposed to intense sunlight and minimizing solar radiation effects which negatively affect urban heat island intensity. The built environment, non-reflective surfaces, and lack of vegetation have led to the creation of urban heat islands. Thus, the temperature difference between urban areas and rural areas increases. Moreover, the vegetations create a canopy layer in urban areas and depending on its size, height, and density, helps shatter the surfaces and decrease their surface temperature and heat gain compared with the exposed surfaces in shading the surfaces and decreasing their surface temperature and heat gain compared with the exposed surfaces (Rosheidat & Bryan, 230 C.E.).

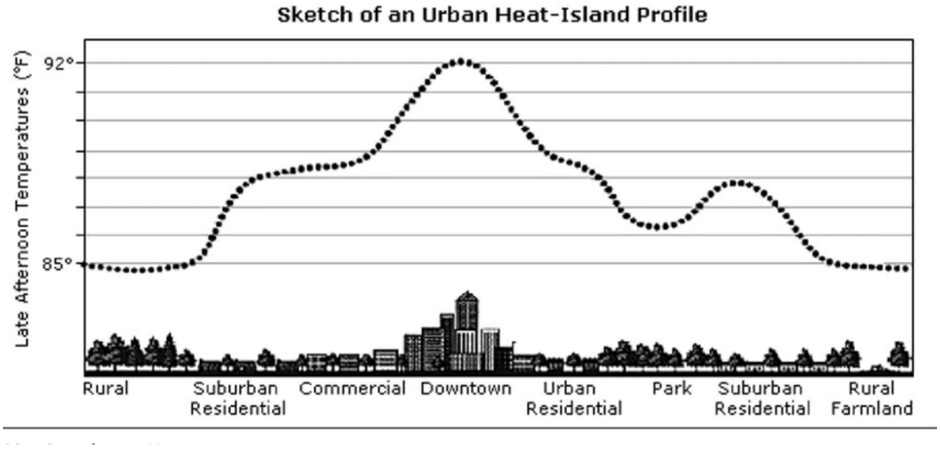


Figure 2.7. Sketch of Urban Heat Island Profile (Frumkin, 2002)

As Figure 2.4. shows, that the presence and the density of vegetation along the canyon affect the urban heat island intensity directly. The vegetation directly impacts meteorological conditions and urban climate because of its effect on reducing urban heat island intensity. Allocating spaces for vegetation in urban areas, reduces urban heat island intensity, balances the urban temperature, provides thermal comfort, and helps reduce air pollution.

2.3.3. Urban Materials

Several prominent factors contribute to the formation of UHI, among them the replacement of natural landscapes with artificial and building materials, building surfaces, and asphalt with low albedo, and poor town-planning configurations (Boukhabla et al., 2013). Besides the geometrical properties of the urban fabric, urban materials also cause undesirable effects on the urban climate. One of the critical factors causing trapped heat in urban areas is the thermal properties of materials that increase heat storage. Increasing heat load on building surfaces and rising temperatures from the surface of buildings cause the air temperature difference between urban and rural areas.

The urban environment with impervious paved surfaces used as urban materials like asphalt, brick, stone, concrete and other materials (materials with s a low albedo value that reflects sunlight less) give urban areas a much higher thermal storage than natural surfaces (Golden, 2004).

2.3.4. Anthropogenic Heat Release

Anthropogenic heat release is one of the major causes of increasing urban heat island intensity and plays an important role in the surface heat balance (Block et al., 2004). Anthropogenic heat can be thought to be the source of the volume for emission of heat from vehicles, HVAC systems, including individuals within the street canyon (Use & Characteristics, 2013). The resources that cause the anthropogenic heat release are oriented toward human activities. Such as cooling and heating buildings (e.g., air conditioning), transportation (e.g., automobiles.), and industrial processes that cause the anthropogenic heat release. Urban centers have these activities more than rural areas and that’s why they have higher energy demands than surrounding areas due to the higher production of anthropogenic heat (Shahmohamadi et al., 2011). This artificial heat is absorbed and stored; thus, warming the urban atmosphere, and leading to the disturbing urban energy balance. Considering the latter, it causes an increase in the urban heat island intensity.

2.4. Effects of Urban Heat Island

Expansion of urban fabric, population growth, and rise in human activities due to these parameters cause a dramatic increase in the urban heat island intensity. Expansion of the city leads to growth in the urban housing market and the built environment. Every parameter that feeds urban sprawl causes significant effects on urban climatology, directly or indirectly.

Elevated temperatures from urban heat islands, especially during the summer, affect the environment, quality of life, human health, and comfort (Shalaby, 2011). Besides these effects, it also contributes negatively to elevated water demand and quality, meteorology and climate, global warming, air pollutant, and greenhouse gas emissions.

Urban heat islands may increase heat-related health impacts by rising air temperatures in cities 2-10°F more than in suburban areas due to absorption of heat by surface and buildings (Gamble et al., 2008). The microclimate caused by UHI has the effect of increasing the energy demand for cooling in buildings, besides increased electricity generation by power plants causes greenhouse gas emissions that contribute to global warming and climate change (Adinna et al., 2009).

2.5. Studies on Mitigating Urban Heat Island Intensity Based on Urban Morphology

In the last decades, there have been simulation and evolutionary algorithm-based studies on urban heat islands to observe their relationship with the factors related. Besides the observations, these studies also aim to develop a design tool to gain a design approach, unlike traditional methods.

In one of these studies, Yuan & Chen (2011), while demonstrated the relationship between sky view factor and urban morphology, in the meantime, site coverage ratio and building height are used as two planning parameters to help increase SVF and mitigate urban heat island intensity.

In this study, a raster-based algorithm (ArcGIS) is used for the calculation of SVF, and it was found that the two morphological parameters used in the parametric model did not have a striking effect on the SVF. So, there is a need to be used more morphological parameters to gain a better understanding of the causing indicators of SVF. Yuan & Chen also point out that the air temperature decreases about 0.4°C if there is a %10 increase in SVF value and indicates that urban planners must consider decreasing the land use density.

Hu et al. (2016) have used parametric modeling, programming, and optimization algorithms to be able to experience UHI intensity by using SVF values on different urban forms. In the study, the experiment tries to find the optimum urban form by changing the urban density of the area. Urban forms were represented as masses with different sizes on each plot area and this form is called as density distribution form. As it is understood, density distribution is the main thing that differentiates a specified urban area. The study aims to generate multiple urban form generations with the optimum value of SVF for the specified total building area as a constraint. In the study, FAR changes while the total building area is steady. At the end of the study, the researchers put forward that SVF is lower when the density is higher and distributing density on the land has significance for mitigating heat island, so it is possible to mitigate UHI intensity by manipulating urban forms due to the SVF value.

Aksoy (2016) has aimed in his study to propose a decision support system that can guide the architect in the early design phase by using evolutionary algorithms. There are two design proposals examined in this study. One of them aims to gain a design alternative that has maximum natural light and minimum energy consumption by using NSGA-II using a multi-objective evolutionary algorithm. The other is the Sustainable Multi-Objective Land Use Allocation Model which considers two conflicting criteria: maximum open space and maximum development by considering the conditions of suitability for neighboring settlements and closeness to existing settlements.

Since the study aims to create a sustainable land model, the constraints that are used in the model are determined according to the design criteria of LEED and BREEAM. The site is digitalized without disregarding the topography and natural formations.

2.5.1. The Critics of Existing Methods

According to the research in the literature, it has been found that most of the studies reveal the SVF values on actual land use and UHI values corresponding to these SVF values. Except for the studies revealing the inverse relationship between SVF and UHI values, it is also observed that there are case studies that calculate the SVF values in actual urban areas that have different urban settlement patterns. Although the studies that reveal the relationship between the two values are very guiding for the designer, it is possible to do more evaluating studies with the design tools we have today.

Additionally, many morphological inputs affect the SVF value, one of the most basic and well-known values which is the height-to-width ratio is used in most studies. Although current simulation-based studies based on analysis and estimation are very helpful to observe the current situation, they are insufficient to bring a new design approach and produce design solutions. So, the lack of the search for a design solution to reduce urban heat island intensity by increasing the sky view factor value is the main starting point of this thesis. Considering the lack of studies on the relationship between urban geometry and SVF value in Turkey, this study also aims to open up a discussion in the name of bringing a new design approach to an urban scale in Turkey.

2.6. The Overall Critics on the Relation Between UHI and SVF

When the studies on urban heat islands are examined within the scope of the literature review, it is mostly seen that most of the studies are on the measurement of the current temperature values in existing urban areas. On the other hand, the existing methods are also mostly based on comparative analyzes of urban areas that have different characteristics. These studies mainly offer a perspective on the effects of the characteristics such as building density of an urban area, the pattern of an urban area, presence or absence of green areas, floor heights of the buildings, etc. on the urban heat island intensity, rather than presenting a model proposal to reduce the urban heat island intensity. Besides the measurement studies, the simulation-based studies on urban heat islands provide foresight for the urban designers by obtaining estimation values on the urban heat island intensity and urban temperature of an urban area that is intended to design.

For all these overall critics of the studies on urban heat islands, one of the biggest goals of the study is to be able to direct the urban planner or an architect during the design process and to create many urban configuration models in a very short time and develop a design proposal. These design proposals are intended to be the design solutions to reduce the urban heat island intensity and its effects. It also aims to provide a design solution to assist urban planners and architect in the decision-making process of a design phase by putting forward the connection between urban heat island intensity and geometrical features of an urban area.

CHAPTER 3
DEVELOPMENT OF URBAN CONFIGURATION MODEL BASED ON COMPUTATIONAL DESIGN APPROACH

The current study is based on developing a generic urban configuration model that aims to support urban planners and architects to facilitate the decision-making process at the beginning of the design phase. The beginning of the design phase gets more difficult and quite complex because of the decisions that need to be taken together at the same time. For this reason, a computational model has to be developed to compute the diverse range of fields that have a complex process.

The computational design method enables a design to be reconstructed over and over again, according to the variable characteristics of each part of a design. Therefore, the models help designers to evaluate multiple solutions, ease of complex data or a complex process of a study, foreknowledge for further studies, evaluate the values obtained from their developed design models, and question the approaches and methods that they used in their design studies. A computational model is also can be developed on a very wide range of a scale and provide designers with control of many variables in the same study.

In this thesis, the computational design method is used for the study. With the variable values assigned to the input parameters that will shape the design, there will be various urban form configurations constructed and the SVF values for each configuration will be calculated automatically. It is not possible to obtain various urban form configurations with different variable values and to calculate SVF values separately for each sample. In this respect, computational design is important in terms of evaluating and examining several various samples.

While constructing a generative urban configuration model, to make the design more sustainable and adaptive in any urban area, the geometrical features that are going to shape the urban geometry and differentiate the urban configuration alternatives need to be carefully selected. One of the significant contributions of the study is to integrate urban planning practices into the parametric modeling environment. This integration is aimed to provide urban planners and architects with an advantageous urban design approach in bringing about many solutions/cases. To fictionize the outline of the geometrical definition of the model and reflect this outline in the parametric modeling environment is the first step to actualizing this integration. In this study, it is aimed to develop a generative model to reduce

urban heat island intensity. Therefore, in the first step of the geometrical definition of the model has been defined regarding to relate between the building coverage ratio and sky view factor. The building coverage ratio is one of the most important factors that contribute to differentiate the urban configuration models.

The second step of the geometrical definition of the model is to adapt the mathematical definition of the sky view factor to the parametric modeling environment. To ensure this integration between parametric modeling and urban planning system, it is important to have a good understanding of the aspects of parametric modeling.

Therefore, in this chapter, the development of the generative model will be described in three progress steps: set up the geometrical definition of the urban layout, the calculation of the sky view factor value and its relation with the urban layout, and the optimization process. To mitigate urban heat island intensity, it is first to understand the geometrical features that most influential effects on this intensity. These geometrical features were examined in detail in the second chapter, and it was explained the strong relationship between urban geometry and sky view factor value, also the sky view factor value and urban heat island intensity.

In this chapter, it is tried to adapt the constraints and parameters determined by the urban planning regulations in Turkey, to create a generative urban configuration model. Within the framework of these constraints, there are also needs to be decided the design parameters of the model as for differentiating the outcomes of the urban form configuration generations. In the methodological approach of the study, the basis of the model is grounded on creating a computational design method that will be able to provide a sustainable perspective to urban planners and architects in the challenging design decision-making process.

3.1. Methodological Approach

With the computational tools that we have nowadays, it is possible to foresee the problems that might take a place after the implementation and also avoid them in the early design phase. Besides, using computational tools and their opportunities offers a more flexible working environment both on an architectural and urban scale. To this end, the study aspires to create an alternative design solution by developing a generative urban layout model just with the changes in the morphological parameters. The model that will be developed also aims to ease the decision-making for urban planners and architects during the design process.

The aim of the study, as mentioned before, is being able to meet the need for a model that can be effective to minimize the negative results at the very beginning of a design process, that will occur after the implementation of the design.

In this chapter, the development of the generative model is described, which this model is intended to contribute to a design decision-making process. The model has developed thanks to an algorithmic design environment and responds to any change in the parameters. The process of urban form-finding aims to be evaluated as an approach to bringing a new perspective to urban design thanks to the advantages of algorithmic design.

The urban configuration model developed within the scope of this thesis primarily addresses to be applied in three main urban areas: gated communities, urban transformation areas, and urban development areas. Therefore, it is intended to be an adaptive model for implementation easily in the aforementioned urban areas.

