ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

IMPLEMENTATION OF MULTI-OBJECTIVE GENETIC ALGORITHMS FOR OPTIMIZATION OF SITE LAYOUT PLANNING : TOKI AYAZMA AND ŞAHİNBEY CASES

M.Sc. THESIS

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<u>ISTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ</u>

YERLEŞİM PLANLAMA OPTİMİZASYONUNDA ÇOK HEDEFLİ GENETİK ALGORİTMA UYGULAMALARI: TOKI AYAZMA VE ŞAHİNBEY

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Nilüfer YÜKSEL, a M.Sc. student of ITU Graduate School of Science Engineering and Technology student ID 523171008, successfully defended the thesis/dissertation entitled "IMPLEMENTATION OF MULTI-OBJECTIVE GENETIC ALGORITHM FOR OPTIMIZATION OF SITE LAYOUT PLANNING : TOKI AYAZMA AND ŞAHİNBEY CASES", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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To my family,

FOREWORD

I would like to express my gratitude to my supervisor Assoc. Prof. Dr. Sema ALAÇAM for the useful comments, remarks and always positive approach through all processes of this master thesis.

I also would like to thank my family for their support throughout the entire process of my master's study.

June 2020

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(Architect)

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ABBREVIATIONS

GA	**:** Genetic Algorithms
SOGA	**:** Single Objective Genetic Algorithm
MOGA	**:** Multi Objective Genetic Algorithm
EPW	**:** Energy Plus Weather

SYMBOLS

W/M²	**:** Watts per Square Meter
M	**:** Meter
M²	**:** Square meter

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IMPLEMENTATION OF MULTI-OBJECTIVE GENETIC ALGORITHMS FOR OPTIMIZATION OF SITE LAYOUT PLANNING : TOKI AYAZMA AND ŞAHİNBEY CASES

SUMMARY

Design decisions taken in the early stages of design play an important role in economizing energy consumption in residential buildings. The placement of blocks in site layout planning is one of these factors to reduce energy consumption. There are several criteria for the blocks settlement in site layout planning in residential buildings. In this study, two parameters were selected for placement of blocks in site layout planning. The first one is solar radiation which plays an important role in electric lighting savings and heating inside buildings during the winter semester. The latter one is the shadow which affects solar access for buildings. In the scope of this study, an optimization abilities of Genetic Algorithm are applied for solving site layout planning problems in the early stage designs.

In the second chapter, Genetic Algorithm based design optimization approaches in site layout planning are examined under a four-fold taxonomy in this study; (1) change in time; (2) shape representation; (3) dimension of shape; (4) site layout. Later on, examples are given for studies of GA in site layout planning by mentioned factors.

In the third chapter, Genetic Algorithm have been reviewed as a method for solving optimization problems in various fields of science. The subject of working mechanisms and elements of Genetic Algorithm such as fitness function, selection, population, search space, crossover, and mutation are explained in this chapter.

In the fourth chapter, an experiment model is defined for two Genetic Algorithm optimization methods such as single-objective and multi-objective in Rhinoceros/Grasshopper CAD modeling environment. In this part of the study, two parameters that affect Genetic algorithm performance for blocks settlement in site layout planning such as solar radiation and shadow are examined. Solar radiation and shadow are calculated in Ladybug plugin in Grasshopper. The main purpose of this thesis is to maximize solar radiation and minimize shadow areas on vertical surfaces of blocks. In addition, movement and rotation are defined as two variable factors for optimization of blocks settlement.

In the fifth chapter, two house projects of TOKI (Mass Housing Development Administration) are selected for optimization. TOKI is one of the public housing development institutions in Turkey which, affordable enough to buy for low and middle-income target groups. The main reason for choosing TOKI's projects as case studies is that similar block types in different locations and climates.

In the last chapter, by analyzing the result of optimization of TOKI projects with parameters and variable factors , which kind of research could be developed to improve optimization methods for future research are discussed.

YERLEŞİM PLANLAMA OPTİMİZASYONUNDA ÇOK HEDEFLİ GENETİK ALGORİTMA UYGULAMALARIş TOKİ AYAZMA VE BAŞAKŞEHİR

ÖZET

Tasarımın erken aşamalarında alınan tasarım kararları, konutlarda enerji tüketiminin tasarrufunda önemli rol oynamaktadır. Toplu konutlar özelinde tasarımın erken aşamalarında alınan kararlardan birisi de yerleşim planına ilişkindir. Vaziyet planı oluşturulurken yönetmelikler, kullanıcı beklentileri, konut tipolojisi, arazinin eğimi, projenin bütçesi gibi çok sayıda fiziksel, sosyal ve ekonomik faktör etki edebilmektedir. Ancak bu tez kapsamında toplu konutların yerleşim planı kararları aşamasında iklim koşullarının değerlendirilmesine odaklanılmaktadır. Toplu konut yerleşim planı kararlarında, konutların kullanım aşamasında enerji tüketimlerini azaltabilmek amacıyla iki iklim parametresi seçilmiştir. Birinci iklim parametresi, binalarda elektrik, aydınlatma tasarrufu ve aynı zamanda kış döneminde ısıtmada önemli rol oynayan güneş radyasyonudur. Binalara güneş erişimini etkileyen gölge ise ikinci parametredir. Bu tez çalışmasında, T.C. Başbakanlık Toplu Konut İdaresi (TOKİ) tarafından üretilmiş olan Toki Ayazma ve Toki Şahinbey toplu konut uygulamalarını, vaziyet plan yerleşmelerini enerji tuketimine gore değerlendirip ve aynı zamanda optimize etmektedir.

Tezin ikinci bölümünde, Genetik Algoritmalar kullanılarak vaziyet yerleşim planlamasının optimizasyonuna odaklanan bir literatür araştırması sunulmaktadır. Literatür araştırması dört temel başlığı esas almaktadır: Zaman içindeki değişim, bina biçiminin bilgisayar ortamında nasıl temsil edildiği, binanın temsilinin 2 boyutlu ya da 3 boyutlu oluşu ve kullanılan temsil tekniği. Zaman içinde değişim başlığı statik ve dinamik analiz olarak iki alt başlıkta incelenmektedir. Burada kullanılmakta olan statik analiz ifadesi, proje sürecinde değişime uğramayan tesislerde kullanılan Genetik Algoritmaya dayalı optimizasyon yöntemleri için kullanılmaktadır. Dinamik analizinde, belirli bir görevin türüne ve süresine bağlı olarak tesislerin şantiye süresine dahil edilmesi veya çıkarılan bölümler ele alınmıştır. Bina biçiminin bilgisayar ortamında nasıl temsil edildiğine odaklanan ikinci başlık üç alt başlık içermektedir: 'meta', 'yaklaşık' (approximate) ve 'analog'. Meta modelde, nesnelerin şekli ve boyutu göz ardı edilerek, bir nokta olarak temsil edilirler. Yaklaşık (approximate) modelde, binaların biçimi dikdörtgen veya silindir kütleleri gibi kendisine en yakın temel geometrilerden birine yakınsama yapılarak değerlendirir. Analog model, nesneleri gerçek şekilleriyle analiz eder. Üçüncü temel başlık, bilgisayar ortamında temsil edilen bina modellerinin analiz ve optimizasyon aşamasında 2 boyutlu mu 3 boyutlu olarak mı değerlendirildiğine göre literatürdeki örnekleri incelemektedir. Dördüncü kategori ise, vaziyet planının bilgisayar ortamında temsil edilirken matris tabanlı temsil tekniği ya da vektörel temsil tekniği kullanılmasına bağlı olarak bir değerlendirme sıunmaktadır.

Genetik Algoritmalar (GA), 1970'li yıllarda John H. Holland tarafından doğal seçim ilkeleriyle geliştirilmeye başlanmış bir arama ve optimizasyon (iyileme) yöntemidir. Tezin üçüncü bölümde, Genetik Algoritmanın tarihçesi ve çalışma Mekanizması açlıklanmaktadır. Tek hedefli ve çok hedefli genetik algoritmalar, tezin dördüncü bölümünde yer almaktadır. Tek hedefli ve çok hedefli genetik algoritmalar için, Rhinoceros/ Grasshopper programında Galapagos ve Octopus eklentilerinin kullanıldığı aynı zamanda eklentilerin kullanılan elemanlar, kurallarından ve kontrollerinden bahsedilmektedir. Çalışmanın bu bölümünde, vaziyet yerleşim planlamasında blok yerleşimi için Genetik Algoritma performansını etkileyen güneş radyasyonu ve gölge parametreleri incelenmiştir. Ayrıca, Rhinoceros/Grasshopper programında Ladybug eklentisinin güneş radyasyonu ve gölge parametreleri her bir blok için nasıl hesaplandığı açıklanmaktadır. Bu tezin temel amacı, güneş ışınımını en üst düzeye çıkarmak ve aynı zamanda blokların dikey yüzeylerindeki gölge alanlarını en aza indirmektir. Bu çalışmada, vaziyet planındaki blok düzeninin optimizasyonu için Hareket ve rotasyonu değişken olarak tanımlanmıştır. Araştırmanın bu bölümünde, tek hedefli ve çok hedefli Genetik algoritma optimizasyonunu uygulamak ve sonuçları kıyaslamak için küçük bir prototip modelin üzerinde uygulanmıştır.

Toplu Konut İdaresi Başkanlığı (TOKI) 1984 yılından bu yana devlet desteği ile Türkiye'de toplu konut geliştirme kurumlarından biridir (Url-2). TOKİ'nin hedefi, hızlı konut üretimi ile Türkiye'nin konut ihtiyacının% 5-10'unu sağlamaktır. Ancak bu yaklaşım, TOKİ projelerinde konut planlaması ve tasarımında birçok yerde ve ortamda tekrarlanan standart planlara neden olmaktadır. TOKİ'nin vaka çalışması olarak incelenmesinin temel nedeni, benzer plan şemalarına sahip konut bloklarının farklı coğrafi konumlarda uygulanması, dolayısıyla iklim verisinin karşılaştırılabilir bir parametre olarak optimiasyon modelinde kullanımasına olanak tanımasıdır. Tezin beşinci bölümde, İstanbul Başakşehir'de ve Gaziantep Şahinbey'deki benzer plan şemalarına sahip olduğu toplu konut blokları örnek olarak incelenmiştir. Bu çalışmada, İstanbul ve Gaziantep hava durumu verileri Energy Plus web sitesinden EPW dosyası olarak indirilip ve 21 Aralık tarihine göre güneş radyasyonu ve gölgeyi hesaplamak için Ladybug eklentisi kullanılmıştır. Rhinoceros/Grasshopper programında Octopus eklentisini kullanarak, iki örnek çalışmasının yerleşim planında blok yerleşiminin Çok Hedefli Genetik algoritma optimizasyonunu başarıyla gerçekleştirdi ve elde edilen bulgular değerlendirilmiştir.

Tezin altıncı ve son bölümünde ise, beşinci bölümdeki sonuçların değerlendirilmesi ile birlikte parametrelerin ve faktörlerin sınırlamaları incelenmiştir. Çok amaçlı Genetik Algoritma optimizasyonunun sonuçlarına dayanarak, blokların yerleşim planındaki yer değiştirmenin enerji tasarrufunda önemli bir etkisi olduğunu göstermektedir. Bu çalışmada, deneme ve yanılma sürecinin sonucunda hesaplama süresini azaltmak için çeşitli alternatifler önerilmiştir: (1) Parametre sayısının az olması; (2) Blokların geometrisinin yaklaşık olarak temsil edilmesi (3) Blokların hareketini ve rotasyon kısıtlaması; (4)simülasyon zamanının sadece tek bir gün olması. Gelecekteki araştırmalarda, vaziyet yerleşim planlaması optimizasyonunda çeşitli parametreler örneğin kat sayısı, pencere boyutu vb. de eklenmesi de mümkündür. Ayrıca, bu çalışmanın, bilgisayar ortamında optimizasyon sonucu olarak geliştirme potansiyeli yüksektir. Tezin sonuçlarına göre, tasarımın erken aşamasında çok amaçlı Genetik Algoritma optimizasyonunun vaziyet yerleşim planlamasında başarılı bir şekilde kullanılabileceği gösterilmiştir.