Any urban block in the form of a quadrilateral that has different coordinates on the X and Y axis can be applied to this model. As mentioned earlier, the model is developed to be adapted only to urban areas that have flat topography. The form of the initial urban area and flat topography are the two constraints of the model that should be developed for further studies to be conducted to contribute to the literature.

3.2. Progress Steps of The Model

In the thesis, the framework will be developed in the visual programming tool Grasshopper which is a plug-in in the computer-aided design application software, Rhinoceros. Grasshopper is used in the model for defining design criteria parametrically. The optimization process is held by the Octopus plug-in for Grasshopper. Octopus is developed for multi-objective evolutionary optimization, and it is accessible easily in Grasshopper. Octopus plug-in allows the user to define criteria more than one to be included in the optimization. Octopus is a plug-in that let the researchers have a chance to specify objectives, and in the direction of these objectives, to choose any results at the end of the optimization. Also, the researcher has a chance to do a comparison and evaluation among chosen generations. It also searches for the best solutions for any number of goals. Since the thesis aims to optimize the sky view factor and open spaces in an urban area, multi-objective evolutionary optimization is used in this optimization process because of its search for many goals at once.

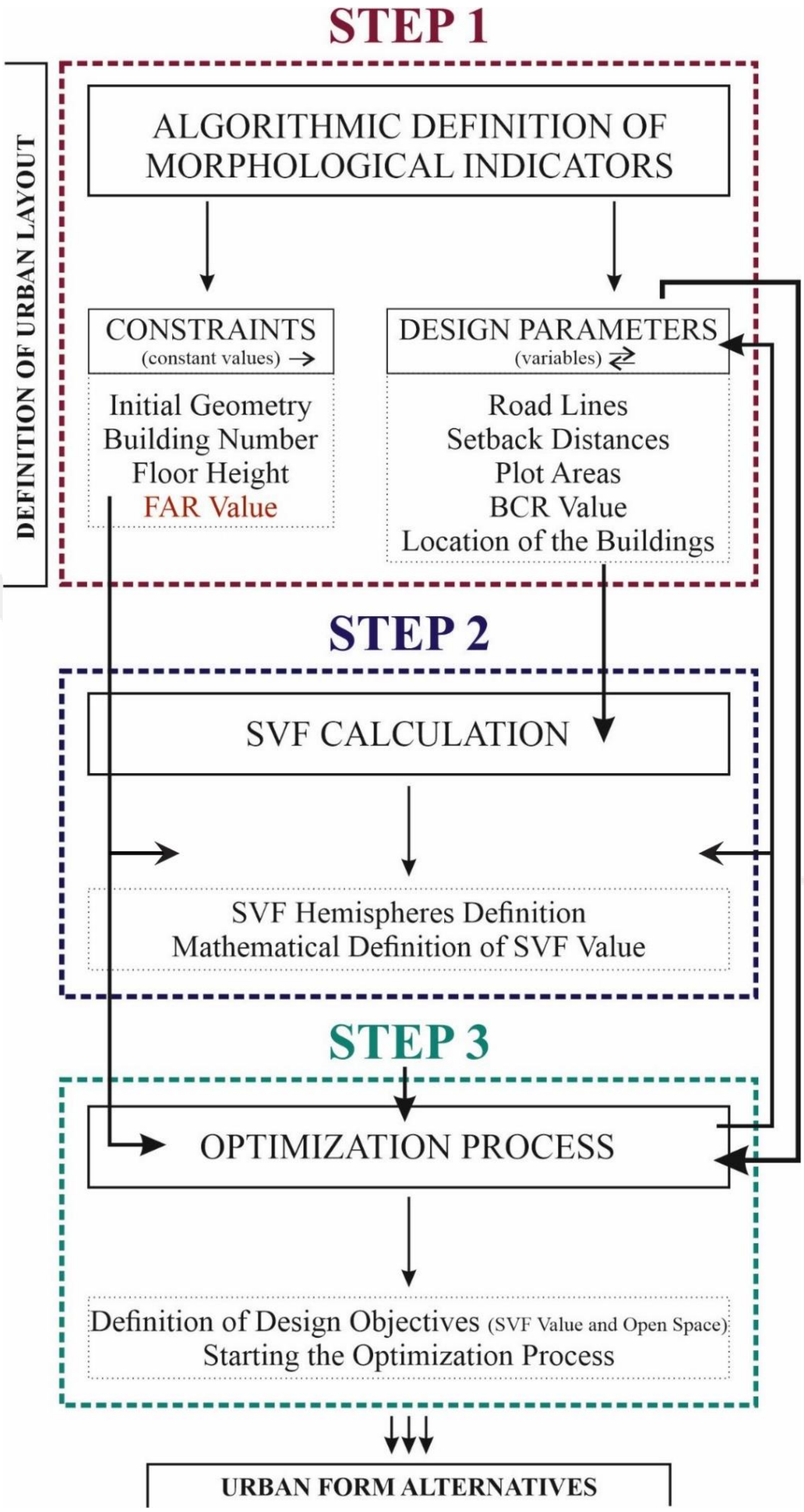


Figure 3.1. Workflow of the Grasshopper Definition

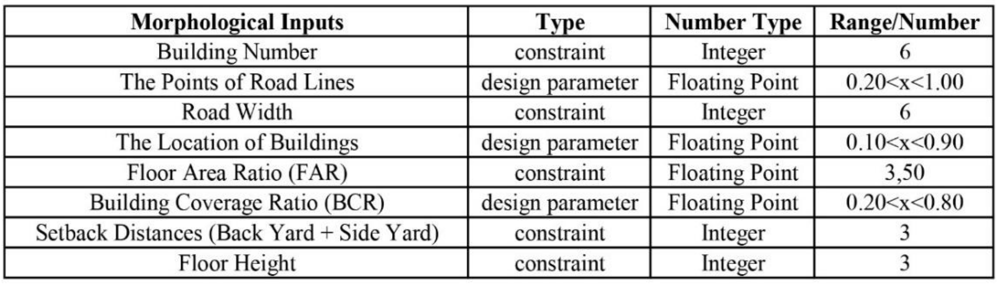
The model is developed in three basic steps. The first step is to create the initial urban layout with the help of the limitations that are used as urban design criteria in current urban planning practice. In the model, floor area ratio (FAR), number of the buildings, floor height, and setback distance of plot areas are defined as user-defined constraints. These constraints can be changed until the optimization process is started but cannot be changed during the optimization process. Building coverage ratio (BCR), Hmax, building locations on their plot areas, and the points on each side of the quadrilateral shape of the hypothetical urban area that generates base road lines are considered design parameters.

The second step is defining the algorithmic and mathematical definition of the SVF hemisphere. Consequently, the last step is to define two objectives of the optimization and begin the optimization process after defining whole design parameters, constraints, and SVF hemispheres that will be working simultaneously with each urban configuration.

3.2.1. Step 1: Initial Geometry Creation: Algorithmic Definition of Morphological Indicators

To create a generative model and to apply the model in real life, it has been tried to be constructed as adaptively as possible. The design parameters and the values assigned to these parameters are user-defined, so urban area (initial-boundary) size, road width, building coverage ratio, floor area ratio, and setback distances can be determined according to the characteristics of an urban area.

In this study, the road width, floor area ratio (FAR), setback distances and the number of the buildings to be located in the urban layout were accepted as constraints.



Morphological Inputs	Type	Number Type	Range/Number
Building Number	constraint	Integer	6
The Points of Road Lines	design parameter	Floating Point	0.20<x<1.00
Road Width	constraint	Integer	6
The Location of Buildings	design parameter	Floating Point	0.10<x<0.90
Floor Area Ratio (FAR)	constraint	Floating Point	3,50
Building Coverage Ratio (BCR)	design parameter	Floating Point	0.20<x<0.80
Setback Distances (Back Yard + Side Yard)	constraint	Integer	3
Floor Height	constraint	Integer	3

Table 3.1. The Values of Morphological Inputs Used in the Model

The morphological inputs (the design parameters of the model) that are going to shape urban form generations in this thesis are defined as it is seen in Table 3.1. The number of the buildings, the road width, the FAR, setback distances, and floor height are the constraints of this study. The values of these morphological inputs can be defined as any numerical value while constructing the generative model. However, the values assigned to these inputs cannot be changed during the optimization.

The morphological inputs defined as design parameters are the inputs that will cause the differentiation of the urban form generations at the end of the study. For the road network to change, the starting and ending points of the road lines can be swapped on the edge they are on. The location of the buildings and the building coverage ratio (BCR) area is also the design parameters (variables) of this model. These parameters are defined as changing between certain limits of the numerical values. The values assigned to these design parameters will constantly change during the optimization and contribute to the diversification of the urban form configurations.

The most important thing in the study is that the FAR is defined as a constraint and an initial input value to the initial geometry so that the total construction area can be calculated. And any change in the design parameters cannot change the total construction area. At the end of the study, the urban form alternatives will be formed by the parameters that change in the intervals defined in Table 3.1. Each urban form alternative will have the same total construction area.

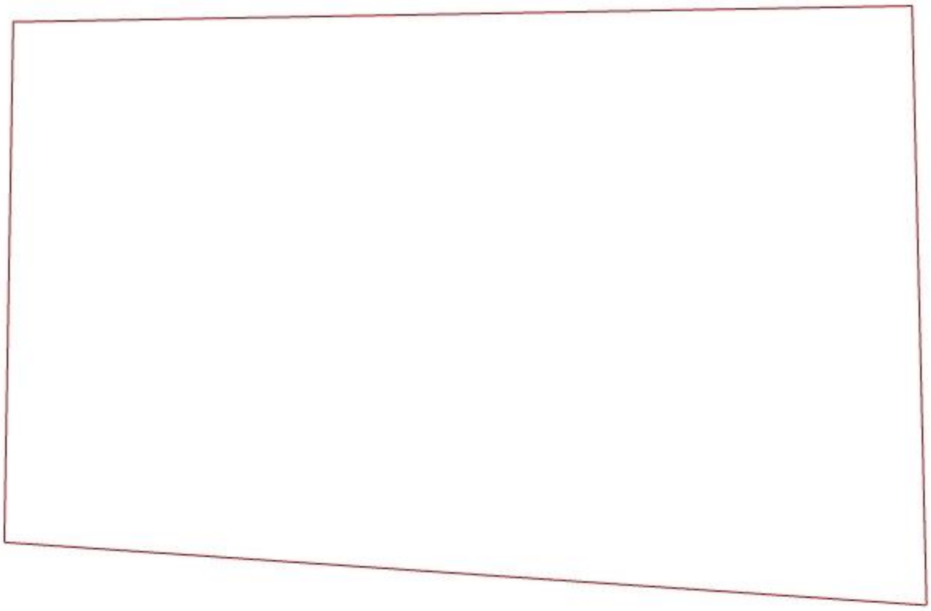


Figure 3.2. Initial Boundary Curve

The initial boundary curve is a closed curve for the representation of the boundaries of the urban area of the study. The boundary curve of the urban area is defined as a hypothetical area for the model to be adaptive easily on actual lands which have various geometries. However, the topography features are excluded from the scope of the thesis.

‘Curve’ component is used to create initial geometry. So that any urban area that has a quadrilateral shape can be applied in the context of this urban configuration model. ‘Curve’ component is also used to ease defining the urban area to the Grasshopper. The curve used as an initial boundary in the urban configuration model is representing a certain square meter (m2).

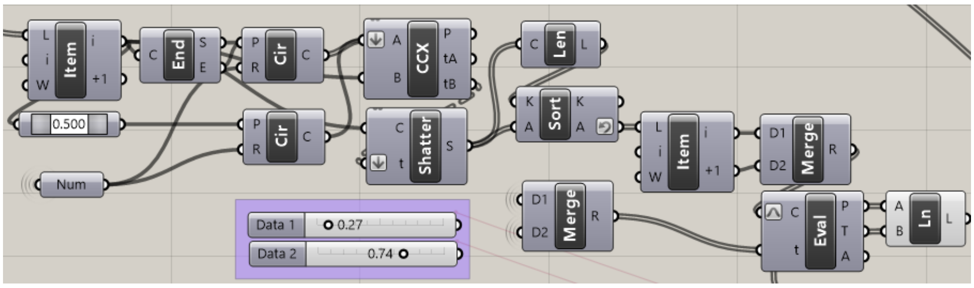


Figure 3.3. The Algorithmic Definition of the Road Axis

The grasshopper definition of the road lines between the buildings is shown in Figure 3.3. After defining the initial boundary of the urban area, it needs to be defined road lines for both the generation of plot areas and to locate the SVF hemispheres. First of all, with the help of the ‘End’ component, the corner points of the initial boundary are selected. After that, one point on each of the four sides of the boundary is randomly selected, and lines are created between those points. These lines will be the base of the road axis. In the following step of the model, the roads will be created with offset components.

After the initial curve is defined, the axes (road lines) where the SVF hemispheres will be located are defined. The start and endpoints of each road line to be created are defined on each edge of the initial geometry (urban area).

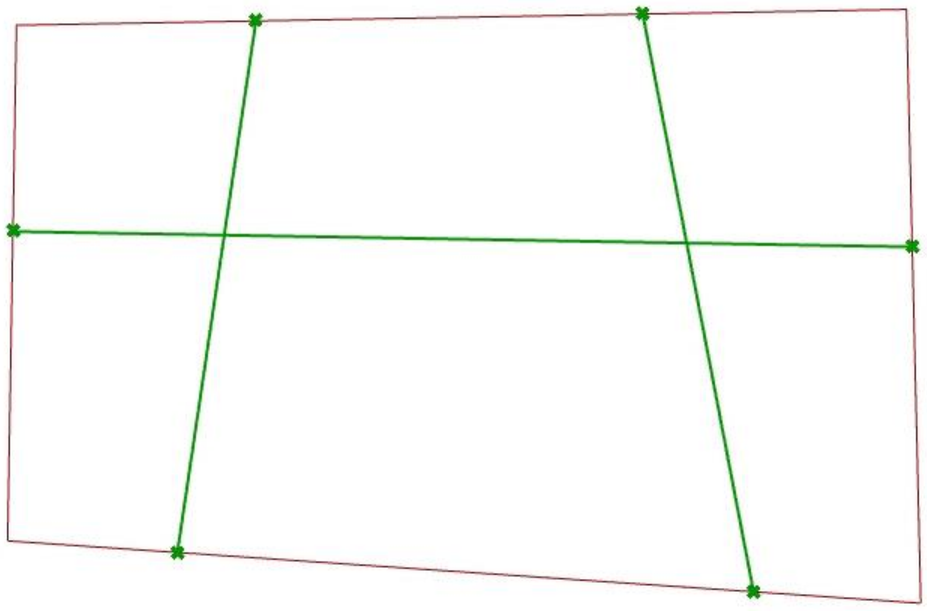
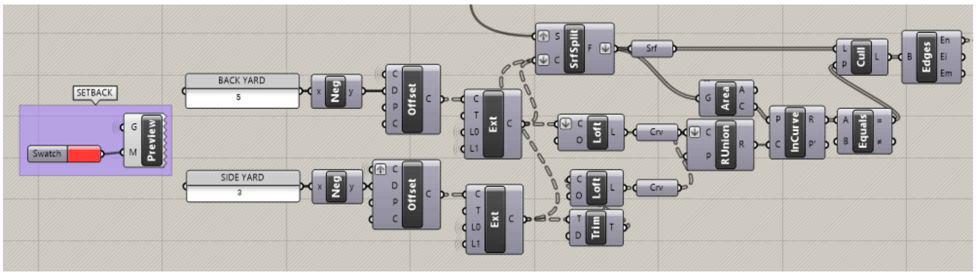


Figure 3.4. The Representation of the Road Lines on Rhino 3D

Since the number of buildings and plot areas will work simultaneously in the urban area, there have to be plot areas with the same number as the building has. Each area that remains between the defined road lines creates plot areas equal to the number of buildings defined in the beginning.

Since the plot area number and building number are constraints, their values cannot be changed during the optimization in the suggested urban configuration model.

After setting up the Grasshopper definition of the road lines, defining the setback distances is the following step.



BACK YARD
5

SIDE YARD
3

Figure 3.5. Algorithmic Definition of Setback Distances

In Figure 3.5., the setback distances of each plot area are defined in the algorithmic definition on the Grasshopper. In this model, the back yard and the side yard of each plot area are numerically defined as 5 meters and 3 meters. These number is defined initially in the model and cannot be changed during the optimization. But according to the characteristics of an urban area, planning regulations, or the design approach of the designer, these numbers can be set up with different numbers, before the start of the optimization process. After the definition of these distances, the plot areas will be created as in Figure 3.6.

Some sort of definition is defined in the model so that the buildings do not go out of their plot areas and approach the plot area boundaries at a certain rate. While the setback distances of each plot will be ensuring that the buildings don’t go out of their boundaries, they also allow the building to move freely within these setback boundaries.

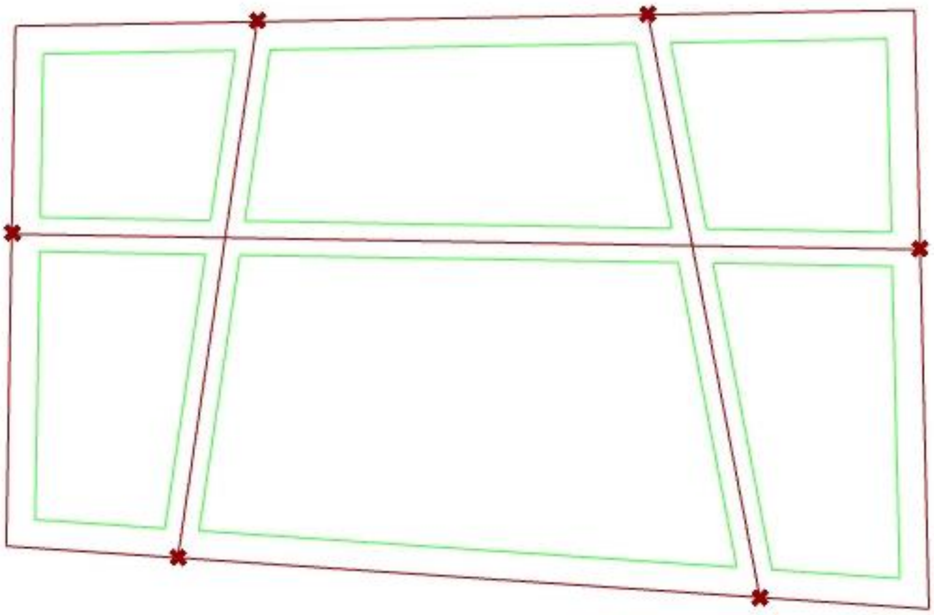


Figure 3.6. Boundary Curve, Road Lines, and Plot Areas on Rhino 3D

After the definition of setback distances, the location generator is defined for the displacements of the buildings, in the X and Y coordinates.

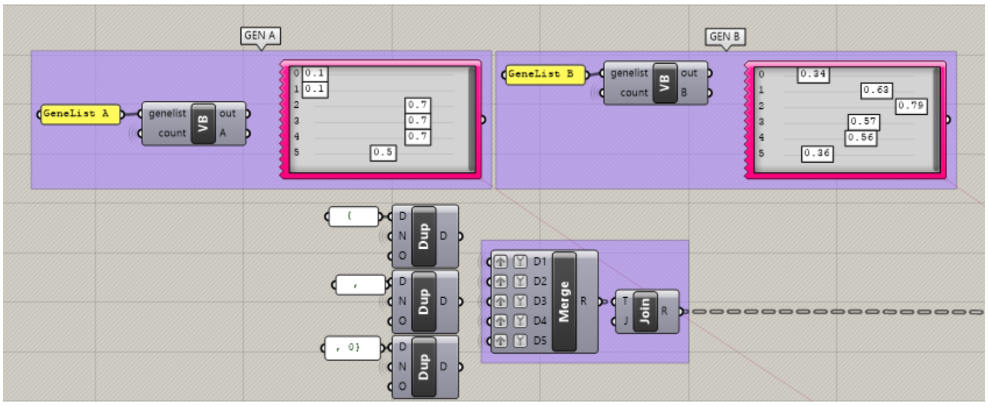


Figure 3.7. Building Location Generator

In Figure 3.7., to generate the locations of the buildings, the 'VB Script' component is used. The VB Script component is a simple component that allows the user a simple custom code. The building number is the input of the VB Script component. The outputs of the component can be seen in Gene Pool as a decimal number (between 0 and 1). These decimal numbers refer to the location of the buildings on their plot areas. Also, the locations are set up to not go out of their boundaries.

The location generator is one of the parameters that will be changed during the optimization, thus it will contribute to the diversity of urban forms. To change the buildings' locations, the process is carried out under the Location Generator section. Gene List A and Gene List B refer to U and V axes. The positions are defined to be numerically between 0 and 1. With the Gene Pool component, the designer can determine the Gene Count according to the building number, because the number of the Gene Count needs to be equal to the building number, and their ranges are between 0 and 1.

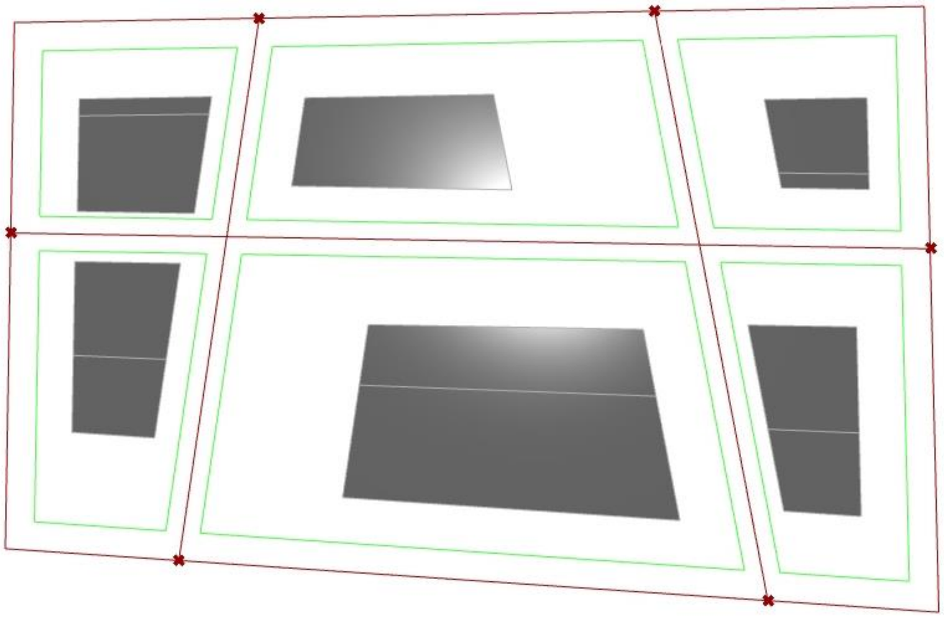
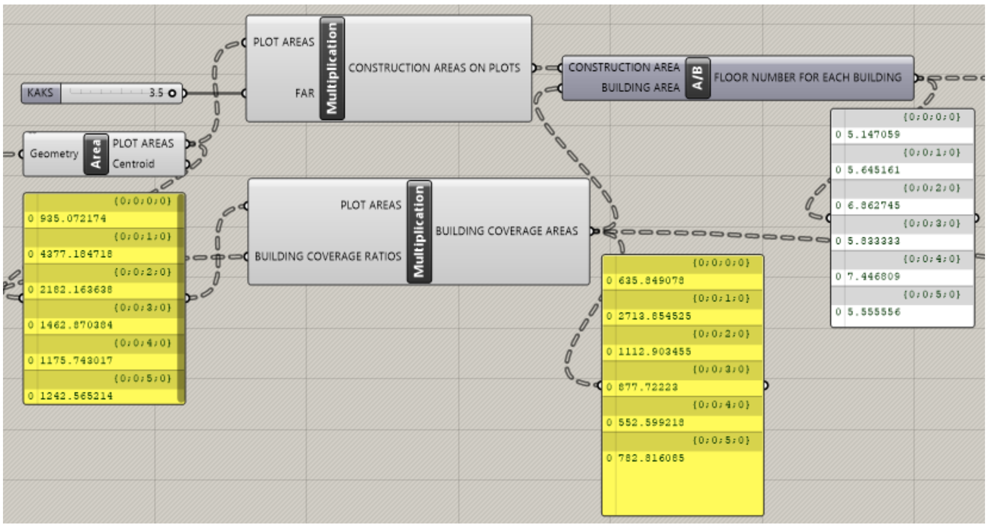


Figure 3.8. Top View of the Plot Areas, Road Lines, and Buildings

After defining setback distance, plot areas, and building locations, the Floor Area Ratio and Building Coverage Ratio (their mathematical definitions) are assigned to the Grasshopper definition. FAR is assigned to the initial boundary to calculate the total construction area that will be built within the boundary. BCR is assigned to each plot area to be able to differentiate the urban form configuration.