1. INTRODUCTION

1.1 Problem Description

Design decisions taken in the early phases of design play an important role in economizing energy consumption in residential buildings. In designing residential buildings, architects have several criteria for designing site layout planning. Direct sunlight is one of the significant factors of designing site layout planning that leads to reduced building energy consumption for heating. Various parameters like climate, building blocks shape, orientation, height and the distance between blocks can affect the direct solar access for each block.

In this study, two parameters are calculated for direct sunlight. The first one is Solar Radiation which computes incident radiation of the facade and roof in a single simulation. The other one is the shading effect of the surrounding blocks on blocks in a settlement. The shadow areas on vertical surfaces of blocks will be calculated. solar radiation and shadow play an important role in electric lighting savings and heating inside buildings during buildings lifetime in winters. All these parameters are related to each other for the optimum value of each parameter. The main purpose of this thesis is to optimize the location of apartment blocks in site layout planning for reducing energy consumption for heating in the winter semester.

1.2 Aim And Scope

The main purpose of this study is to recommend a mathematical model and optimization process for determining the location of blocks in site layout planning. The case study of this research is the Governmental Mass Housing Administration (TOKI) site layout planning for various climate zones in Turkey. In most of the existing housing construction in Turkey, particularly in apartment-type housing manufactured by TOKI, the same plan is used repeatedly. The repetition of similar types is performed to reduce the cost and perform mass production (Torus, 2016). The same or similar types of plans are being implemented in many different climate zones in Turkey. In this thesis, two case studies with the same plan type but the different locations were selected : (1) TOKI Ayazma Istanbul (2): TOKI Şahinbey Gaziantep.

1.3 Method

There are many optimization theories and techniques in a large area of applied mathematics. Optimization is finding the feasible parameter combination among all parameters for giving the best performance (Boyabatli, 2004). In this study, Genetic Algorithm method is used for the optimization of building blocks settlement in site layout planning. Among various softwares, Galapagos and Octopus which are add-ons for Rhino/Grasshopper environment are selected to implement for Genetic Algorithm optimization in the case study. In the first part of the study, two parameters such as solar radiation and shadow were calculated for each block by using the Ladybug plugin in Grasshopper. After these analyses, variables such as move and rotation are defined in GA to optimize the placement of blocks for maximizing solar radiation and minimizing shadow.

2. GENETIC ALGORITHMBASED DESIGN AND OPTIMIZATION APPROACHES IN SITE LAYOUT PLANNING

There are several computational tools for designing a site layout planning. This chapter presents a literature survey focused on optimization of site layout planning by using GA. This section consists of two main sections. This first section presents the different approaches of the constructs of site layout planning. The advantages and disadvantages of these approaches are discussed. The second part of the section has been analyzed the data with the mentioned parameters and compare to each other. Table 2.1 summarizes the literature of site layout planning based on the mentioned parameters criteria.

Table 1.1 : Implementation of GA in site layout planning.

	Change in Time		Shape Representation			Dimension Of Shape		Site Layout	
	Static	Dynamic	Meta Shape	Approximate	Analog	2D	3D	Matrix	Vector
Li and Love (1998)	•		•			•			•
Hegazy & Elbeltagi	•				•	•		•	
Mawdesley et al (2002)	•		•			•		•	
Zouein et al (2002)	•			•		•			•
Osman et al (2003)	•				•	•		•	
Elbeltagi et al (2004)		•			•			•	
Jang (2004)	•		•			•		•	
Khalafallah and El-Rayes (2011)	•			•		•			•
Derya (2014)	•			•		•			•
Yi & Kim (2015)	•				•		•		•
Aksoy et al (2016)	•			•			•	•	
Mustafa et al (2016)	•			•		•		•	
RazaviAlavi & AbouRizk (2017)	•			•		•		•	
Farmakis and Chassiakos (2018)	•	•		•		•		•	

2.1 Genetic Algorithm Based Construction Site Layout Planning And Optimizing

2.1.1 Change in Time

This chapter represents the site layout planning, which is categorized as a static and dynamic site layout planning.

2.1.1.1 Static site layout planning

In this approach, the facilities do not change during the project, and all objects exist on the site for the entire duration of the project (Andayesh, 2013). Static site layout planning has been used by many researchers for many years (Li & Love., 1998; Hegazy & Elbeltagi., 1999; Li & Love., 2000; Mawdesley et al., 2002; Osman et al., 2003). It is to be chnoted that Static models can be useful when there is no change in the field.

2.1.1.2 Dynamic site layout planning

In this definition of dynamic site layout planning, facilities that depend on type and duration of task change in site layout planning during construction. This approach was a term coined by Tommelein and Zouein (1993). Some researchers have attempted solving this dynamic settlement problem by using evolutionary algorithms such as the Genetic Algorithm. It should be noted that the dynamic model is more realistic than the static one, due to dynamic layout planning create different space requirements on the site at different periods of time (Nguyen, 2013).

2.1.2 Shape representation techniques of building blocks

This section will summarized the site layout object boundaries, which refer to the size and shape of the objects that exist on the site for any period of time. Three approaches to the description of these object boundaries on the site layout as follows:

2.1.2.1 Meta

The definition of Meta objects, objects are presented as a point, that the shape and size of objects will not play any role to find the optimal location. (e.g., Yeh 1995; Li and Love 1998; Mawdesley et al. 2002). This representation simplifies the algorithm because there will be no need to overlaps or space conflicts between objects(Figure 1.2.1 (b)).

2.1.2.2 Approximate shape

In this approach, the actual shape of objects is presented as an approximate geometry construct such as rectangular or cylinder masses. (e.g., Zouein et al. 2002; Khalafallah and El-Rayes, 2011; Derya 2014; Aksoy et al. 2016; RazaviAlavi & AbouRizk, 2017). This approach is more realistic than the previous one because the algorithm Considers objects of different sizes, detects overlaps and resolving space conflicts between objects(Figure 1.2.1 (c),(d)).

2.1.2.3 Analog representation

An analog shape which means that objects represented with their actual shape that give rise to the complexity of the calculations (e.g., Hegazy & Elbeltagi, 1999 ; Osman et al, 2003 ; Elbeltagi et al, 2004). This approach is required more sophisticated algorithms to recognize and resolve space conflicts (Figure 2.1 (a)).

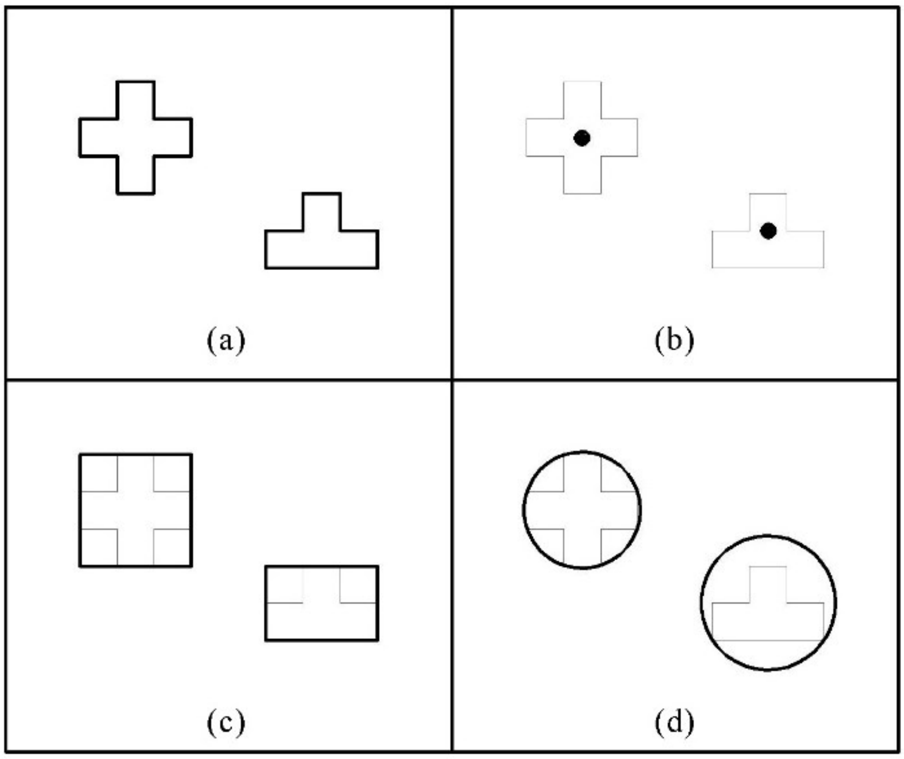


Figure 2.1: Shape representation of building blocks: (a) Analog representation. (b) Meta shape. (c) Approximate shape. (d) Approximate shape.

2.1.3 Dimension of shape

The dimension of shape means that objects represented in 2D or 3D with their approximate or analog shape representation. Even if there are more 2D-dimensional studies(Li and Love, 1998; Hegazy & Elbeltagi; Mawdesley et al, 2002; Zouein et al, 2002; Osman et al, 2003; Elbeltagi et al,2004; Khalafallah and El-Rayes, 2011; Derya, 2014; RazaviAlavi & AbouRizk, 2017; Farmakis and Chassiakos, 2018) than 3D(Aksoy et al, 2016; Yi and Kim, 2015), this study focused on the implementation of MOGA through 3D-dimensional representation of building blocks.

2.1.4 Representation techniques of site layout

In this approach, verification of space availability and referencing specific locations on the site are two important factors for definitions space in the site layout model. This section has described the two approaches to representation techniques of site layout planning to identify the optimum location for objects on the construction site as follows:

2.1.4.1 Matrix-Based Representation

In this proposed model, site space is divided into the two-dimensional grid. Having a grid base site representation helps the facilities to locate on the grid as a number and the position of any facilities on the site by using the column and row boundaries.

2.1.4.2 Vector-based Representation

Unlike the previous approach, blocks can be located any available space on the site without any limitation to a grid system and the position of any blocks on the site by using the x-y axis movement.

2.2 Genetic Algorithm Approaches Of Site Layout Planning

In this section, GA of site layout planning are reviewed according to the mentioned parameters in the previous chapter.

Li & Love (1998,2000) presented a Genetic Algorithm system to find an optimal solution for construction site-level settlement problems. The main purpose of this research is to minimize total travel distance between facilities, which saves time for related personnel. This algorithm only addressed the problem of the static layout. In this research, facilities are optimally positioned in predefined positions; thus, the algorithm presentation was specific and limited. Because of its limitation problem, it is used fewer than other systems. Figure 2.2 shows the construction site layout restriction, facilities and shortest distance among them. This paper demonstrates the effectiveness of the GA approach that solves construction site-level settlement problems ,which leads to faster and more efficient results than traditional methods.

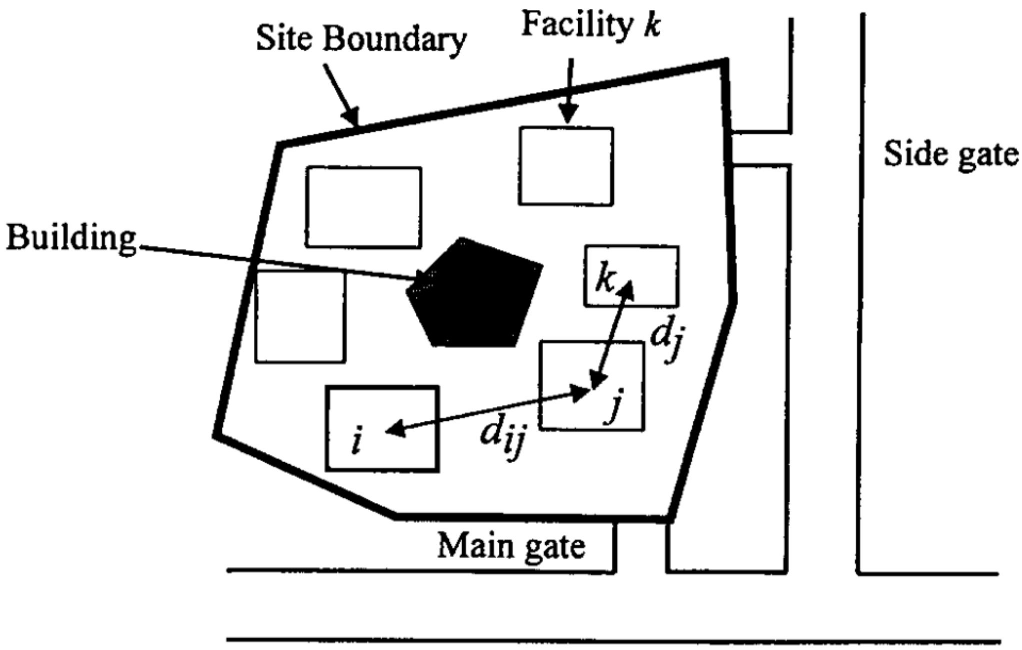


Figure 2.2 : The construction site layout restriction.