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0 5.555556
```

Figure 3.9. Mathematical Definition of FAR, BCR, and Floor Numbers

In Figure 3.9., it is simply explained a mathematical definition and calculation of FAR, BCR and floor numbers. According to the urban planning system in Turkey, the multiplication of FAR and the m^2 of the plot area gives the total construction area. So, each plot area of the buildings is selected and multiplied by the floor area ratio (the value of FAR; 3,5). Since the FAR is constant in this study, to diversify the urban configuration layouts, the BCR values are defined within a certain range. In the model, BCR values on each plot area are defined between 0.4 and 0.8. The multiplication of building coverage ratio and plot area gives the area of a building. So to meet the total construction area, the division of the total construction area into building coverage area gives the floor number.

There are two values defined in the 'Urban Master Plan' where the prediction of a population in the projection year is calculated. According to the population expected to come to the urban centers, the densities of urban settlements are decided by the FAR value. BCR, Hmax (height of the building), and setback distance are also defined in the 'Urban Master Plan' According to the planning regulations, these values are the values that restrict the location choices, geometries, and morphological characteristics of buildings in an urban area. However, as mentioned before, it becomes essential to provide a certain construction area according to calculations of the population projection.

To not reject the decisions taken in the ‘Urban Master Plan’, the FAR value is accepted as the main constraint of this study. It means that the values cannot be changed during the optimization or cannot define a range to this parameter. So, in the model, the total area is provided under all conditions and each urban form configuration.

On the other hand, to diversify the urban configuration forms, the BCR value is defined to change within a certain range while FAR is kept constant. While providing the total construction (floor) area, the change in the BCR value is changing the floor numbers simultaneously. While the building coverage of the building changes, the floor height will be changed simultaneously to meet the total construction area. In the model, there are calculated floor numbers such as 8.27 or 6.83. To avoid the non-integer floor numbers, the construction areas are calculated from these decimal parts of the numbers and added to the top of the buildings to meet the total construction area.

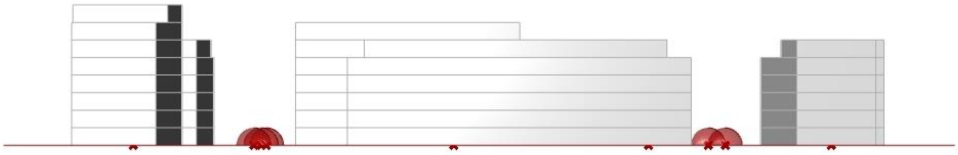


Figure 3.10. Front View of Buildings and SVF Hemispheres on Rhino 3D

As it can be seen in the figure above, with simple math, the lower the building coverage value, the higher the total floor height, and the higher the building coverage value, the lower the total floor height. To define this mathematical calculation to the grasshopper definition, Scale Generator is set up for each building area and the scale generator values determine the building coverage of the buildings. With decimal numbers varying between 0 and 1 on the X and Y axis, the building coverage of the buildings that will be occupied in their plot areas is calculated. Therefore, the floor heights change according to the calculation while FAR is constant.

3.2.2. Step 2: Algorithmic Definition of SVF Hemisphere

To assign the SVF hemisphere as test points, first of all, the road lines in which the hemispheres will be located have to be defined in the algorithmic definition. To calculate the SVF value, the rays must be sent from the center of the SVF Hemisphere to the building's top corner points. Therefore, the SVF Hemisphere needs to be located between buildings. Mid-points of the buildings are accepted as test points and the test points can be copied to any points on those lines.

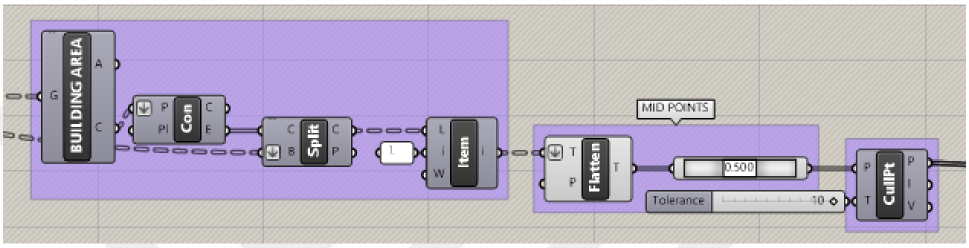


Figure 3.11. Definition of SVF Hemisphere and Test Points

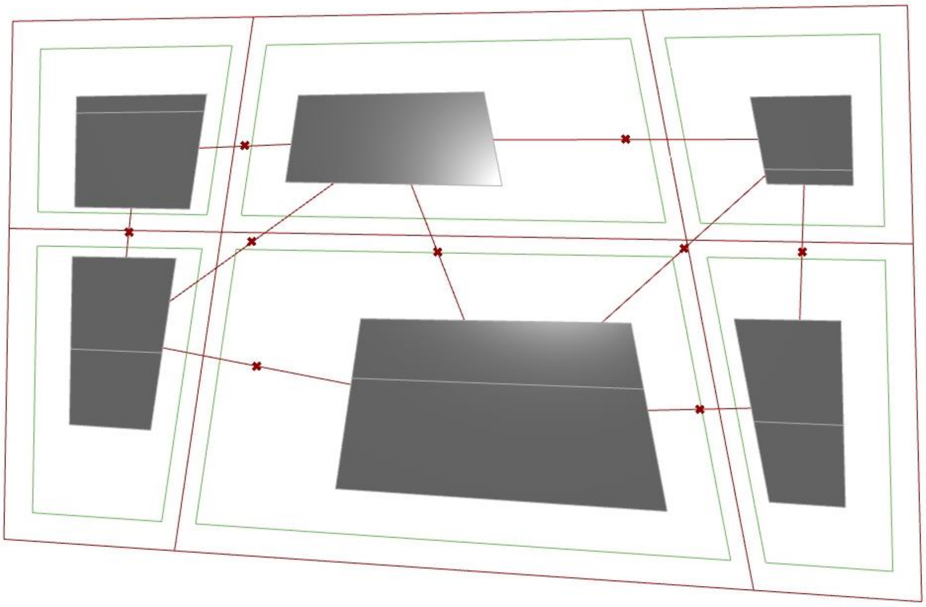


Figure 3.12. SVF Hemisphere Points on Rhino 3D

To restrict the optimization process, the parameters that are used in this study need to be restricted too. Therefore, in the generative urban form model, the SVF hemispheres are defined as to be as one hemisphere between every two buildings. However, it is a fact that if the hemisphere test points increase, the accuracy of the obtained SVF value will be more reliable too.

3.2.3. SVF Calculation: Mathematical Definition of Grasshopper

SVF is one of the most important geometric parameters that reveal the effect of urban geometry on urban heat island intensity. SVF value can be calculated from any point in an urban environment. SVF value changes between 0 and 1 when it’s equal to 1, which means the sky is completely visible and unobstructed.

There are 4 commonly known methods for calculating SVF value, and these methods are analytical, photographic methods (with fish-eye images), GIS and software methods (Chen et al., 2012).

Figure 3.13. Fisheye Images, Konya (Center), 2017 (Canan, 2017)

As it is seen on fisheye images, it is so easy to understand the logic of the SVF value calculation. Oke stated that SVF calculation, thus UHI (ΔTu−r(max)) calculation (Oke, 1987), as:

SVF0: 1 – (obstructed area / total area)

ΔTu−r(max): (15.27 – 13.88* ψ)

The SVF value is calculated over the hemisphere (Canan, 2017).

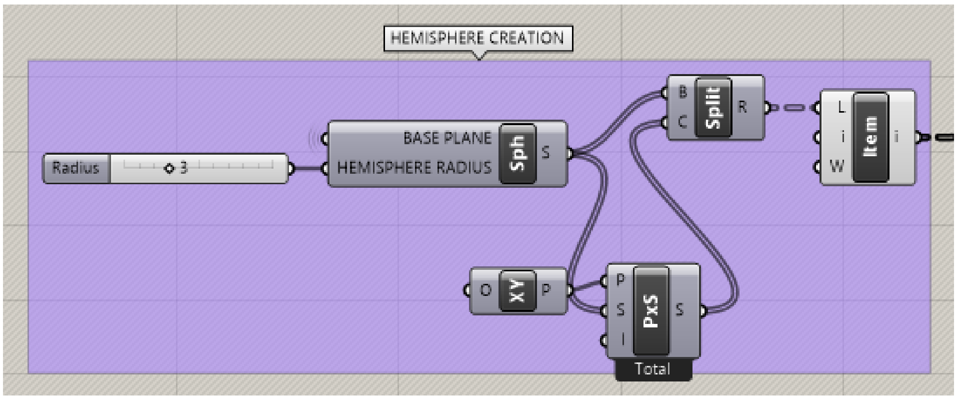


Figure 3.14. Sphere Component for SVF Hemisphere

The following step is defining the hemispheres between buildings. The SVF hemisphere is created with the 'Sphere' component and the radius of the component is adjusted to fit the width of the path where the hemisphere is located. In this study, the paths or the roads are considered pedestrian roads and are defined to be 6 meters, so the radius of the sphere is defined as 3 meters. If the model is to be applied to an existing urban area or an urban area that has any width, the radius needs to be defined as half of the road width. After this definition, the 'Split' component is used with the 'Sphere' component to create a hemisphere.

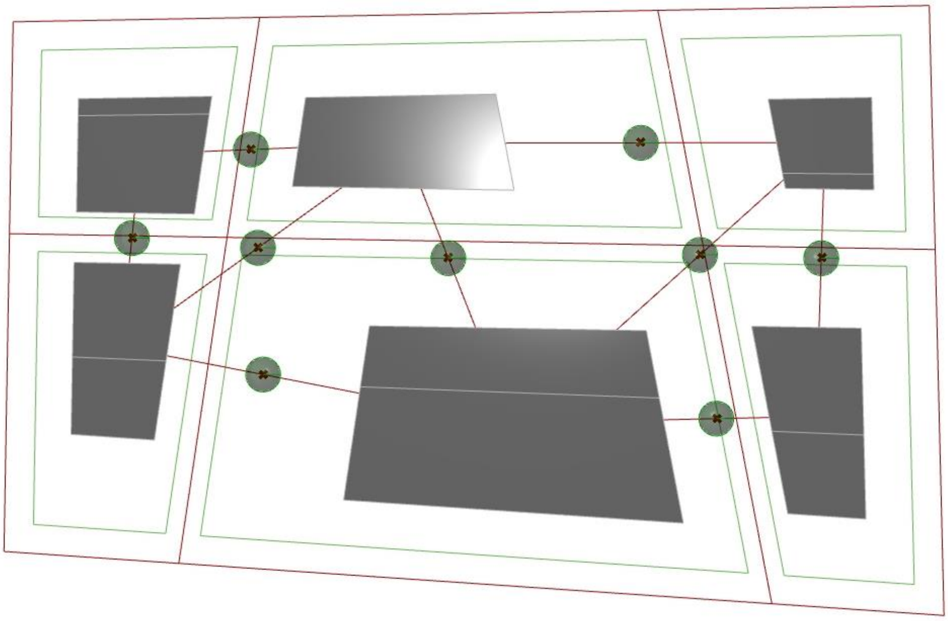


Figure 3.15. SVF Hemispheres on Rhino3D

The rays (in algorithmic definition: lines) are sent from the centers of the hemispheres placed between the buildings to the highest corner points of the buildings. After that, a fisheye image is formed as a result of the projection from the rays to the hemisphere, and thus the SVF value is easily calculated.

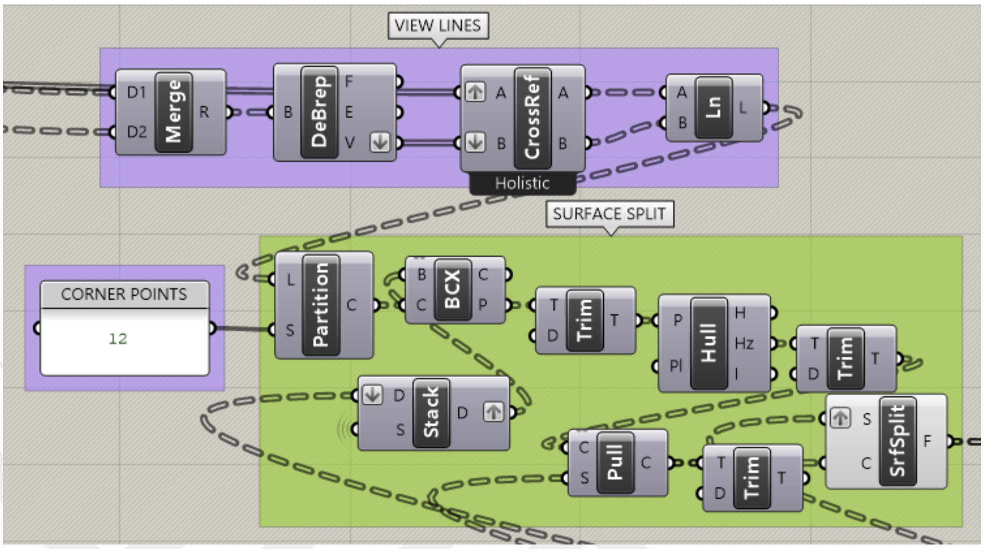


Figure 3.16. Algorithmic Definition of the Projection Lines and Creating Hemisphere

The 'Deconstruct Brep' component is used to deconstruct the building breps and create points where the rays touch the hemisphere surface. This component is also used for creating points on SVF hemisphere centers. After that, the help of the 'Cross Reference' component is used to create the projection lines.

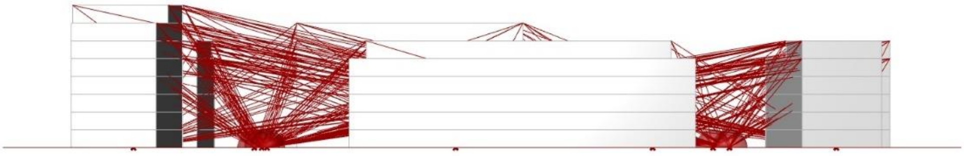


Figure 3.17. SVF Hemisphere Projection Lines on Rhino 3D

In the projection phase of the SVF extraction, a hemisphere is located in the center of the roads between buildings. The hemispheres that have 3 meters radius (half of the road width to fit the road) are centered on measurement points on the roads. After that, projection lines are generated between the top corner points of the buildings and the center of the hemispheres. To be able to detect obstructed and unobstructed areas, projection lines are reflected on SVF hemispheres' bases via the 'Projection' component. Thus, obstructed, and unobstructed areas are represented on the 2D flat circle.

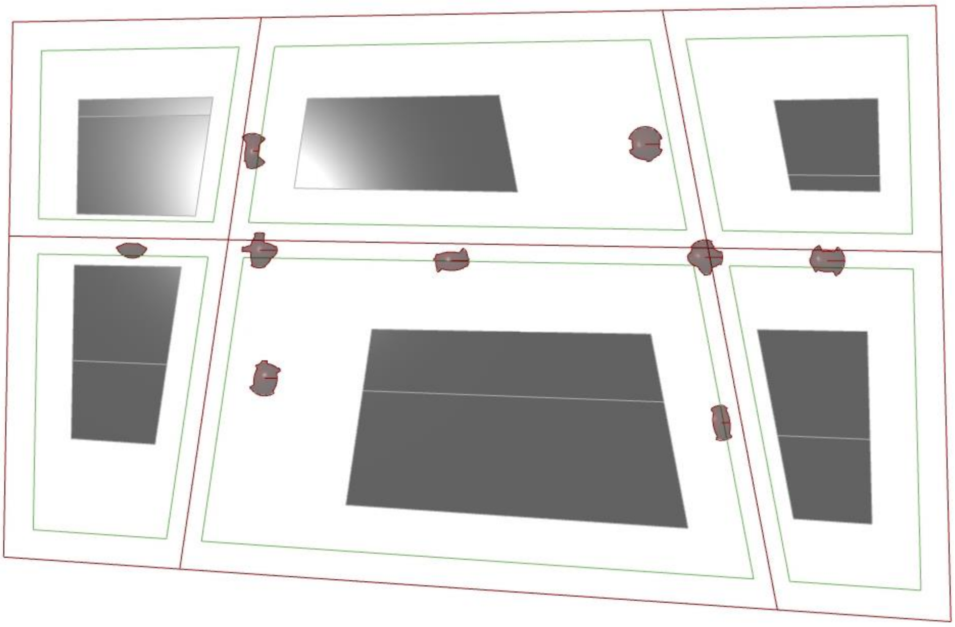


Figure 3.18. Top View of the Unobstructed Areas

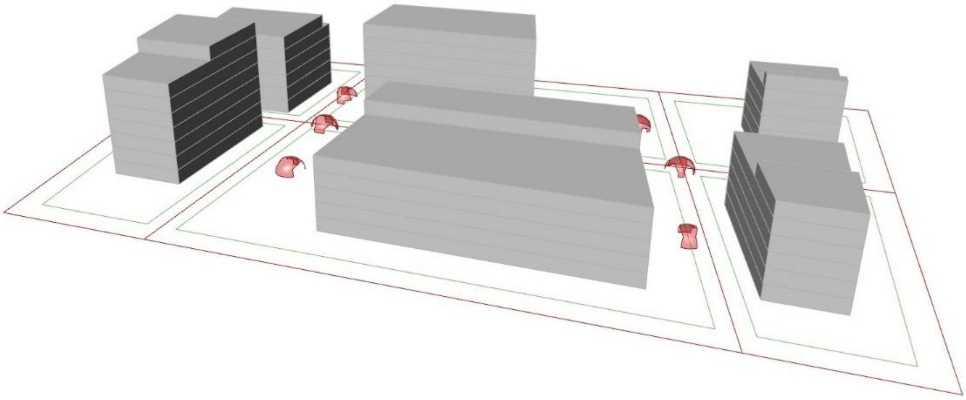
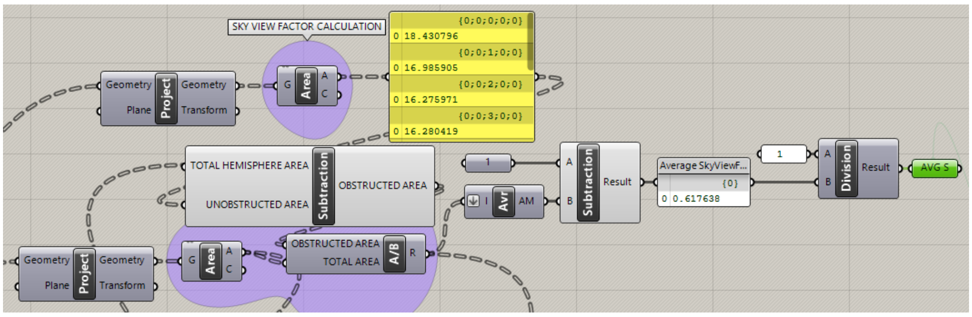


Figure 3.19. Perspective View of the Unobstructed Areas

The areas shaped in the hemisphere as a result of the projections of the rays sent from the hemisphere centers are defined as unobstructed areas. The area of the hemisphere is known since the hemisphere breps defined.

Since the radius of the hemisphere is 3, and π is a 3,14, the 2D flat circle's area will be 28,26 m^2 according to the area of the circle equation.

$$A = \pi r^2$$



```
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{0;0;1;0;0}
0 16.985905
{0;0;2;0;0}
0 16.275971
{0;0;3;0;0}
0 16.280419
```

```
Average SkyViewF...
{0}
0 0.617638
```

Figure 3.20. The Mathematical Definition of SVF value on Grasshopper

Since the area formed by the projection lines gives the unobstructed area, when the unobstructed area is subtracted from the entire circle area, the obstructed area is obtained. Therefore, the SVF value is obtained when dividing the obstructed area by the total area and subtracting it from 1.

SVF: 1 – (obstructed area / total area)

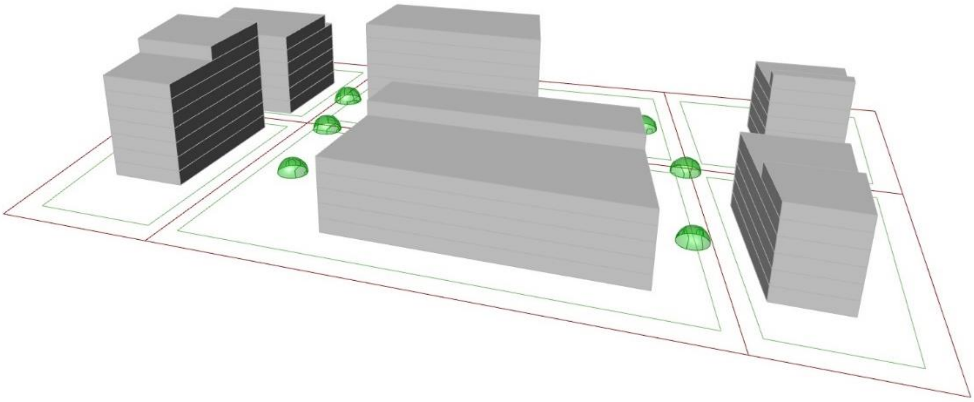


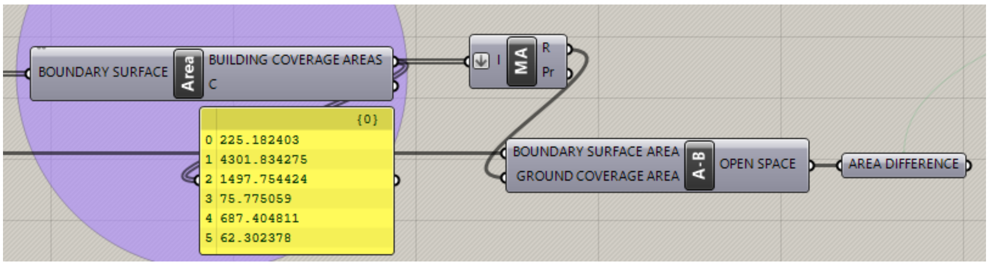
Figure 3.21. Perspective View of the SVF Hemispheres

3.2.4. Step 3: Design Objectives of the Model

As it is known, to be able to reduce UHI intensity and its effects, SVF needs to be maximized (close to 1). Since UHI intensity and SVF value act in contrast with each other, and UHI intensity value is calculated with SVF value, the two values cannot be taken as two objectives, cause in that scenario, the optimization obtains the results as a linear graph, which is not desirable. The result to be obtained at the end of the optimization needs to be a Pareto curve, therefore, a second objective must be found to maximize and evaluate SVF.

Many studies have been carried out on existing urban areas to reveal the inverse relationship between the sky view factor and urban heat island. The increase in building density is inevitable because it is necessary to meet the need for accommodation cause of the rise in the population density. According to the urban planning regulations in Turkey, it is almost impossible to achieve different urban configurations in urban morphology. FAR, BCR, and maximum building height are the three basic urban planning constraints that restrict urban planners and architects studying urban design. However, it is possible to bring a different perspective to urban planning and move away from traditional methods to a contemporary design approach.

Since the main aim of this study is to meet a total construction area, it is possible to gain different urban configurations just with the change in parameter values of urban design constraints.