Hegazy & Elbeltagi (1999) developed the EvoSite model, which placed construction site layout facilities by using GA. The main purpose of this study was user could define any site shape and incorporates a flexible GA procedure for the optimal settlement of facilities. The facilities are located on the site in three different types:(1) placed any empty space; (2) place user-defined fixed location by defining closeness relationships; (3)place user-defined fixes location that has not closeness relation. The proposed model was located on a two-dimensional site grid that helped the user to define the position of any facility on the site by using the column and row boundaries of the whole site. The closeness relation between facilities that the facilities close or apart from each other were calculated (Figure 2.4). In addition to calculating travel distance between facilities, it also indicates the movement of vacancies around the construction site (Hegazy & Elbeltagi, 1999).

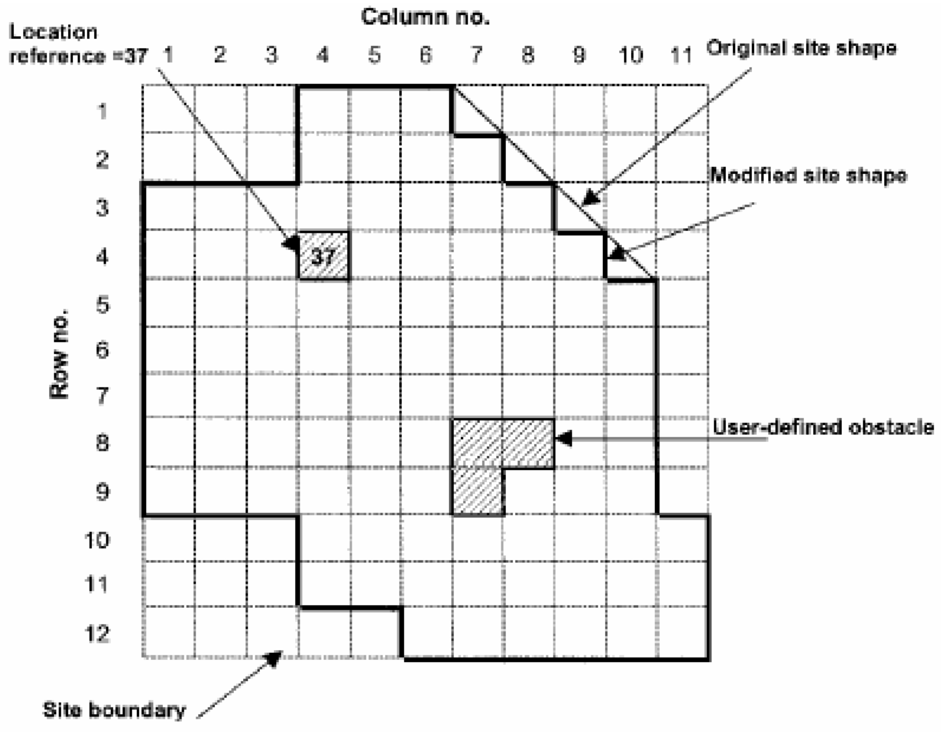


Figure 2.3 : Site representation in EvoSite model (Hegazy & Elbeltagi).

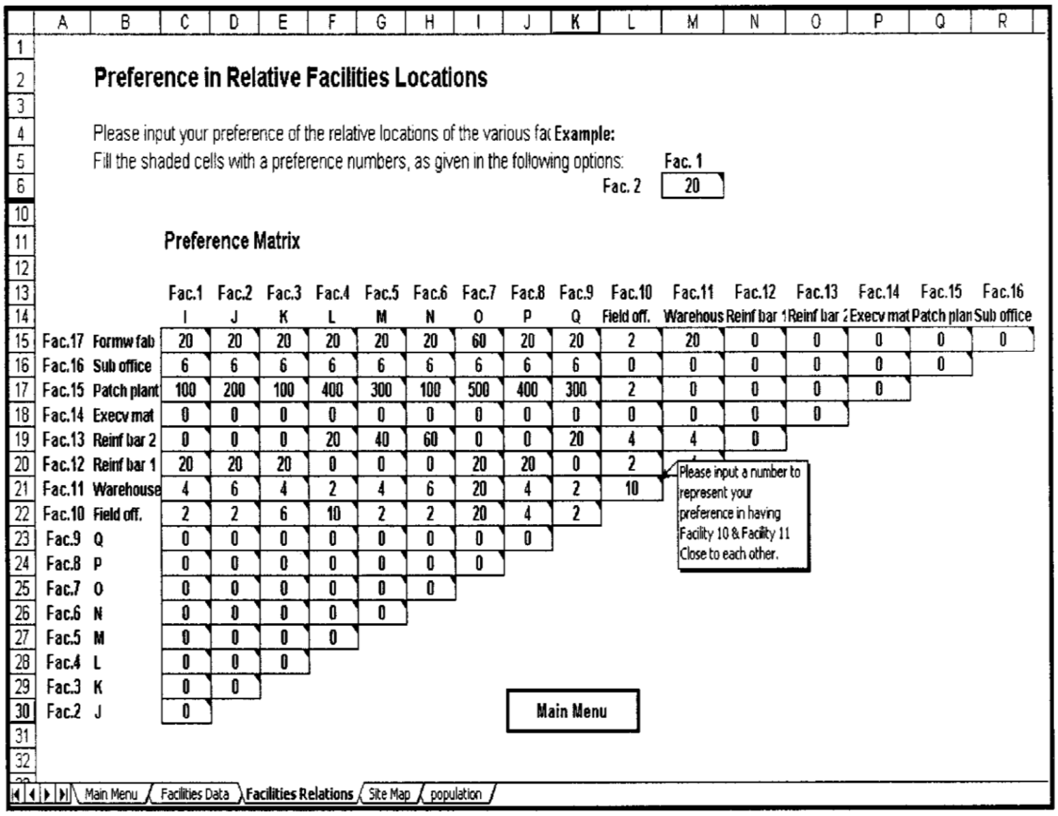


Figure2.4 : Proximity weights between facilities (Hegazy & Elbeltagi).

Cheung et al. (2001) developed the GA model for minimizing the traveling distance between facilities and save time for site pre-casting public housing in Hong Kong. In this study, facilities location is predetermined, and the rectangular distance is used instead of the diagonal distance. Using a rectangular distance between facilities is similar to actual welding movements. Figure 2.5 indicates the near-optimal solution of the model, which was applied to a 50 x 50 m pre-cast yard layout arrangement plan.

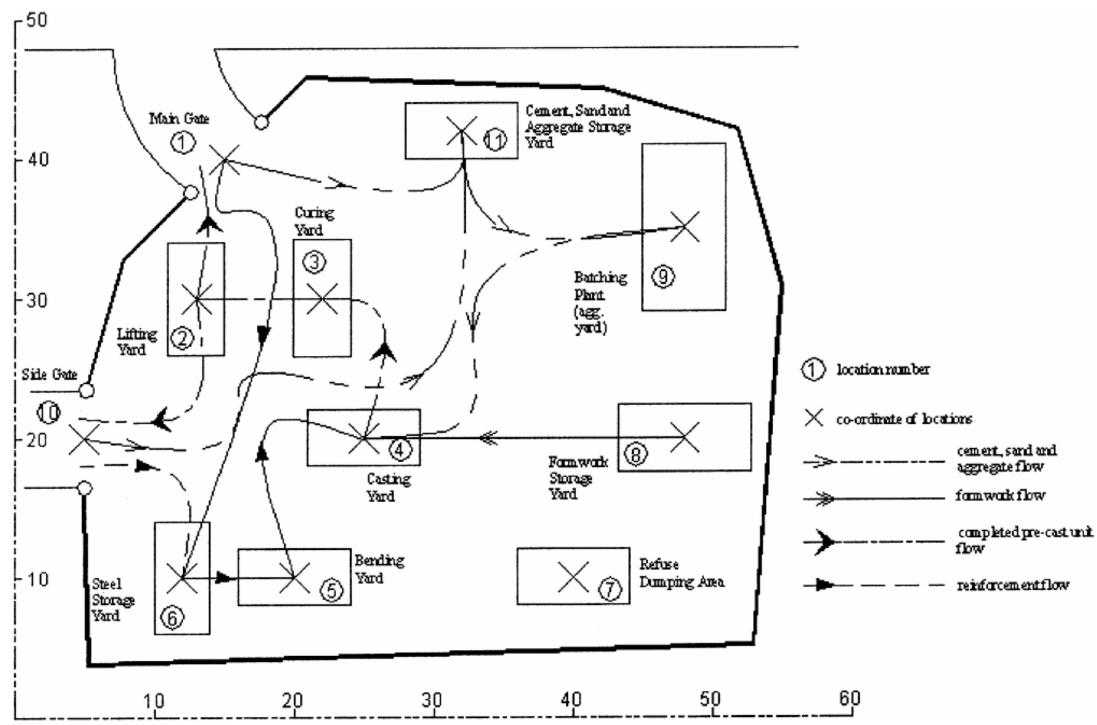
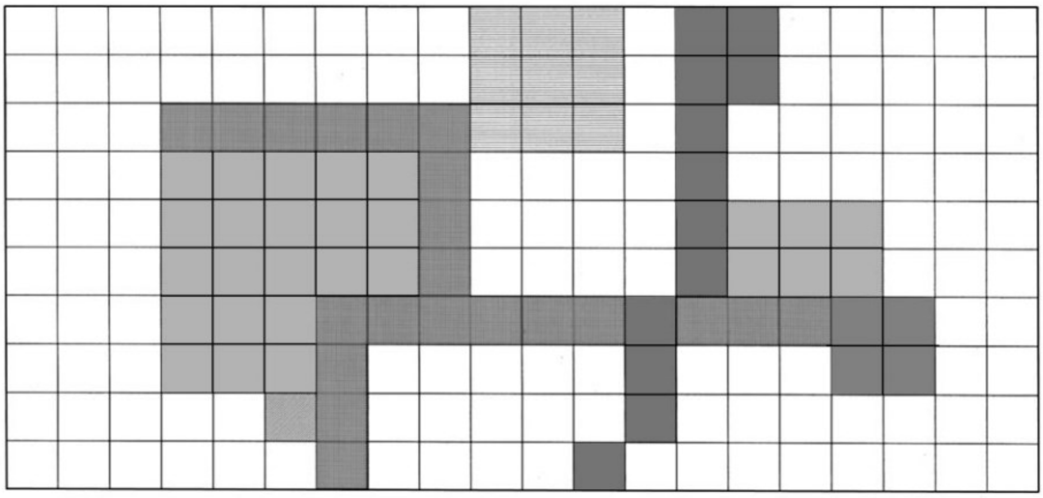


Figure2.5 : Pre-casting site layout for the optimum solution.

Mawdesley et al. (2002) presented the GA based model for construction site layout problems. The main purpose of this research was the extraction of unnecessary movements between facilities to minimize travel times, which improve the quality of work and reducing the project cost. Floor area requirements and the location restrictions are two sets of constraints considered for facilities construction site. In the proposed model, a rectangular grid is used to define and solve the problem (figure 2.6). Two samples were examined in this research. It is to be noted that the smaller the grid size accurate, the more solution, but the computational effort required more(Mawdesley & Al-Jibouri & Yang, 2002).