```
{0}
0 225.182403
1 4301.834275
2 1497.754424
3 75.775059
4 687.404811
5 62.302378
```

Figure 3.22. The Calculation of Ground Open Space

In the study, the ground spaces except constructed areas are accepted as open areas, thus, in the optimization, the relationship between Sky View Factor and the difference between the total construction area calculated according to the BCR and the total construction area calculated according to the FAR on the urban layout.

3.3. Summary of the Chapter 3: Progress Steps of the Model

Briefly, in this part of the thesis, the steps are shown in Figure 3.1. The workflow of the Definition has been explained step by step. The urban configuration model of the study is based on the construct of an urban layout with constraints and design parameters, the mathematical and algorithmic definition of the SVF, and the optimization process. As mentioned earlier, the main aim of the study is to mitigate urban heat island intensity, and the SVF is one of the main factors that has been proved by the studies in literature in mitigating urban heat island intensity. Since the SVF is the factor that is shaped and calculated by urban geometry, the geometrical definition of the urban layout and the sky view factor are the main parts of the methodology of the thesis.

The definition of the morphological components of an urban area, and the SVF value which is shaped according to the changes in these morphological components are the first two steps of the workflow. The following step after these two geometrical definitions is the optimization process. The optimization process integrates these two geometrical definitions and reveals the relationship between them.

So, in the study, the important definitions that emphasize the originality of the thesis are;

Geometrical definition of the urban layout

Applying the mathematical calculation and algorithmic definition of the SVF to the geometrical definition of the urban layout.

CHAPTER 4

URBAN FORM CONFIGURATIONS AND OPTIMIZATION RESULTS

The implementation of the model proposal has been located in a hypothetical area and it’s aimed to reduce urban heat island intensity just with the morphological interventions applied on an urban scale. To reduce urban heat island intensity, there are lots of design cases on a building scale, but these morphological interventions of the study are constructed and developed in the scope of an urban scale. According to Jurelionis and Bouris, it is possible to see how urban heat island intensity differentiates according to different urban layouts and provides energy efficiency (Jurelionis & Bouris, 2016). This study focuses on the interventions applied on an urban scale to reduce urban heat island intensity in the very beginning of the design phase. and it’s because the design solutions applied on an urban scale and reduce the urban heat island intensity as much as it could be and following that applying density-reducing interventions on a building scale, such as façade design, building materials or HVAC systems, etc. would be more effective.

In this chapter, after defining the design parameters and constraints on the proposed urban configuration model, the optimization results, evaluations, and comparing the generations will be tried to be explained.

4.1. Optimization Results and Evaluating Generations

Since there are two objectives aimed at in the study, the optimization process is carried out with a multi-objective evolutionary algorithm. The name of the evolutionary algorithm, as it is understood, the algorithm has a self-developing and learning loop. To actualize the optimization, the Octopus plug-in is included in the Grasshopper. The Strength Pareto Algorithm (SPEA) is chosen during optimization which is a technique used to find Pareto optimal set for multi-objective optimization problems and it is defined within the Octopus plug-in with the ‘Octopus’ component. After all algorithmic definitions and the intervals of the parameters are set up, the model is ready to be started for multi-objective evolutionary optimization.

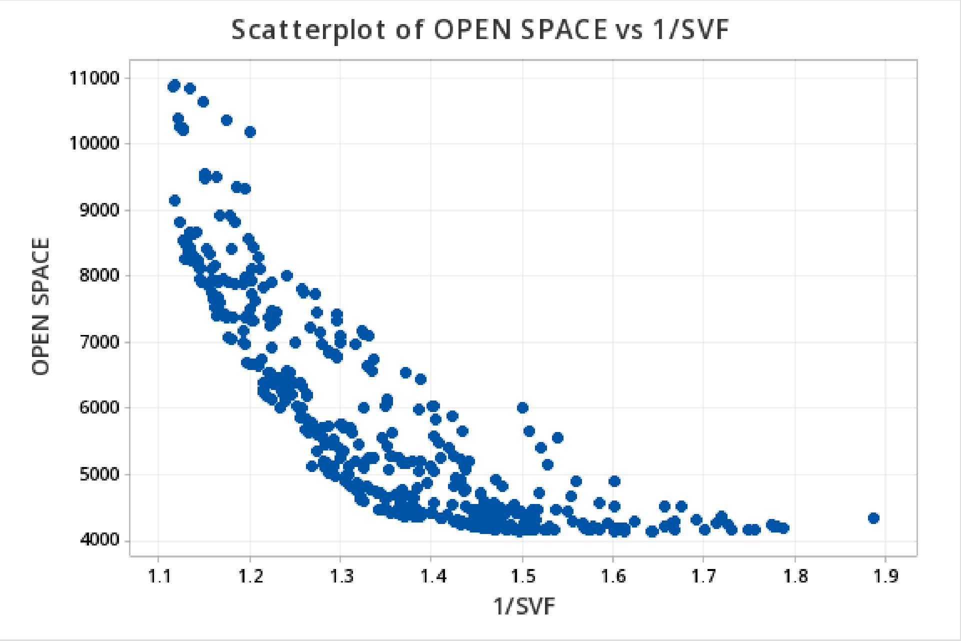


Figure 4.1. Pareto Chart at 110th Generation

The Pareto chart of urban form configurations at the 110th generation for 50 population size is given in Figure 4.1. above. At the end of the optimization process, the optimization algorithm discovered the 1/SVF value within a range between 1.11 and 1.88, and area difference (open space) within a range between 4353 m2 and 10866 m2. Since the optimization process works by reducing the objectives, but the aim is to increase the SVF value, the SVF value objective is defined by dividing it by 1. Thus, the SVF value is discovered within a range between 0.90 and 0.53.

In this graph, there are also shown that the generations are not included on the Pareto curve. The reason for showing these generations is to evaluate by comparing the situations where both generations have the same value on one of the two objectives but one of them is not included in the Pareto curve.

Where the SVF value has the highest value on the Pareto curve shown in Figure 4.2.

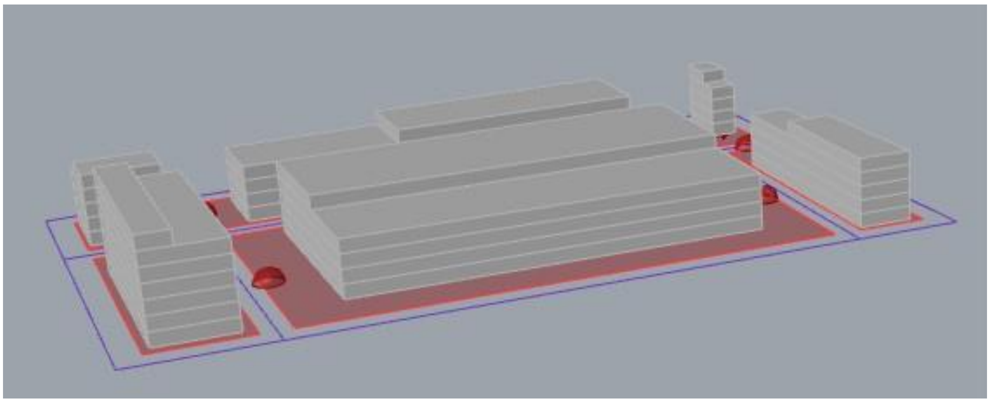


Figure 4.2. The Urban Configuration A with the Extreme Value

In the urban configuration in the figure above, the 1/SVF value is obtained at **1.71**, so the SVF value is **0.58**, and the open space is **4298 m2**. According to the urban heat island intensity equation, the UHI intensity value as a degree is **7,21°C**.

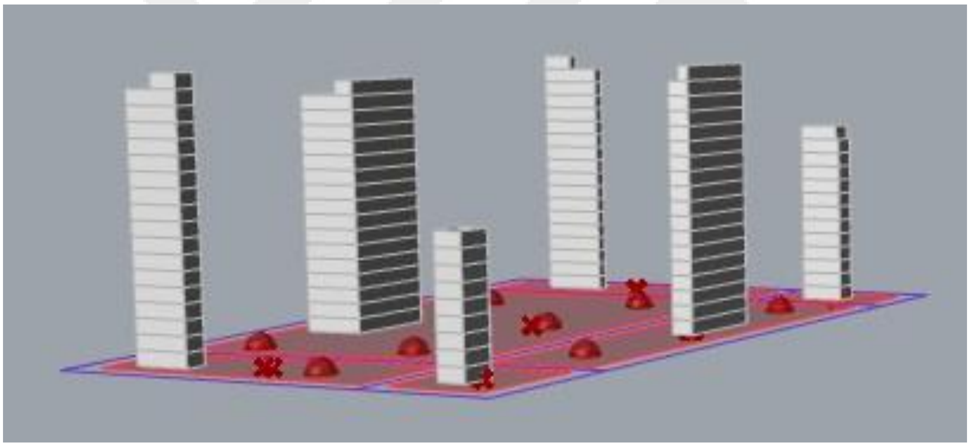


Figure 4.3. The Urban Configuration B with the Extreme Value

In the urban configuration in the figure above, the 1/SVF value is obtained at 1.11, so the SVF value is **0.89**, and the open space is **10,875 m2**. According to the urban heat island intensity equation, the UHI intensity value is obtained as **2,91°C.**

When these two configurations with their extreme values are compared to each other, the SVF value almost changes approximately by %50, and so is the open space. There is also a **4°C** temperature difference between the urban heat island intensities of the two configurations.

According to the optimization results that are evaluated according to the objectives, there is an almost 100% increase in the SVF values between the highest and the lowest. Since Yuan & Chen stated that averaged air temperature (Tmean) could be decreased by about 0.4° with only a 0.1 increase in Sky View Factor Value (Yuan & Chen, 2011), the change in the SVF values obtained at the end of the optimization process is quite remarkable.

Among the optimization results, the designer has a choice to select any urban form among all, according to the characteristics of urban forms that have been generated. Since the values assigned to the design parameters of the study are kept within a wide range for the differentiation of urban forms, there are some buildings are emerged in the urban forms with high-rise buildings with small floor areas. Therefore, these kind of urban form configurations that give undesirables results can be evaluated as the configurations excluded from the scope of the study.

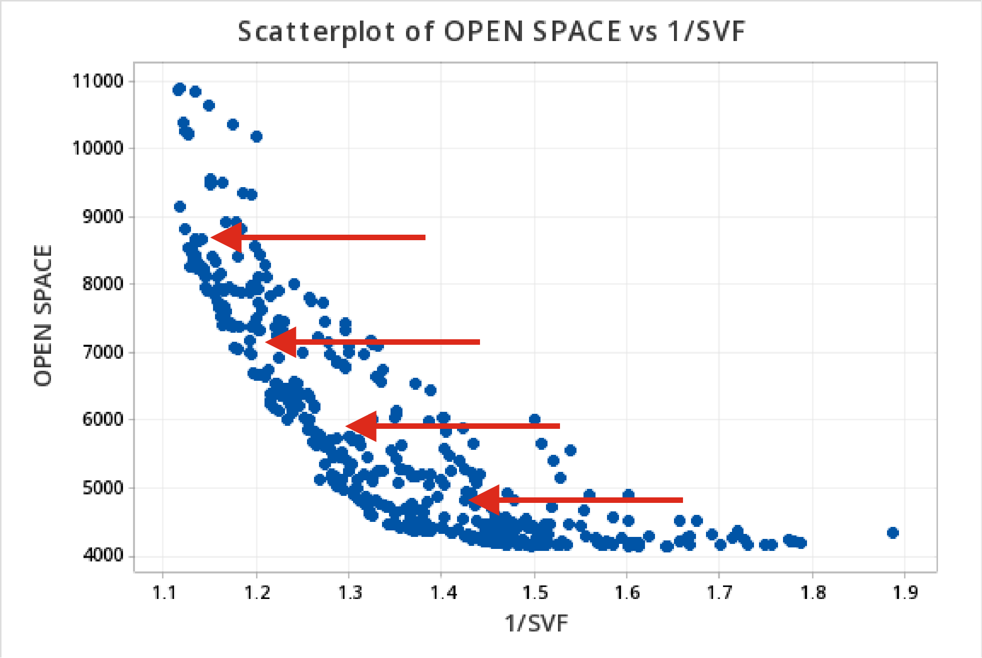


Figure 4.4. Selected Alternative Solutions Among All Generations

When the values on the red arrows on the X and Y axis are examined, it is seen that, in some cases, the same open space values are obtained with different SVF values, and the same SVF values are obtained with different open space values.

Besides, it is seen the crosses on the following figures. These crosses represent the locations of the SVF test points that are excluded from the SVF calculation. Since the midpoints of each two buildings are defined as the test points where the SVF hemispheres will be located, sometimes the SVF test points between the buildings overlap each other. When the two SVF test points overlap, one of them is excluded automatically from the calculation.

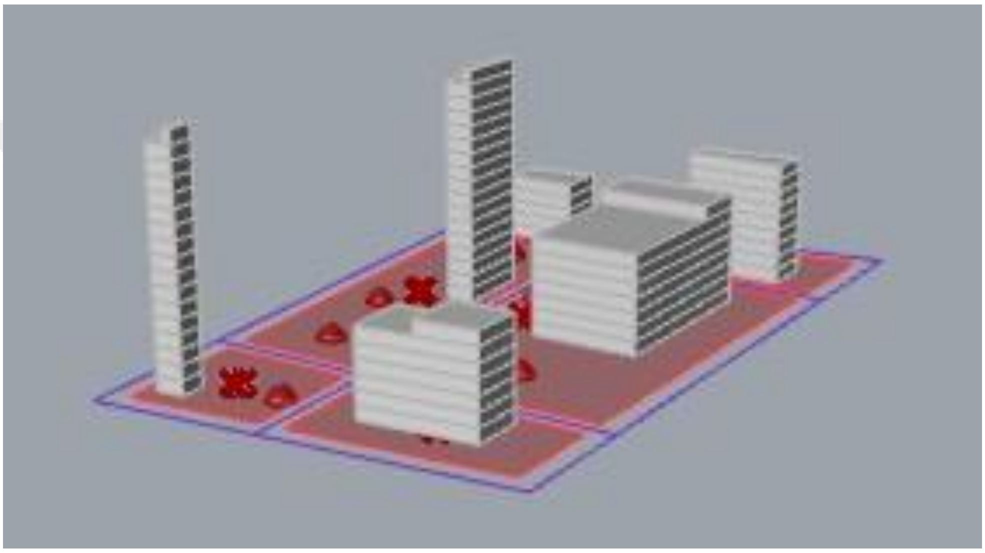


Figure 4.5. Alternative Urban Form Configuration 1

The 1/SVF is 1.31, the SVF value is **0.76** and the open space value is obtained at **8593** m2 as it is seen in the figure above. In this alternative urban form configuration, the buildings' coverage areas change within a range of 183 m2 and 2315 m2 (376m2-539 m2-618m2-650m2), floor heights of each building are changing within a range of 4 and 16 (4,6,7,8,16).

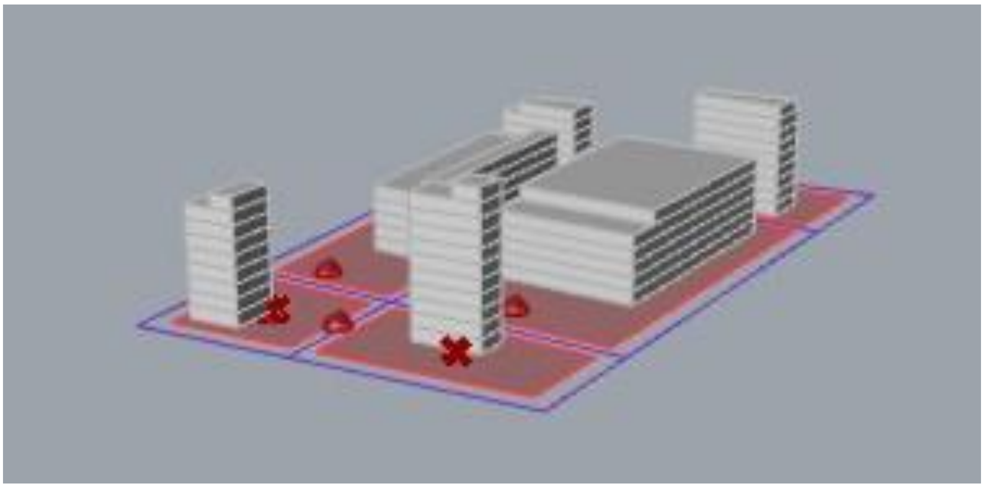


Figure 4.6. Alternative Urban Form Configuration 2

In Figure 4.4., the 1/SVF is 1.50, the SVF value is **0.66** and the open space value is obtained at **6721** m2. In this alternative urban form configuration, the buildings' coverage areas change within a range of 315 m2 and 3148 m2 (358m2-397m2-539 m2-1796m2), and floor heights of the buildings are changing within a range of 5 and 10 (5,8,10).

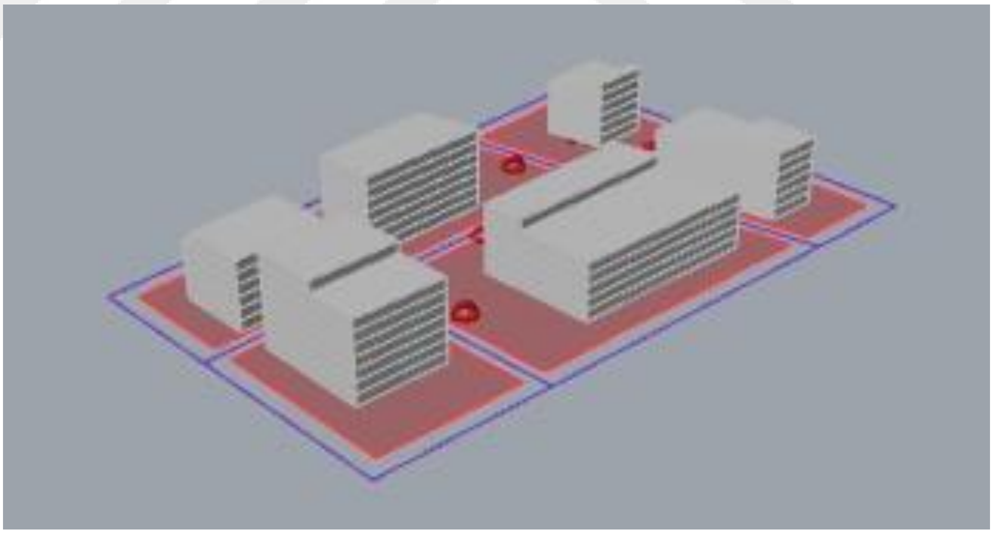


Figure 4.7. Alternative Urban Form Configuration 3

The 1/SVF is 1.56, the SVF value is **0.64** and the open space value is obtained at **6579** m2 as it is seen in Figure 4.5. In this alternative urban form configuration, the buildings' coverage areas change within a range of 552 m2 and 2271 m2 (706m2-877m2-1060m2-1128 m2), and the floor heights of each building are changing within a range of 5 and 7 (5,6,7).

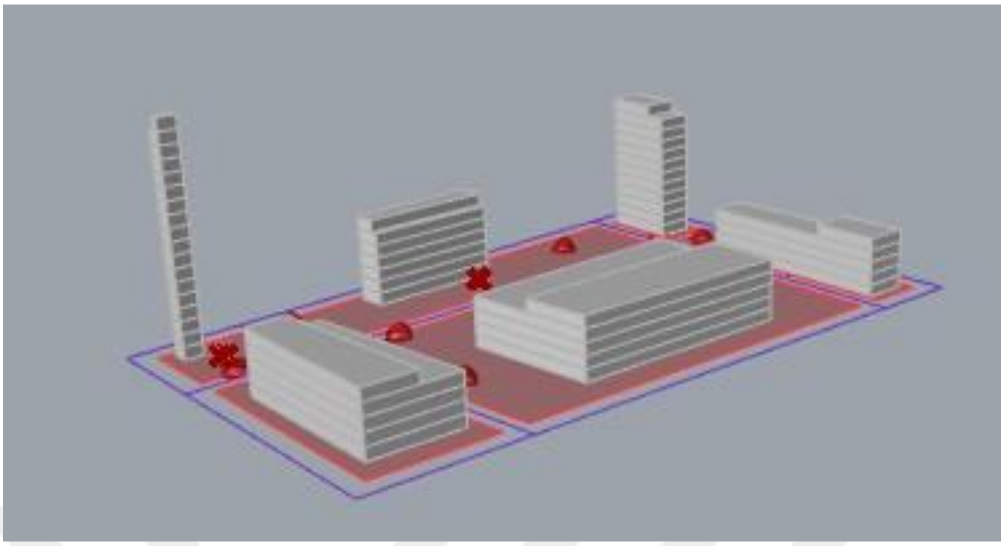
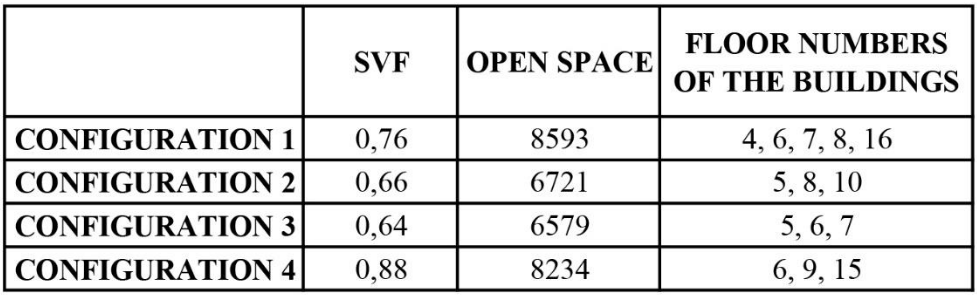


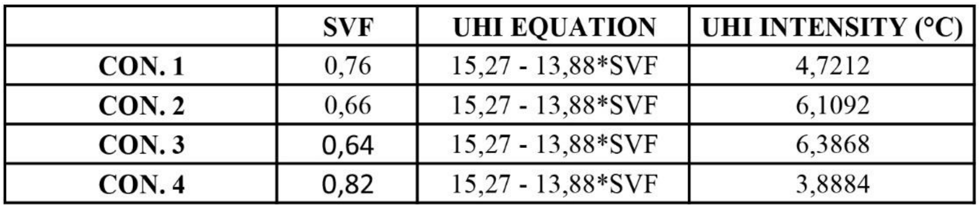
Figure 4.8. Alternative Urban Form Configuration 4

The 1/SVF is 1.13, the SVF value is **0.88** and the open space value is obtained at **8234** m2 in the scenario above. In this alternative urban form configuration, the buildings' coverage areas change within a range of 86 m2 and 3162 m2 (198m2-310m2-501m2-783m2), and the floor heights of each building are changing within a range of 4 and 16 (6,9,15).



	SVF	OPEN SPACE	FLOOR NUMBERS OF THE BUILDINGS
CONFIGURATION 1	0,76	8593	4, 6, 7, 8, 16
CONFIGURATION 2	0,66	6721	5, 8, 10
CONFIGURATION 3	0,64	6579	5, 6, 7
CONFIGURATION 4	0,88	8234	6, 9, 15

Table 4.1. Values of Design Variables and Objectives for Each Selected Urban Form Configuration

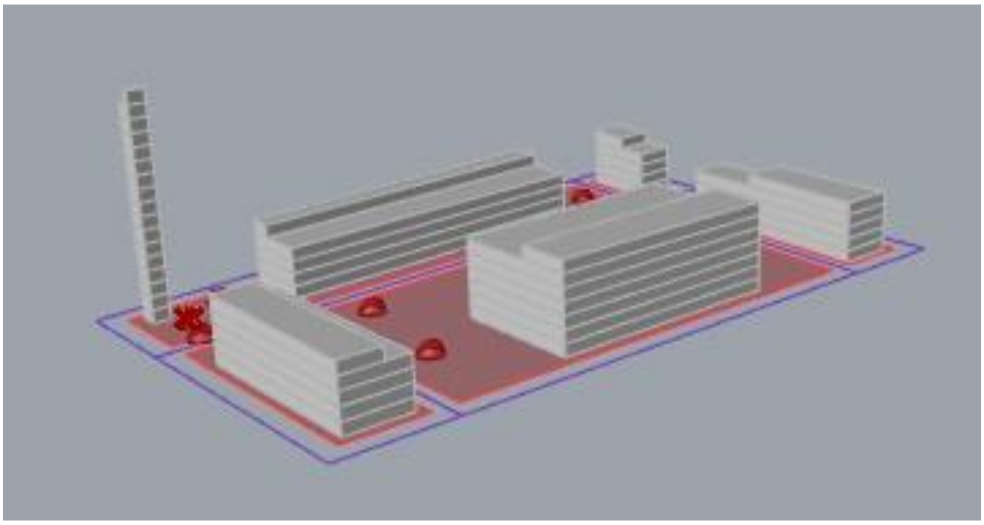


	SVF	UHI EQUATION	UHI INTENSITY (°C)
CON. 1	0,76	15,27 - 13,88*SVF	4,7212
CON. 2	0,66	15,27 - 13,88*SVF	6,1092
CON. 3	0,64	15,27 - 13,88*SVF	6,3868
CON. 4	0,82	15,27 - 13,88*SVF	3,8884

Table 4.2. Urban Heat Island Intensity Values According to the Each Selected Urban Form Configuration