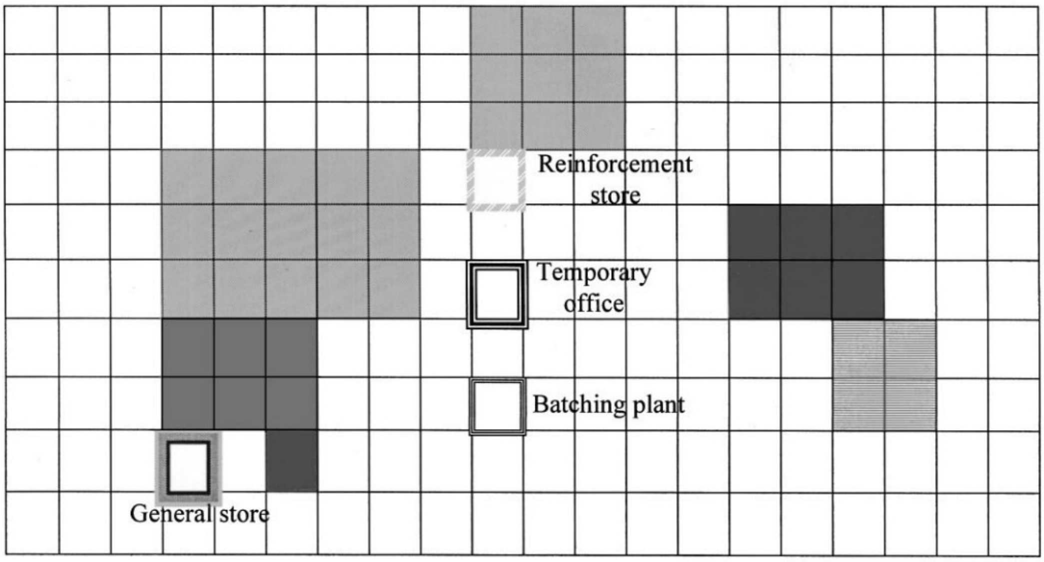


Figure 2.6 : Site layout initial and solution for the factory project (Mawdesley & Al-Jibouri & Yang, 2002).

Zouein et al (2002) developed GA approach for solving the construction site layout problem with unequal-size and 2D geometric constraints between facilities. The algorithm is tested on a variety case of layouts with equal and variable levels of interaction between facilities. Figure 2.7 summarizes the proposed Genetic Algorithm was run on different sets in the following cases: equal size with equal weight objects, unequal size with unequal weight objects, unequal size with unequal weight objects, and 2D constraints between objects. The algorithm was tested on various cases, and it should be noticed that this research focused objects such as the number of blocks, proximity requirements, positions and The relationship between computational time more than developing an integrated site layout planning system(Zouein, 2002).

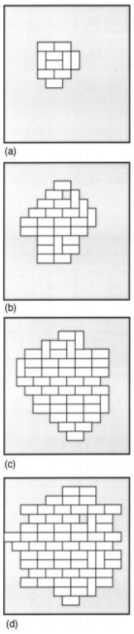
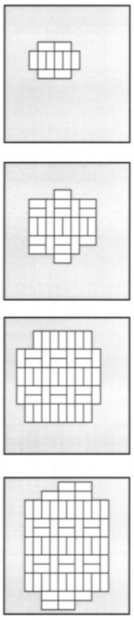
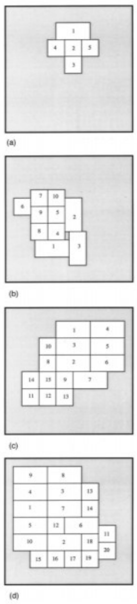
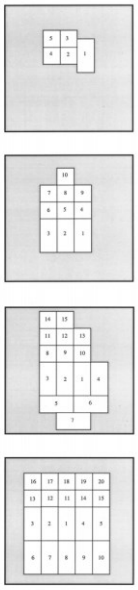
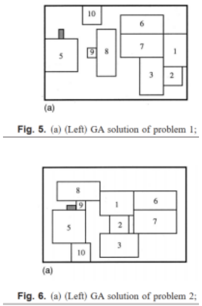
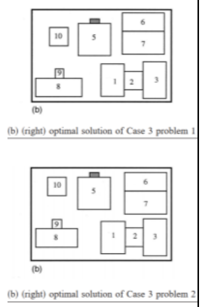
Layout of Equal-Size with Equal-Weight Objects		Layout of Unequal Size with Unequal Weight Objects		Layout of Unequal Size with Unequal Weight and 2D Constraints between Objects	
GA solution	optimal or best solution	GA solution	optimal or best solution	GA solution	optimal or best solution
					

Figure 2.7 : summarizes the results of cases on different sets of problems(Zouein, 2002).

Osman et al (2003) submitted an automated hybrid system to solve layout planning of construction sites in unequally sized facilities. This paper has described the formulation of GA from the CAD environment that is used to determine their size and shape, and location of temporary facilities in the site boundaries with obstacles and available space for assigning the temporary facilities. The objective of this research is to minimize the transportation costs between site facilities by minimizing the distance between them. Figure 2.7 indicates the structure of the formulated CAD-based layout planning of the construction site system. The case study in this research was a swimming pool with all buildings and an access road . Figure 2.8 demonstrated the existing layout facilities and the optimal solution by using an automated system(Osman, 2003).

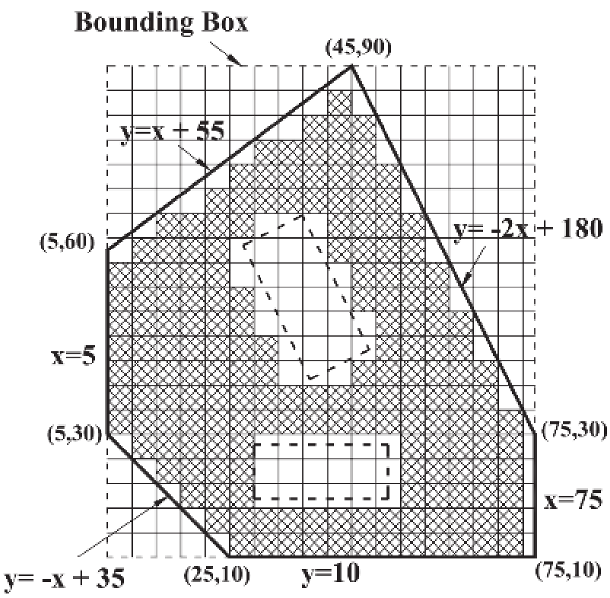


Figure 2.8 : Structure of the formulated Matrix-based layout planning of construction site system(Osman, 2003).

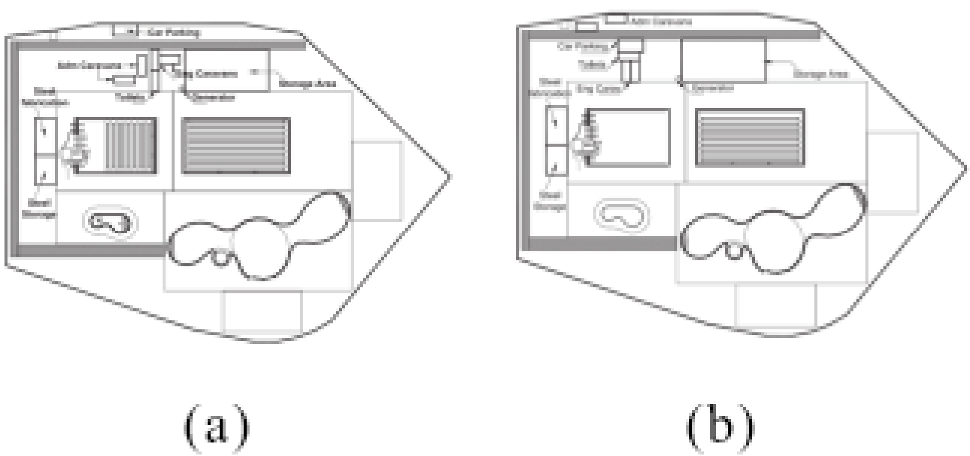


Figure 2.9 : (a) The existing layout facilities, (b) the optimal solution(Osman, 2003).

Jang (2004) managed space for construction materials for deliveries, staging areas, and crane locations in high-rise buildings that are normally situated in congested urban locations that will result in reduce computational costs of material handling and increased productivity by using GA. In the proposed model utilized the grid system in which a floor is divided into grids that each material occupies at least one grid and will not share the grid. The case study of this research was an eight-story building, twenty two temporary materials, two periodic materials with seven activities that were created for the experimentation of the program.

Elbeltagi et al. (2004) developed the GA model for a dynamic construction site layout planning approach that contributes to unsafe construction sites to integrate both safety and productivity. In this research three-step approach is used for site layout planning:(1) identification of temporary facilities for health and safety reasons on the site; (2) Identification of safety zones to minimize accidents around the construction site; (3) Determination of proximity weights based on safety issues of facilities and accordingly optimization of plant placement on site. Figure 2.9 indicates a list of temporary facilities that consider activities at different schedules intervals during the time on the site layout is created. In this study, small grid units are used, which provide the irregular shape of the facilities. Figure 2.10 indicates the optimum layout plan by using a grid system in this case study is presented.

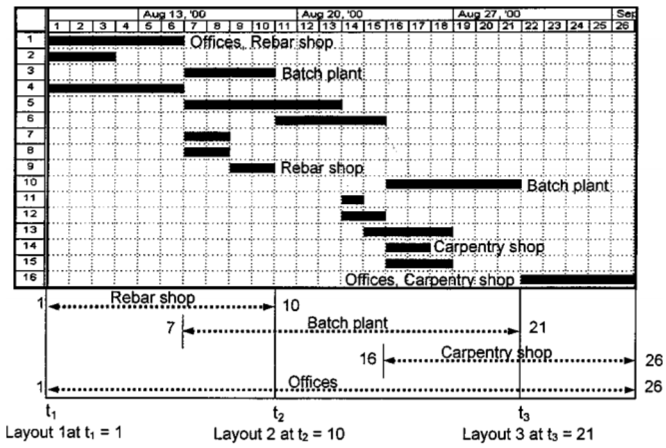


Figure 2.10 : Temporary facilities required in different program ranges.

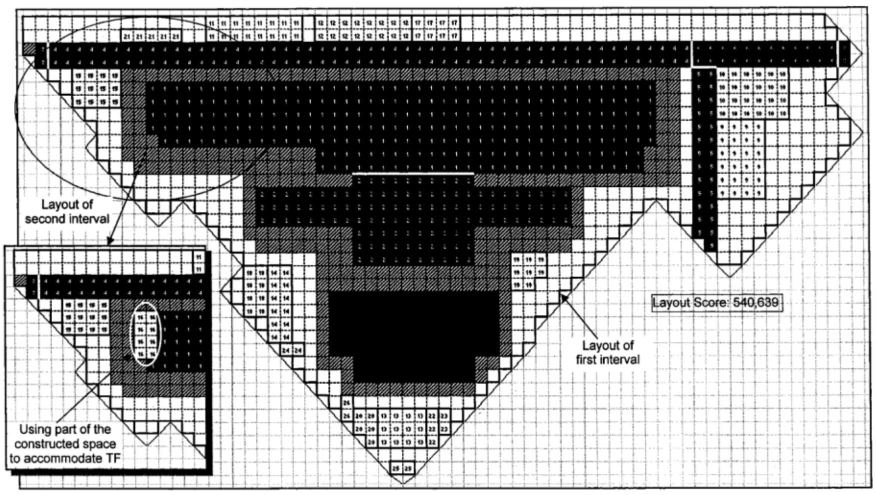


Figure 2.11 : Optimum layout plans.

Khalafallah and El-Rayes (2011) developed the multi-objective Genetic Algorithm based model for airport construction site layout problems. The main function of multi-objective GA is to enable simultaneous optimization of layout objectives such as maximize construction safety, construction-related aviation safety, construction-related security level. In this case, the system stores all the necessary construction site data, and optimization parameters data; and generates the optimum field layout data. The output of this model is visualized in CAD software systems such as AutoCAD that objects are presented as a two-dimensional rectangle in which an object approaches the actual shape (figure 2.11).

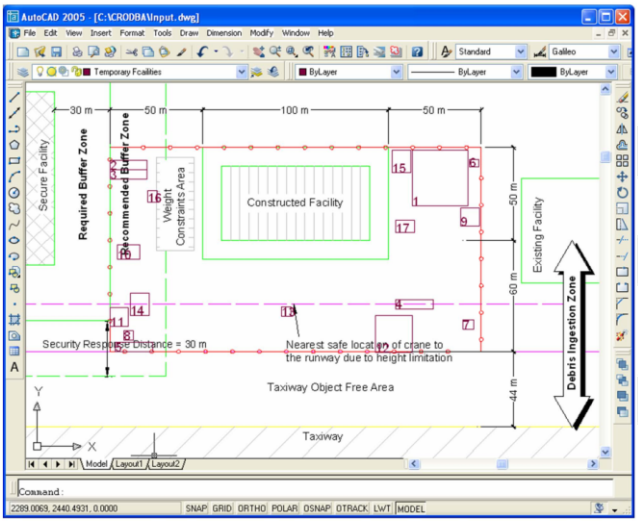
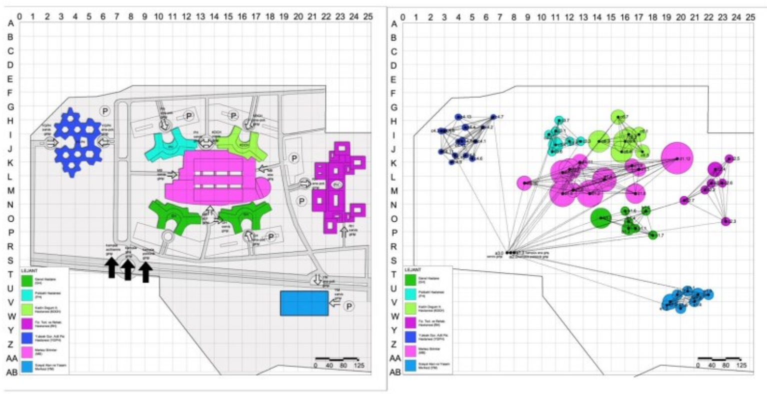


Figure 2.12 : The output of the model in CAD software systems.

Derya (2014) developed the ADA model (Algorithmic Distance Based Accessibility) to define spatial relationships and optimize user movements of Ikitelli and Kayseri health campus's site plan by using GA. This research focused on five criteria, such as the number of spaces, sum of the distances, closest activity, activity potential, and probability selection have been considered to check the accessibility system according to the site plan(table2). These criteria made an important contribution to the formation of three different site plan alternatives. figure 9 indicates the site plan of the Kayseri health campus. In the first stage of the study, the mentioned site plan is analyzed to find the relation and space contact of the essential part of the campus, which is shown in figure 10. This system offers three different alternatives after running 1000 generations(figure 11, 13, 15). According to these alternatives, site plan positioning has been made(figure 12, 14, 16)(Güleç, 2014).

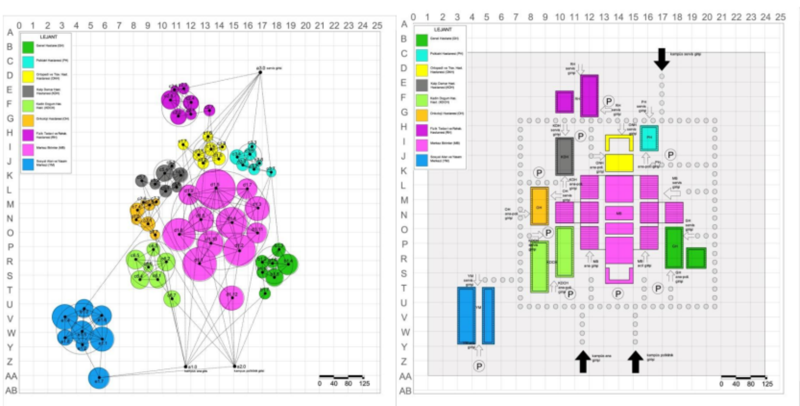
Table 2.2 : Accessibility Criteria (Güleç, 2014).

criterions	Definition	Accessibility criteria
Number of Places	Total number of places to go for an activity	as grow, accessibility increases
Sum of distances	Total access	as shrink, Accessibility increases
Nearest activity	The closest to the desired activity.	as shrink, Accessibility increases
Activity potential	Demand status of the activity.	as grow, accessibility increases
Probability choice	In the possibilities of activity,	as grow, accessibility increases



(a) (b)

Figure 2.13 : Kayseri health campus site plan .
(b): space relation of Kayseri (Güleç, 2014).



(a) (b)

Figure 2.14 : (a) :Alternative 1, 1000th generation space relationship diagram.
(b) :Alternative 1, 1000-generation site plan(Güleç, 2014).

Aksoy et al (2016) sophisticated the SSPM (Sustainable Site Planning Model) for generative site plan alternatives, according to LEED and BREEAM certification systems. LEED (Leadership in Energy and Environmental Design) and BREEAM(the Building Research Establishment Environmental Assessment Method) are certification programs for construction projects that include compliant land use criteria, environmental information, local building codes, and local climatic conditions. The first stage of the study was definition the site to the computer by using a matrix technique in excel (figure 2.14) and the next step was to choose climate type, the direction of the wind, view, Floor space ratio and Floor area ratio in the model by the user. The SSPM model was tested at a site in Istanbul, to find an optimal site plan alternatives for a social housing complex. It is to be noted that the SSPM model presented the slope of the site, roads, lakes, trees, and buildings in 3D space. Figure 2.15 indicates the first generation SSPM model for site plan alternatives(Aksoy, 2016).

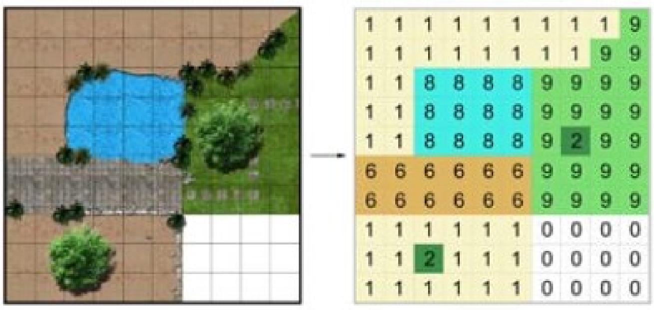


Figure 2.15 : Definition the site to the computer by using a matrix technique in excel (Aksoy, 2016).

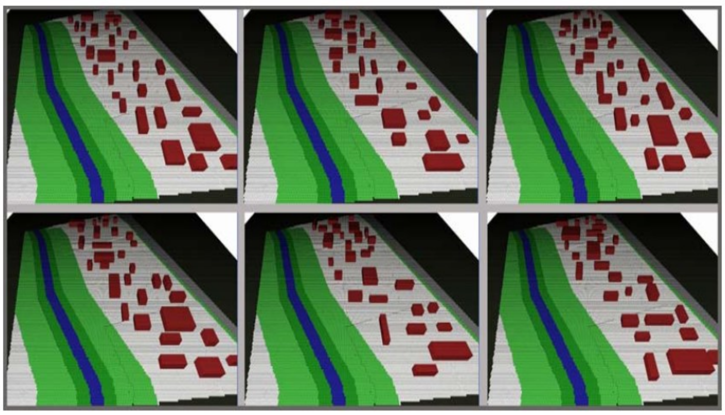


Figure 2.16 : First generation of site plan alternatives for a social housing complex(Aksoy, 2016).

Mustafa et al(2016) developed a YERPLAN tool which is based on GA to solve layout planning of construction sites in unequally sized facilities. The main purpose of this study was minimizing the transportation and walking distance. Therefore, YERPLAN has succeeded in combining both the frequency of use of concepts and the distance between the facilities in a single relationship matrix and giving efficient results. Figure 2.16 indicates the YERPLAN-Site Layout Plan Preparation Program-receives a series of information and data related to placement such as facilities names, number of facilities, facilities features and distance among them through different interfaces and evaluates this data by using Genetic Algorithm approach which presents the optimum layout plan to the users. After the simulation in the YERPLAN program, the site layout is obtained in 2d visual in the example of Figure 2.17 (Oral,2016).

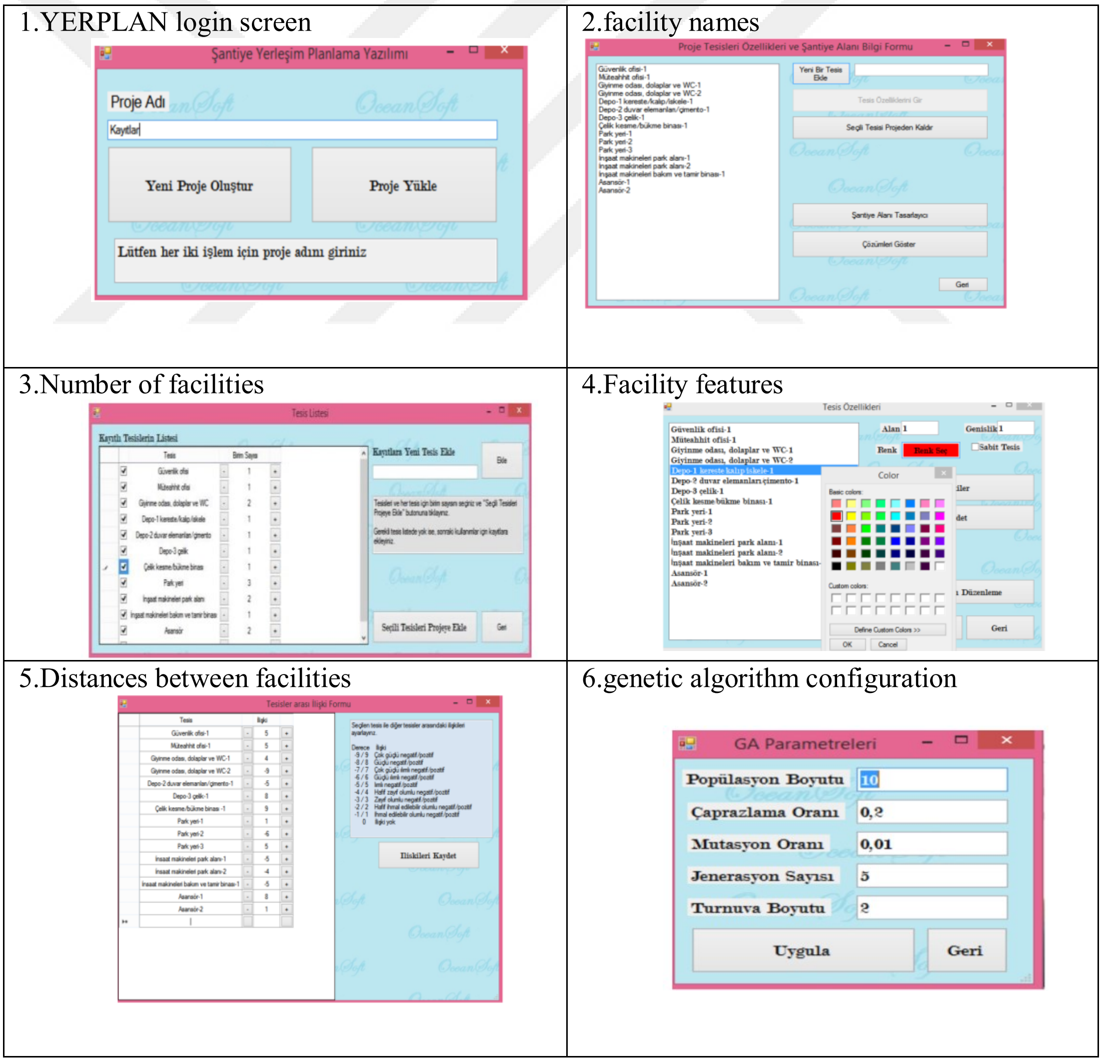


Figure 2.17 : YERPLAN site layout plan program(Oral,2016).