According to the Oke’s formulation (Oke,1987) on UHI intensity, ΔTu−r(max): (15.27 – 13.88* ψ), as is seen in Table 4.2., with a %10 decrease in SVF value, it is observed that there is a %50 increase in urban heat island intensity. Therefore, even a small decrease in the SVF value is highly effective in the formation of urban heat islands and their intensity value. Since Yuan & Chen stated that averaged air temperature (Tmean) could be decreased by about 0.4° with only a 0.1 (%10) increase in Sky View Factor value (Yuan&Chen,2011), the change in the SVF values obtained at the end of the optimization process is quite remarkable.

The most important results faced at the end of the optimization are the urban configurations that have the same SVF with different open spaces, or the configurations which has the same open spaces with different SVF values.



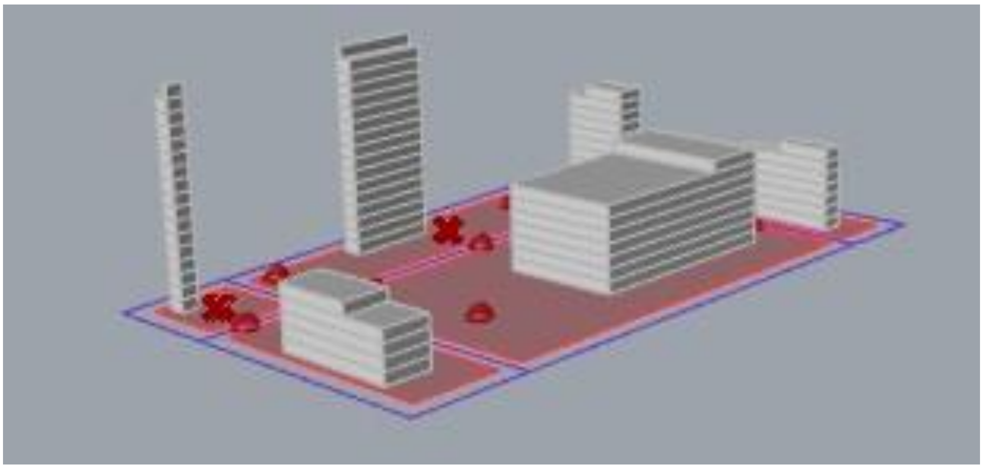
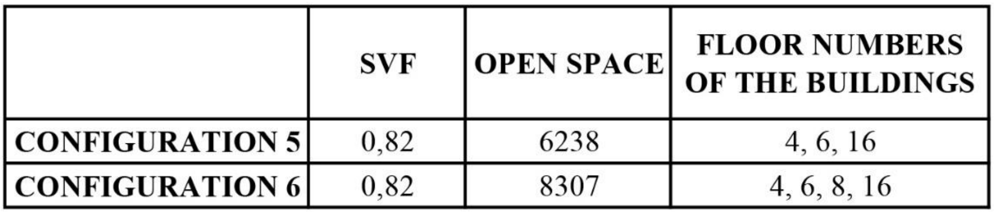


Figure 4.9. Alternative Urban Form Configuration 5 and 6 for Comparison (with Same SVF values)

In the **urban configuration model above**, 1/SVF is 1.21, the SVF value is **0.82** and the open space value is obtained at **6238** m2 Figure 3.27. above. In this alternative urban form configuration, the buildings' coverage areas change within a range of 78 m2 and 3395 m2 (270m2-750m2-872m2-1792m2), and floor heights change within a range of 4 and 16 (4,6,16).

In the **urban configuration below**, 1/SVF is 1.21, the SVF value is **0.82** and the open space value is obtained at **8307** m2 Figure 3.27. above. In this alternative urban form configuration, the buildings' coverage areas change within a range of 82 m2 and 3209 m2 (198m2-343m2-483m2-652m2), and the floor heights change within a range of 4 and 16 (4,6,8,16).



	SVF	OPEN SPACE	FLOOR NUMBERS OF THE BUILDINGS
CONFIGURATION 5	0,82	6238	4, 6, 16
CONFIGURATION 6	0,82	8307	4, 6, 8, 16

Table 4.3. The Values of Design Variables and Objectives for Urban Configuration 5 and 6

When the SVF value is equal to 1, the sky is completely visible. In this thesis, after the geometric components of the urban area are defined in the Grasshopper definition, the SVF value is calculated over a hemisphere. In the SVF value calculation in this thesis, only the buildings are included as the factor that obstructs the sky's visibility in the urban area.

The urban form alternatives and the values obtained from these different scenarios as a result of the optimization process are shown in Table 4.2. As it can be seen, the scenarios which have higher SVF values can be achieved by creating more open spaces in the urban area. Although it is thought that providing open spaces will automatically increase the SVF value, the challenge in this study is to obtain these high SVF values without reducing the total construction area. On the other hand, according to the values in Table 4.1., it is also possible to obtain a high SVF value when the open space is reduced.

The main aim of this study is to increase the value of the Sky View Factor. The SVF value is trying to be increased to minimize the urban heat island effects as much as possible. As mentioned in the second chapter of the thesis, many active and passive design strategies are handled at a building scale to reduce the urban heat island intensity.

Although this thesis focuses on the SVF value which is one of the most effective factors in the formation of the urban heat island intensity, there are many predominant factors in the urban area to increase this formation. Therefore, according to the urban form configurations obtained at the end of the optimization process, the alternative scenarios with the high SVF value and with the increased open spaces in the urban area are the best urban form configurations. Because, while achieving the same high SVF value with more open spaces, if other factors which affect the formation of urban heat islands are also taken into account, there will be more considerable results obtained in the name of reducing the UHI intensity.

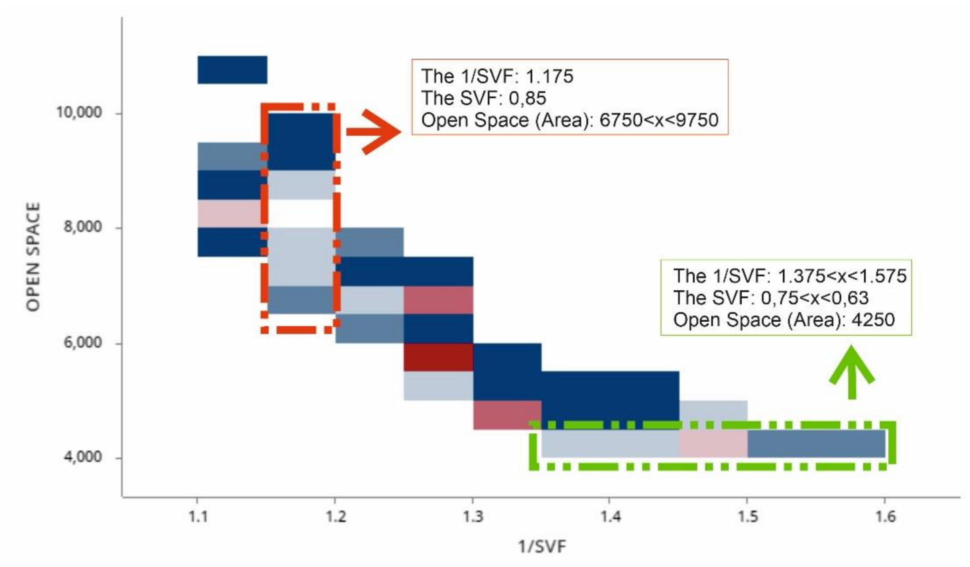


Figure 4.10. The Comparison: The Values of the Urban Form Configurations at 91st Generation

As can be seen in 4.8., there are shown some samples among the generations to gain a better understanding of the results with a comparison. The first sample group chosen among generations consist of the configurations where the SVF value is steady but the open space changes on the Y-Coordinate, and the second consist of the configurations where the open space is steady but the SVF value changes on the X-Coordinate.

This comparison shows that it is possible to generate various urban forms while ensuring that the total construction area always remains the same. It is also possible to increase the SVF value while keeping the open spaces with a constant value or to increase the open spaces while keeping the SVF with a constant value.

In another saying, this comparison shows that even though the open spaces to be provided within the boundaries of an urban area cannot be reduced or increased, there can the different SVF values still be obtained thanks to the computational model applied on the study. As a consequence, although there are certain constraints that make the decision-making during the design process challenging, the study provides the designer a design tool to guide their design approach with multiple design alternatives achieved.

4.2. Summary of the Chapter 4

In this chapter of the study, the optimization process and the results of the optimization are evaluated. The obvious outcome found as a result of the optimization process is realizing that there is a possibility/chance to reduce urban heat island intensity and avoid its effects with the changes on the morphological characteristic of an urban layout.

It is noteworthy that the change in urban heat island intensity is only achieved with the change in the morphological constraints and its parameters within a certain range of values. One of the main implications of this thesis is that it is impossible for any urban designer/architect to create multiple urban configurations in a very short time and to compare each urban configuration with each other.

The model developed within the frame of this thesis is based on finding the optimum urban configuration and the model is conducted on two main parameters, one of them is BCR (building coverage ratio) and SVF. Although the building locations and floor heights of the buildings change, the most important effect on the change of the SVF value is the building coverage ratio (BCR). Providing the same total construction area in each urban configuration with different building coverage areas and floor heights is the challenging part of the study. The BCR and SVF are optimized in the optimization process of the study. While achieving the maximum sky view factor value is the main aim of the study, it is also tried to find the optimum building coverage ratio while achieving this goal.

Due to the range of the values assigned to the design parameters for the diversification of urban configurations, there are obtained some configurations with buildings that have small building coverage areas which are not desirable. Therefore, these configurations are aimed not to be included within the scope of the study.

CHAPTER 5
CONCLUSIONS AND FUTURE RESEARCH

This study focuses on creating a computational design method that will be able to provide a sustainable perspective to urban planners and architects in the challenging design decision-making process. While aiming to improve the generative design approach, it has been tried not to ignore the design constraints used in urban planning regulations in Turkey. Also, the sky view factor which is one of the most important factors that is used to mitigate the urban heat island intensity is included in the study.

The relationship between the sky view factor and urban morphology has been demonstrated by the studies in the literature review. As a result of the decrease in the SVF value due to the building density in urban centers, there is an increase in the urban heat island intensity. Due to this cause-and-effect relation, to prove the accuracy of the relationship between them, the UHI intensity and SVF value calculations have been made on actual urban areas. However, it is important to generate urban design methods to solve the problem besides analyzing current urban situations.

It surely is possible to reduce the heat load on buildings and urban heat island intensity correspondingly with active or passive design strategies. Heating and cooling systems used in buildings, building materials, building form generations, façade design, and natural ventilation are some of the design strategies to reduce UHI intensity. However, as it should be due to the construction industry hierarchy, the architectural studies are carried out after urban planning decisions. Therefore, to increase the SVF value, it is important to search for design approaches. In this study, at the end of the optimization, there emerge multiple urban form configurations rather than a single urban configuration, and the configurations give clues about what would be the design constraints, their values, and the design approach. So, the study aims to deal with the main problems at the very beginning of the design process which cause the increase in SVF value and to detect what kind of interventions can be applied to gain effective design solutions. With that aim, the building-scale interventions can be supportive and can be more effective as an addition to planning regulations. The most important principle of the study is to be able to provide a comfortable designing environment for both architects and urban planners and increase the SVF value by using computational methods.

In this chapter, the objectives and the design constraints that are used in the generative model, and the effect of the computational design approach are discussed to contribute to future studies.

Research Question 1

Provided that FAR is constant, to what extent does SVF change according to the different configurations of buildings on an urban layout?

One of the most important challenges of this study is to keep the SVF value as possible as high by generating different urban form configurations while providing the total construction area required to be achieved with FAR in a defined urban geometry. Reducing the construction area or building density is a predictable solution to increase the Sky View Factor value. But because of the planning decisions taken in urban development plans, the need for a building density that has to be met due to the rising population and reducing the building density cannot be seen as a design solution.

Even though acting by the planning regulations and increasing the sky visibility by preserving the required total construction area calculated with FAR value without ignoring the decisions taken in urban development plans is hard while setting the algorithmic definition of the model, it is not beyond the realms of possibility. Additionally, defining the FAR value as a steady constraint caused the study to obtain reliable and reasonable urban form generations.