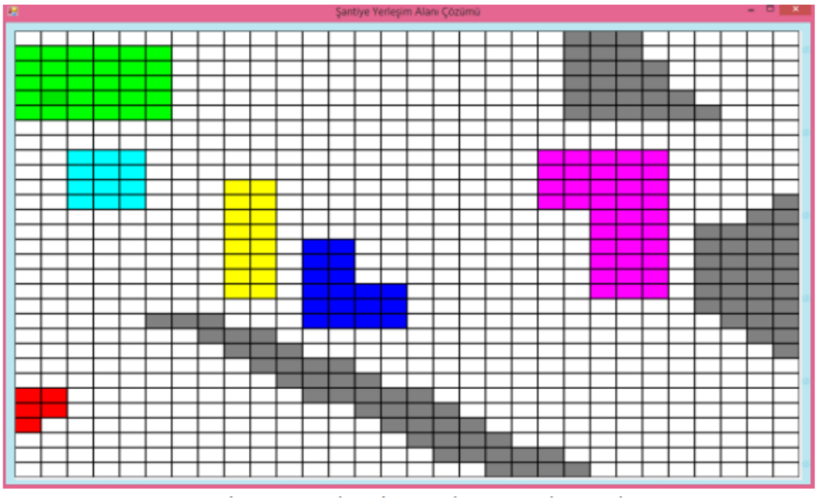


Figure 2.18 : Site layout plan output by using the YERPLAN program(Oral, 2016).

RazaviAlavi & AbouRizk (2017) utilized GA as an optimization tool for generating feasible solutions for the site layout planning by considering three variables; the shape of the facilities, which is defined as rectangles, the size, and orientation of them that is limited to 0 and 90 degrees. Their work is similar to Hegazy and Elbeltagi's research due to the proposed model located on a two-dimensional site grid. Numbering the grid cells assist the facilities in identifying the location and coordinates them in Genetic Algorithm system. In addition, the size of the grid cells affects the optimization and processing time. Because small grid cells increase the search domain and large grid cells reduce it. The case study in this research was the steel erection project in Alberta, Canada. Fig. 6 indicates the overview of the site layout with its facilities and optimum site layout (RazaviAlavi, 2017).

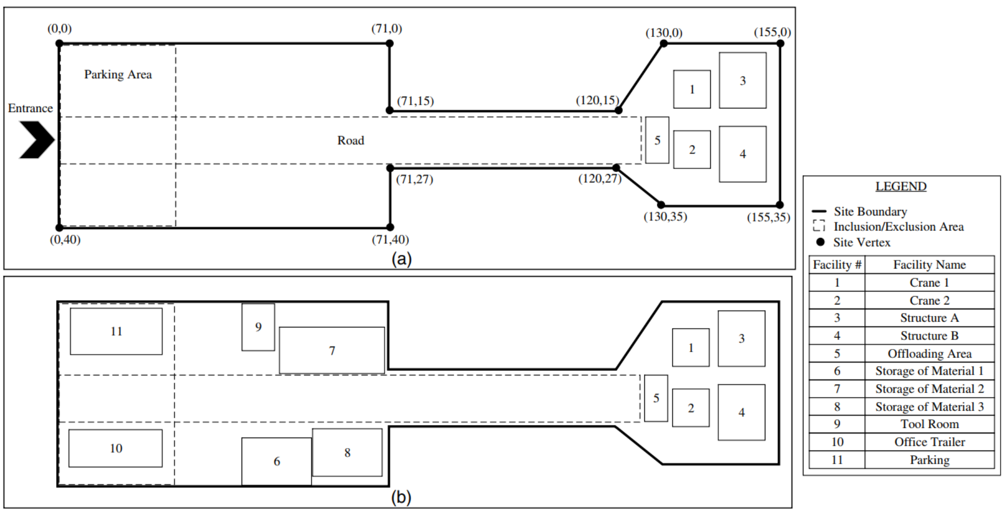
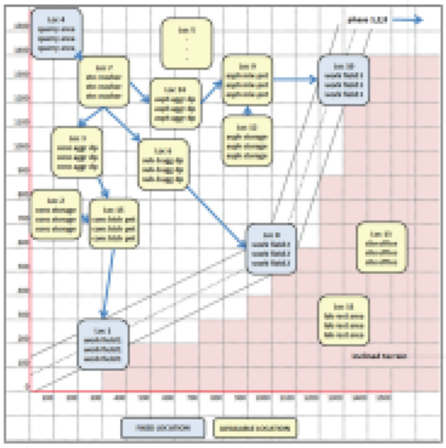


Figure 2.19 : (a) Overview of the site layout; (b) Optimum site layout (RazaviAlavi, 2017).

Farmakis and Chassiakos (2018), formulated a Genetic Algorithm for solving the dynamic construction site layout planning (DCSLP) to minimize the construction and relocation costs. In the first stage of the study, a list of estimated costs for initial placement was drawn up. Then, the formulation of the DCSLP problem includes the identification of the required facilities, determination of their coordinates, size, type of movement and the number of trips between the facilities at each project stage(Figure 2.19). The model has been experienced in several case studies, such as static and dynamic layout configuration. The result demonstrated that progressing the layout planning in dynamic modeling is more effective than a static one(Farmakis, P. M. 2018).

Facility	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	5	1	1	1	1	1	1	1	1	1	1	1	0	0
2	5	0	1	1	3	3	3	1	1	1	1	1	1	1	0
3	1	1	0	1	3	1	1	3	1	1	1	1	1	2	0
4	1	1	1	0	1	3	1	1	1	3	2	1	1	1	0
5	1	3	3	1	0	1	1	1	1	1	1	1	1	2	0
6	1	3	1	3	1	0	1	1	1	1	2	1	1	1	0
7	1	3	1	1	1	1	0	1	3	1	1	1	1	1	0
8	1	1	3	1	1	1	1	0	1	1	1	1	1	1	0
9	1	1	1	1	1	1	3	1	0	1	1	1	1	1	0
10	1	1	1	3	1	1	1	1	1	0	1	1	1	1	0
11	1	1	1	2	1	2	1	1	1	1	0	1	1	1	0
12	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0
13	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0
14	1	1	2	1	2	1	1	1	1	1	1	1	1	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0



(a) (b)

Figure 2.20 : (a) Number of trips between facilities.(b) Construction site layout(Farmakis, P. M. (2018)).

3. GENETIC ALGORITHM

3.1 Mechanism Of Genetic Algorithm

Charles Darwin suggested the theory of natural selection that the result of adapting to the millions of years of environmental demands of plants and animals that exist today in 1859. Individuals in the population compete with each other for obtaining resources such as shelter, food; therefore, the most adapted individuals remain relatively alive and produce offspring and weak individuals are less likely to survive and are eliminated by others(Darwin, 1987). It is noticed that individual which is well adapted to the environment, allows natural selection to be more effective on chromosomes than organisms based on their performance, and affect the next generations (Sivanandam& Deepa, 2008). Further to introduction of Genetic Algorithm term by John Holland in his 1975 book "Adaptation in natural and artificial systems", DeJong (1975) and Goldberg (1989) continued to develop GA as a computational method.

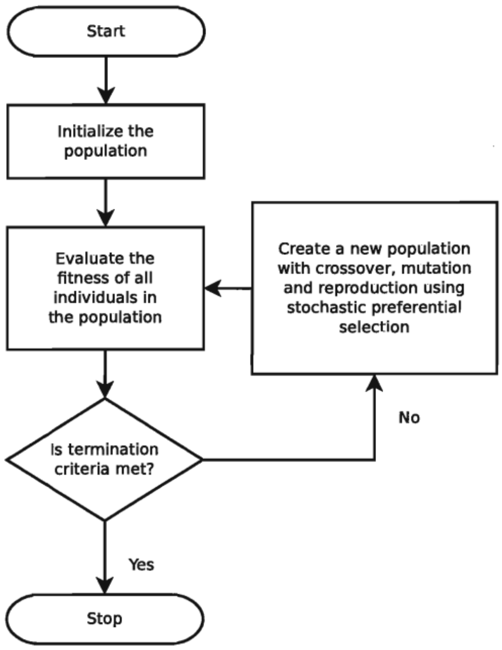


Figure 3.1 : GA flow chart (Flack & Ross, 2011).

In a very broad sense, GA are a kind of meta-heuristic search and optimization algorithms based on the mechanics of natural selection and natural genetics (Goldberg, 1989). The GA are a subclass of Evolutionary Algorithms that occur in a natural selection based on "Survival of the fittest" that organism mimics the process of evaluation to optimize their chances for survival in a given environment, and this process creates new artificial systems (Mitchell, 1998). In addition, GA foresee new exploration directions by utilizing the data in previous generations (Goldberg, 1989).

There are several working mechanisms and elements such as fitness function, selection or reproduction, population, search space, crossover and mutation in GA (Sivanandam & Deepa, 2008 ; Eiben & Smith, 2003). Figure 3.1 indicates the Genetic Algorithm flowchart.

3.1.1 Search space

The space that GA search for the best solution among a set of feasible solutions is called search space (Noorian, 2015).

3.1.2 Fitness function

The most significant component in the optimization process based on more than one variable in GA is Fitness Function or Objective function. Each chromosome, which is composed of genes, has its own fitness value determined by calculating the objective function value.

The aims of GA is to achieve the best chromosomal reach, which gives the best objective function value. Therefore, the populations move to the next generation is considered a degree in the evaluation of a member of this fitness value (Flack & Ross,

2011).

3.1.3 Selection

Selection process or reproduction is the first operation on population and the main component of the GA. During each generation, the chromosomes in the population were chosen randomly to produce a new generation (offspring) via crossover and mutation operations in each generation (Hinçal, 2011).

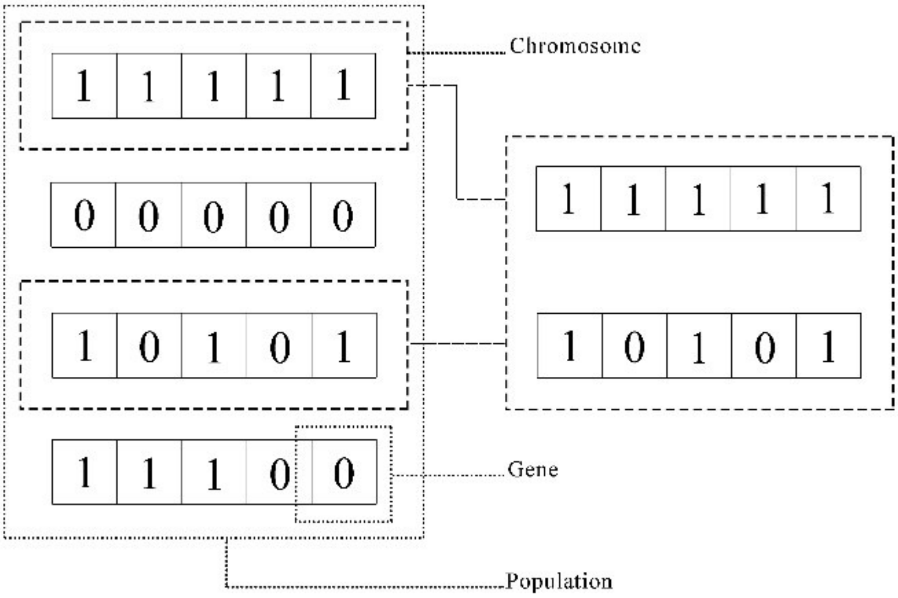


Figure 3.2 : Selection operation (Drawn by the author).

3.1.4 Crossover

The crossover operation or sexual recombination is an operation to create a new offspring by exchanging the genetic information of the individuals and create a new population for the next generation. The crossover has various types of exchange operation methods such as one-point, two-points, uniform, linear-order, partially matched and cycle crossover types (Reeves, 1993). The most common operator used is a one-point crossover in Figure 3.3 (Boyabatl, 2001).

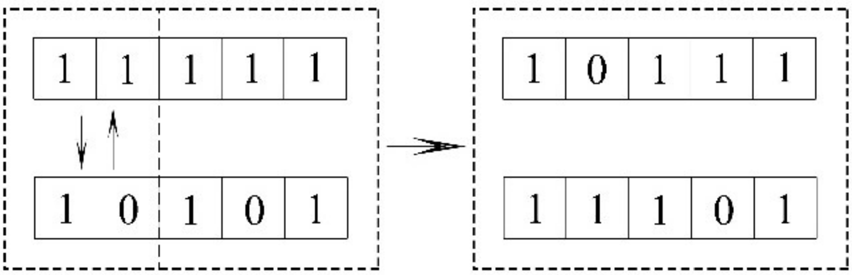


Figure 3.3 : Example of mutation (Drawn by the author).

3.1.5 Mutation

Mutation is one of the important factors due to the diversity of the population by changing the structure of the parent chromosomes in GA processes. This operator is a random process that utilizes a chromosome to reposition genes to create a new individual structure for the next generations. The difference between crossing and mutation is that crossing changes the genetic information between the two chromosomes to create new offspring, but mutation operators investigate the entire search space by changing the genes in the chromosomes (Noorian, 2015) (Osman, 2002).

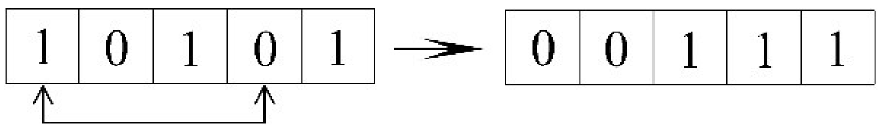


Figure3.4 : Example of mutation (Drawn by the author).

4. A PROPOSED MODEL FOR OPTIMIZATION IN SITE LAYOUT PLANNING BASED ON SINGLE AND MULTI-OBJECTIVE GA

This part of study discusses the analysis of parameters such as Solar Radiation and Shadow, , that affect the performance of GA to optimize the best position of blocks in a site plan for residential complexes. . In this study, initially applying GA simulation will be investigated for a small prototype model and then the results of SOGA and MOGA will be compared. After this analysis, this action will proceed with TOKI’s layout planning site.

4.1 Genetic Algorithm Optimization Parameters

In this proposed model, optimization will be realized by considering wo main parameters for eco-friendly building with optimum natural energy use. The first one is maximizing the solar radiation for buildings and the latter is minimizing shadow for maximizing solar access on vertical surfaces of the building in winter periods.

4.1.1 Solar radiation

There are several Environmental factors for site layout planning, but Solar Radiation is one of the significant of these factors (Zhang et al., 2016). Solar radiation not only plays an active role on heating inside buildings, especially in residential constructions during cold seasons but also it has positive effects on saving electricity consumption and creating a higher quality indoor environment (Flor et al., 2005). Baker and Steemers's research indicates that changing parameters like shapes, orientation can save up to 40% of energy (Baker & Steemer, 2003). Most of the researchers believe that sunlight can affect a positive role in energy performance, health and comfort (Neman et al., 1976; Boyce et al., 2003). In this section, a brief literature review of solar radiation on the building design is presented.

Kämpf et al. (2010) developed the Multi-Objective evolutionary algorithm with the RADIANCE program which is the computation of radiation (W/m^2) by using a cumulative sky model to maximize the utilization of solar energy on the building. The parameters of this study are the height of buildings up to their facade and the height and orientation of roofs. The case study in this research was in the Matthaus district in Basel, Switzerland and parameterized three urban forms: (1) the Terraces Flat Roofs,(2) the Slabs Sloped Roofs, (3) the Terrace Courts. The methodology can be applied to practical design problems, such as the energy consumption of buildings for heating, cooling, lighting and grey energy investment or even carbon dioxide production and costs (Kämpf et al, 2010).

Yi and Kim (2015) proposed a method for optimizing a building's access to direct sunlight by using an agent-based geometry control system in Genetic Algorithm optimization. The main variables for genetic algorithm optimization are the location and the rotation of the buildings (figure 4.1). ''Y"-shaped buildings are selected for the study case and the method found an optimal solution without restricting design possibilities.

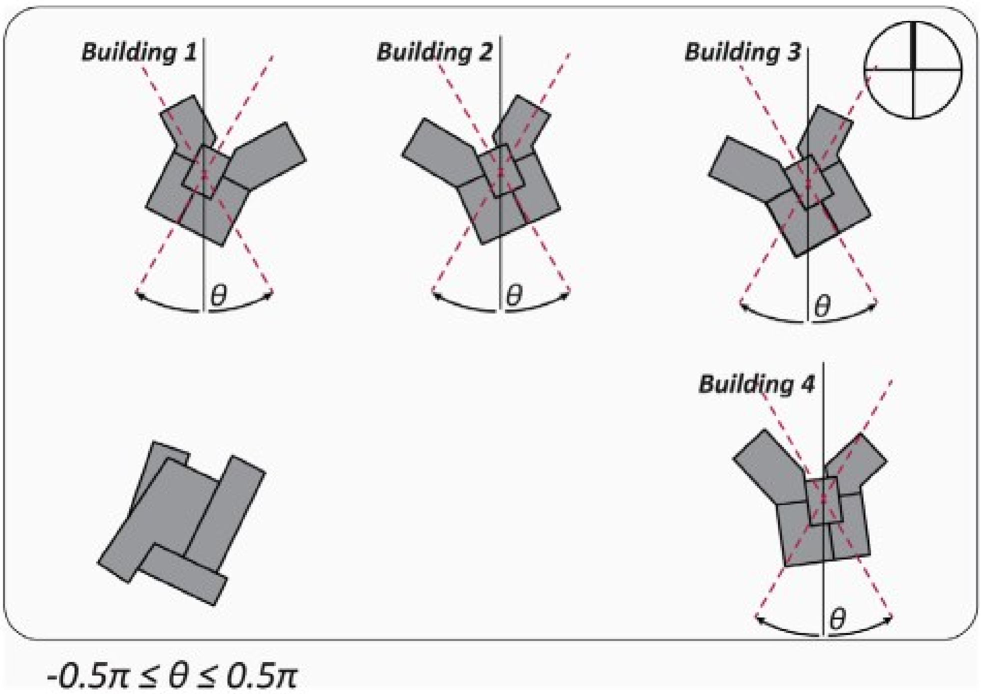


Figure 4.1 : The Rotation of buildings.

Ouarghi and Krarti (2006) presented a method to optimize the selection of office building shapes to minimize the energy and construction costs by combining Neural Network and Genetic Algorithm. In this proposed model, initially an approximate model is created by using a neural network for predicting energy use; then, the optimization process is performed using the GA to minimize the use of energy. In this proposed model, the input parameters include climate, window-to-wall ratio, glass type, and wall or roof insulation. The models are optimized for different locations such as Cairo, Gabes, Rome and Tunisia (Ouarghi and Krarti, 2006).

Jin and Jeong (2014) proposed a free-form building shape by determining thermal characteristics. In this study, the surface of the model was divided into finite elements by generating a mesh in Rhino and the Grasshopper Add-in to estimate the heat gain, after that GA method was utilized to optimize the buildings shape. The shape of the model was optimized for various climate zones and the result indicated that the process can rapidly predict the solar and envelope heat characteristics and optimize the varying building shape. Figure 4.2 indicates the optimal shape for Phoenix and Tehran climate (Jin and Jeong , 2014).

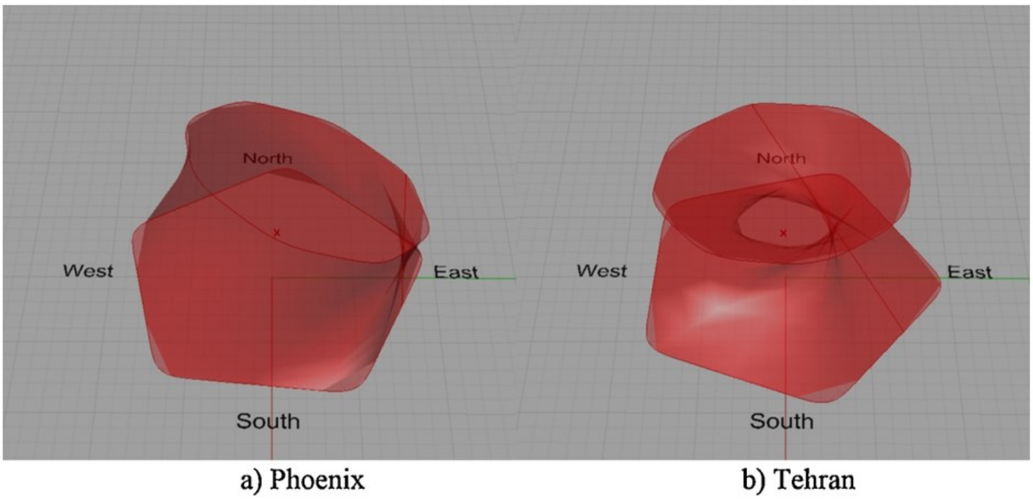


Figure 4.1 : Optimal shape of building for Phoenix and Tehran climates.

Seong et al. (2011) developed a mathematical model to acquire quantitative data on the solar radiation of the residential buildings and an optimal algorithm for determining the height of apartment buildings. Two methods utilized for solar right assessment during research: WALDRAM diagram method and 3D Shadow diagram method.

Wang et al. (2006) presented a methodology to optimize building shapes in a plan to evaluate the performance of energy efficiency, cost, and aesthetics by using a multi-objective GA. The case study of this research was an office building located in Montreal, Canada in which its footprint takes the shape of a pentagon. Length-angle and length bearing are two methods that link with energy simulation programs for the description of the building geometry (Wang et al., 2006).

Oral and Yilmaz (2003) described a methodology to determine the building heat transfer and the effect of direct solar radiation for thermal comfort and minimizing energy conservation. The main parameters considered in this research from the indoor climate are building form and heat transfer. The building form was the ratio of the total facade area to building volume and parameters that affect the heat transfer are orientation, window type, optical and thermo physical properties of the building. The proposed methodology was applied in three different climates which consisted of humid (Istanbul), temperate dry (Ankara) and cold zones (Erzurum) in Turkey and the result of this climate showed that the methodology could be used for temperate and cold zones.

The literature review of design buildings based on solar radiation parameter criteria demonstrates that GA are a popular and useful method to find an optimal solution and are used more than other algorithms. These studies utilized various parameters such as unit position, rotation, height, orientation, size, shape, geometry, material, window type, ratio of window to façade etc., for optimizing solar radiation.

4.1.2 Shadow

The second structure parameter is the shadow which affects the performance of GA optimization in this study. The dark area behind a substance that blocks direct light and radiant heat is shadow (Tahbaz, 2012). In the 21st century, one of the most significant considerations for building design is reducing fossil energy by using renewable energy especially solar energy. There are two strategies for replacing fossil energy by using solar energy in the building. The first one is passive strategies, which are based on-site plan, mass and space, form, interior design, openings. The second is active strategies based on transformation using the latest technologies(Building Integrated Photovoltaic). The preliminary parameter that must be accounted into special consideration in both strategies is shadow (Tahbaz, 2012). The shading not only affects solar access for buildings but also affects solar access for pedestrians in open public spaces (Erell et al., 2012). Hence, solar access and shadow are important factors for pedestrian traffic and different outdoor activities (Chen et al., 2012). Thus shadow analysis can be defined as a method to help designers on the selection of parking areas, open space, children's parks, street furniture and etc. in site plan (Rehan and Islam, 2015). This section presents case studies that show the impact of solar access and shadow analysis on building design.

Liu et al. (2014) suggested a method for natural ventilation design in residential buildings. Multiple factors such as sun radiation, weather conditions and shadow can affect the buildings natural ventilation. The spacing and orientation of buildings are optimized in this research. The case study in this study was a real residential community in Chongqing, which has the least sunshine in China. The other optimization step was window size and position in some rooms to improve daylight. The result of optimization in Chongqing's residential buildings shows that the energy-saving potential of natural ventilation in the server can roughly estimate up to 40% in terms of electricity consumption.

Chan (2012) proposed a method for minimizing energy use in buildings. In this study, the effect of shading on the thermal and energy performance of the high-rise building blocks has been investigated in Hong Kong from the past two decades. The climate in Hong Kong is subtropical which has a long and humid summer, so the cooling load is one of the most significant factors in buildings. This study was applied in different blocks and the conclusions of this simulation demonstrated that solar shading has an important factor in the building cooling load and energy performance.

Nikoofard et al. (2011) investigated the shading effect of neighboring parameters like houses and trees, in annual heating and cooling energy requirements of buildings in four Canadian cities. Shading reduces solar heat gain, which increases the energy requirement for heating and reduces the energy requirement for cooling. The effect of parameters such as distance, orientation and size of neighboring parameters was investigated for heating and cooling energy requirements. The result of the house in Canada indicates that the annual heating energy requirement may increase as much as 10 percent and the cooling energy requirements decrease as much as 90 percent.