The main design parameters caused to generate various urban forms are building locations on their plot areas, building positionings among themselves, building coverage ratios, and floor numbers (thus building height) that act and change accordingly to building coverage areas.

As a result, with the help of the computational design approach and generative urban design, it is possible to gain urban configuration models by keeping SVF value high, just with the modifications and changes applied to building coverage areas and locations of the buildings.

Research Question 2

Is it possible to keep the SVF value as possible as high even though the open spaces in an urban area are decreased? Or is it possible to capture the same SVF value on different open space values?

When the generation results are examined, it is seen that alternative urban configuration results are obtained that give the same SVF value when the open space m2 decreases or increases. Likewise, alternative urban configuration results are obtained that give the same open space m2 when the SVF increases or decreases.

As mentioned earlier, urban heat island intensity is affected by many direct or indirect factors. In this study, the main aim is to reduce the urban heat island intensity (maximizing SVF) just with the urban modifications. Therefore, configurations that give the same open space with different SVF values, or configurations that give the same SVF value with different open spaces are the most important generations among all generation results. Thus, it is possible to keep the SVF constant and increase the open area, so that the open spaces can be used as green areas and help to reduce urban heat island effects more. Or, if the building coverage area that needs to be met according to the regulations by the municipalities or governments cannot be reduced, it is possible to increase the SVF value with the same open area. The challenging constraints of urban planning can make the design more flexible and useful with such urban configuration alternatives. These alternatives can both facilitate the workforce for the architects/urban designers and contribute to nature by reducing environmental impact.

5.1. Recommendations for Further Studies

There are some limitations within the context of the model which are worth mentioning in the name of contributing to future studies. One of the most challenging parts of the model was deciding the values of the intervals of the parameters. In the suggested model, there are tried to obtain different urban form configurations which will give always the same total construction area in a defined urban boundary. To obtain different urban form configurations with the same total construction area, it was necessary to define the design parameters in the model that affects urban morphology such as setback distance, building coverage ratio, the locations of the buildings, and the locations of the road lines. Since the intervals of each design parameter will affect the urban form configuration diversity and the optimization time, these values had to be kept within a certain limit. Besides, if the intervals are left uncontrollable and unlimited, the optimization process will turn into a complicated and time-consuming process. The computational design of the model has a self-sustaining and evolving process while generating multiple urban forms that vary according to each parameter value.

As mentioned earlier, the ranges defined in the parameters of the study are important. To adapt the model to the real world, there must be proper urban configurations generated. In this study, there are observed that some urban configurations with buildings which has a floor area (building coverage) of about 86m2. To avoid these kinds of urban configurations, the values defined in the design parameters of the study need to be determined carefully.

Another limitation in the scope of this thesis is topography. The model can only be applied in urban areas which have a flat topography. Also, the model can be adapted to any urban area with four edges, but if the urban area has more than four edges, the model may not be working properly. While solving this problem, the road network should also be well established.

Apart from the limitations mentioned above, this thesis firstly aims to reduce the urban heat island intensity as much as it can be reduced at the urban scale.

Furthermore, as mentioned before, the SVF is the main factor that is evaluated in the scope of this thesis, but there are also many factors that are highly effective in the formation of urban heat island intensity. Some of them are building materials, building typology, building facades, meteorological conditions, cooling systems, and vegetation are excluded from this research.

The interventions that will be applied to those factors and the studies carried out at a building scale to reduce or prevent the urban heat island intensity will be additional interventions on an urban scale.

Consequently, many factors that increase the urban heat island intensity, it is quite difficult to consider and evaluate each influential factor in one study. Since this study focuses on morphological features in an urban area, the building orientation and topographical features which are excluded from the framework of the study can be improved in further studies.

In addition to all these, it is thought that the computational design method developed within the scope of the thesis will guide the urban designers or architects at the beginning of the design phase. In the design phases where the many design decisions are taken together, these processes can be very challenging. In this sense, both saving time for the designer and providing an environment for comparison and evaluation by seeing many design alternatives together are the main contributions of this study. One of the significant contributions of the study is also to integrate the urban planning practices into the parametric modeling environment. This integration is aimed to provide urban planners and architects with an advantageous urban design approach in bringing about many solutions/cases.

Most importantly, there are two contributions of the thesis that brings fresh motivation and a design approach to this field of research. One of them is the geometrical definition of the urban layout. While constructing the urban layout, the features that have to be considered according to the urban planning regulations in Turkey are included in the parametric modeling. In addition, while defining the mathematical calculation of the parameters and constraints used in urban planning in Turkey, it is ensured that each sample to be generated gives the same total construction area. The other contribution of the study is setting up an algorithmic definition of the SVF and its mathematical calculation.

In the computational design approach of the study, the building coverage ratio, the locations of the road lines, and the locations of the buildings on their plot area are the variables of the model. These morphological features are aimed to be applied to the computational model to mitigate urban heat island intensity only with providing to differentiate urban forms. But, for further studies, to make the model more effective in reducing urban heat island intensity, building orientation, topographical features of the urban area and the building materials should also be considered in the scope of the study.

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APPENDIX 1

OPEN SPACE	1/SVF	SVF	UHI
5192,564158	1,283862	0,7789	4,458868
4165,440192	1,507954	0,66315	6,065478
6691,689567	1,197279	0,835227	3,67704924
4389,678823	1,381626	0,723785	5,2238642
7857,83212	1,15392	0,866611	3,24143932
5641,494843	1,265993	0,789894	4,30627128
4234,038024	1,447065	0,691054	5,67817048
6671,67078	1,200575	0,832934	3,70887608
8229,331327	1,139696	0,877427	3,09131324
4843,118011	1,310441	0,763102	4,67814424
5696,898391	1,262298	0,792206	4,27418072
5011,031602	1,307766	0,764663	4,65647756
6194,85763	1,219683	0,819885	3,8899962
4210,733837	1,455733	0,686939	5,73528668
4742,968199	1,340351	0,746073	4,91450676
8460,662393	1,131195	0,884021	2,99978852
8542,364653	1,12756	0,886871	2,96023052
7958,903794	1,145217	0,873197	3,15002564
4620,154316	1,34957	0,740977	4,98523924
6654,537064	1,209383	0,826868	3,79307216
4344,985432	1,412056	0,708187	5,44036444
6110,849505	1,239913	0,806508	4,07566896
5994,960944	1,255789	0,796312	4,21718944
4385,962968	1,383208	0,722957	5,23535684
4482,291213	1,372151	0,728783	5,15449196
4163,795917	1,585399	0,630756	6,51510672
4783,605732	1,316082	0,759831	4,72354572
9136,248125	1,11809	0,894382	2,85597784
7650,720756	1,159379	0,862531	3,29806972
4168,902229	1,49084	0,670763	5,95980956

4191,145505	1,469117	0,680681	5,82214772
7046,217199	1,180233	0,84729	3,5096148
9157,362701	1,118023	0,894436	2,85522832
4178,400331	1,48327	0,674186	5,91229832
4998,46587	1,309019	0,763931	4,66663772
4505,573102	1,364266	0,732995	5,0960294
4275,072872	1,434508	0,697103	5,59421036
7413,704476	1,170718	0,854177	3,41402324
8395,265702	1,133372	0,882323	3,02335676
5221,404319	1,282354	0,779816	4,44615392
10875,28574	1,11719	0,895103	2,84597036
6966,292399	1,194966	0,836844	3,65460528
7529,297363	1,161996	0,860588	3,32503856
5134,775855	1,288882	0,775866	4,50097992
6034,273304	1,251701	0,798913	4,18108756
6671,67078	1,200575	0,832934	3,70887608
5624,201691	1,275224	0,784176	4,38563712
8297,40127	1,137376	0,879217	3,06646804
7075,594553	1,177239	0,849445	3,4797034
5586,139839	1,279273	0,781694	4,42008728
8816,201728	1,184426	0,844291	3,55124092
5759,224425	1,302324	0,767858	4,61213096
5250,60052	1,411329	0,708552	5,43529824
7004,160089	1,250613	0,799608	4,17144096
9540,921225	1,150496	0,86919	3,2056428
9466,532064	1,151815	0,868195	3,2194534
5285,848872	1,357747	0,736514	5,04718568
6859,929646	1,287344	0,776793	4,48811316
4562,36788	1,492274	0,670118	5,96876216
4569,062316	1,469752	0,680387	5,82622844
4604,934184	1,458066	0,68584	5,7505408
4943,937222	1,432659	0,698003	5,58171836
7451,316277	1,229701	0,813206	3,98270072
6885,365003	1,287121	0,776928	4,48623936
4477,307917	1,537319	0,650483	6,24129596

5767,684788	1,299218	0,769694	4,58664728
8909,791087	1,166834	0,85702	3,3745624
6773,175841	1,296047	0,771577	4,56051124
4466,11863	1,55058	0,64492	6,3185104
6834,770756	1,294428	0,772542	4,54711704
7929,112498	1,201695	0,832158	3,71964696
6969,688489	1,280324	0,781052	4,42899824
7905,774107	1,224905	0,81639	3,9385068
8578,574399	1,199141	0,83393	3,6950516