Frank et al. (1981) developed the OBSTRUCT program, where buildings randomly represent arrangements for the ideal city. The main parameters of this study were the spatial relationships of buildings that block sunlight and shaded surfaces, and the variables of the program were the location, direction and height of the buildings.

Not only buildings but also trees are important factors for lighting and ventilation. Hongbing et al. (2010) examined the effects of tree shade for building day light and natural ventilation. Three cases with different green spaces in Shanghai were investigated to optimize tree design among buildings for daylight and ventilation by determining the relationship between maximum tree heights and building separation. Figure 4.3 shows the degree of four different tree type shades in the same building.

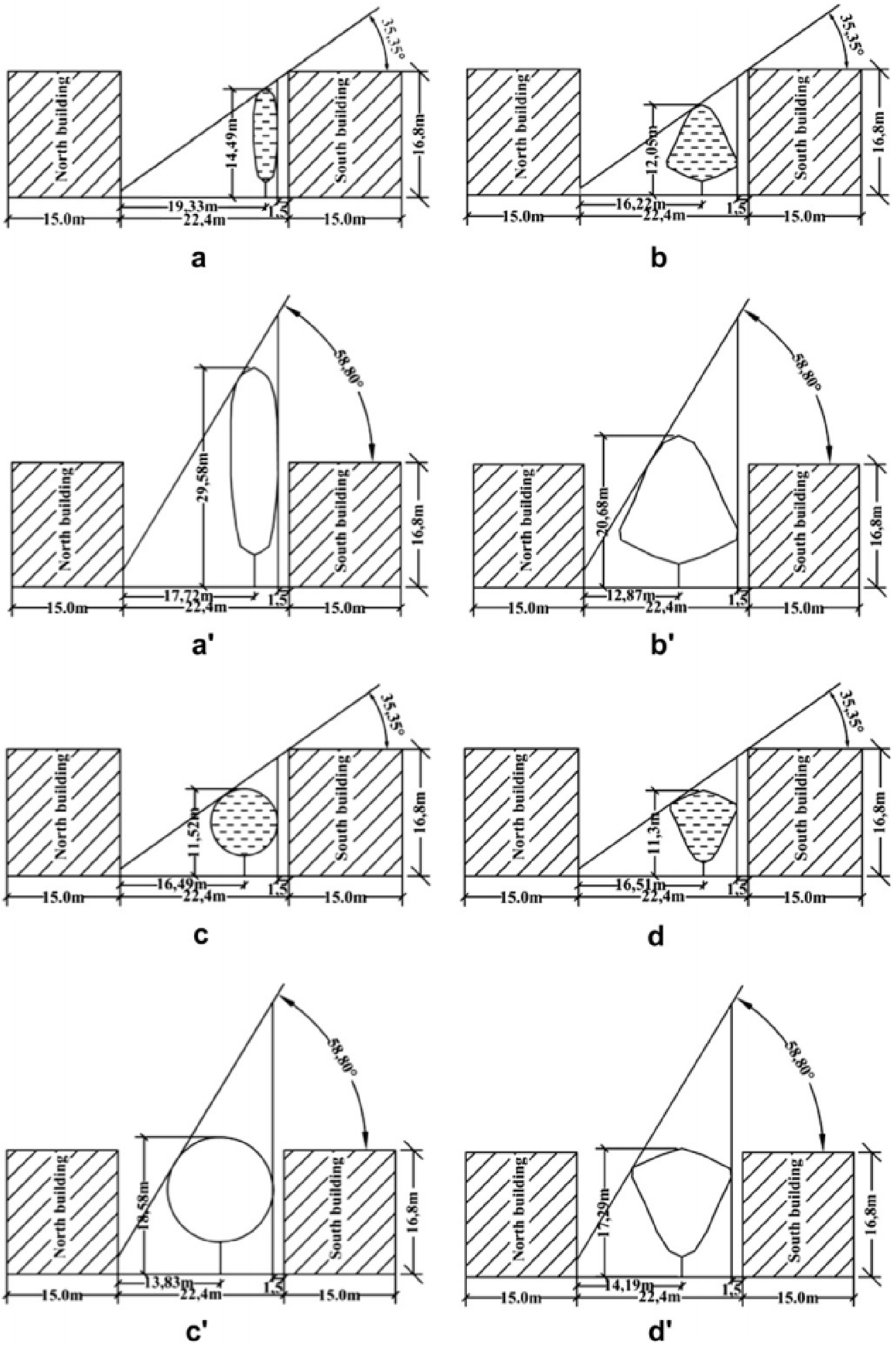


Figure 4.3 : The effect of the shadow of four different tree type in the same buildings.

Ok (1992) proposed a simulation model to determine the effect of shadow in residential buildings for calculating cooling loads. The proposed model consists of three phases. The first phase is calculated data for solar radiation relying on location. In the second phase, the shadow on the vertical surfaces of the building based on neighboring buildings is simulated. After all, a computer program is developed to calculate the thermal performance and cooling of buildings by using the shading effects on buildings. The location of buildings for solar radiation, distances between buildings, shape and orientation of obstruction are the variables in this research. The case study was simulated for July 21st for a multi-story residential building located in Istanbul. The result of this simulation showed that the environmental effects and shadings play an important role to save energy consumption.

To sum up, there are three main energy consumptions for buildings: (1) lighting which leads to visual comfort, (2) ventilation which affects indoor air quality, (3) space condition for thermal comfort (Stavrakakis et al., 2010). These studies demonstrated that the effects of direct solar radiation and shadows for energy-consuming are not only for indoor spaces but also urban spaces in different climates. One-third of the total energy consumption in buildings are consumed by mechanical air-conditioning and ventilation devices (Türkoğlu, 1997). Moreover, parameters such as buildings location, form, height, orientation, windows size and the distance between obstructions can affect the shading on buildings and energy consuming.

4.2 Optimization Via Genetic Algorithm For The Proposed Model

In this part of the research, for verifying the optimization result, a small prototype model is defined for applying GA optimization. Rhinoceros software and Grasshopper plugin are used to optimize the best position of blocks. Grasshopper is a graphical algorithm editor plugin in Rhinoceros that allows designers to generate parametric forms quickly without having experience with the scripting (Day, 2010). In this proposed model, the site is rectangular with a size of 9m ×12m which accommodates two cubic shapes that are 2m ×2m ×5m (block 1) and 2m ×4m ×3m (block 2) in size. Figure 4.4 indicates the predetermined position of the blocks on the sites, which are modeled in the Rhinoceros software.

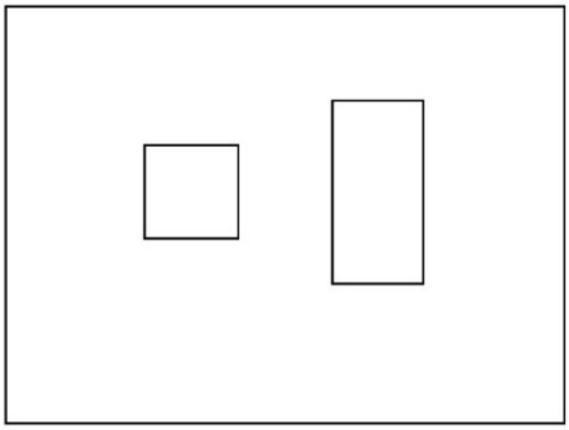


Figure 4.4 : Predetermined position of the blocks on the sites (Top View).

There are two optimization methods in GA. The first one is Single-objective method which is a single criterion decision making such as solar radiation or shadow. The other one is the Multi-objective method which is a multiple criteria decision making that in this study both of the criteria, solar radiation and shadow are optimized (Papon et al, 2012).

4.2.1Optimization via GA for single-objective: solar radiation

In the proposed model, to achieve the solar-radiation simulation for blocks the Ladybug (version 0.0.67) plugin is utilized. Ladybug is an open-source environmental plugin for Grasshopper and Dynamo which was developed by Mostapha Sadeghipour Roudsari (Roudsari et al., 2013). Ladybug imports energy plus weather data files (.EPW) that can be downloaded online from (https://energyplus.net/weather) to calculate the climate data, sun path, shadow studies, solar access, outdoor thermal, local thermal, radiation studies and more (Eltaweel and Su, 2017).

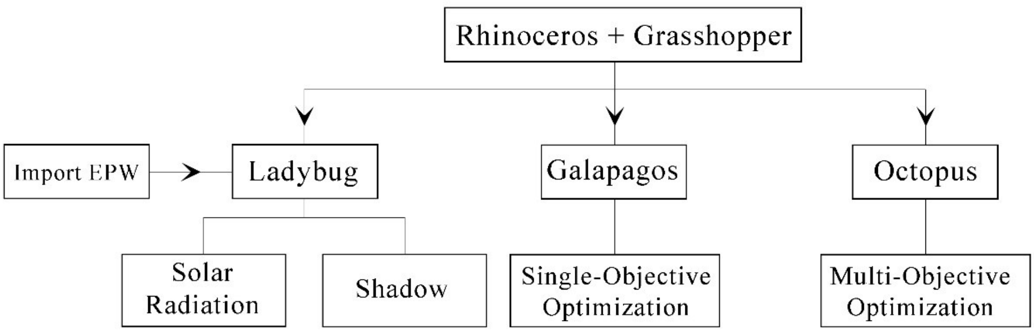


Figure 4.5: Various plugins used for Rhino/Grasshopper in this study (Drawn by the author)

Ladybug component calculates the solar radiation of each block for Istanbul's weather on 21st of December. The main purpose of choosing December 21st is the shortest day during the year due to the sun being at its lowest point (Olariu et al, 2005). It should be noticed that the position of blocks could affect the measurement of radiation. In the proposed model, blocks are divided into grid bases to measure the radiation (Figure 4.6). Table 4.1 indicates the measurement of solar radiation not only for each block but also when it affects each other. In this case, blocks are divided into 0.5-meter grids to calculate solar radiation. In addition, as the size of the grids decreases, the total number of grids increases and calculations become more accurate(Figure4.6).

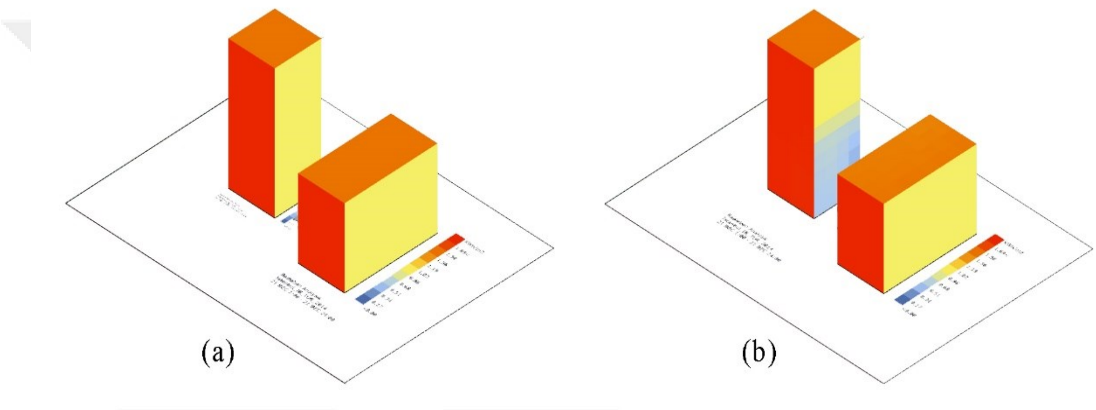


Figure 4.6: measurement of solar radiation: (a) each block, (b) when blocks affect each other.

Table 4.1 : Measurement of solar radiation.

Measurement of solar radiation (kWh/m2)	Block 1	Block 2
Without shading	40.96	41.19
With shading	39.23	38.33

The main purpose of this chapter is to maximize solar radiation in the winter semester by using GA optimization method. Therefore, single-objective GA optimization is applied in Galapagos plugin, which Rutten has developed for Grasshopper. Figure 4.7 indicates the user interface of Galapagos and interface parts such as Fitness Function, Generations, Genome map, Genome Graphs, and Crossover Coalescence.

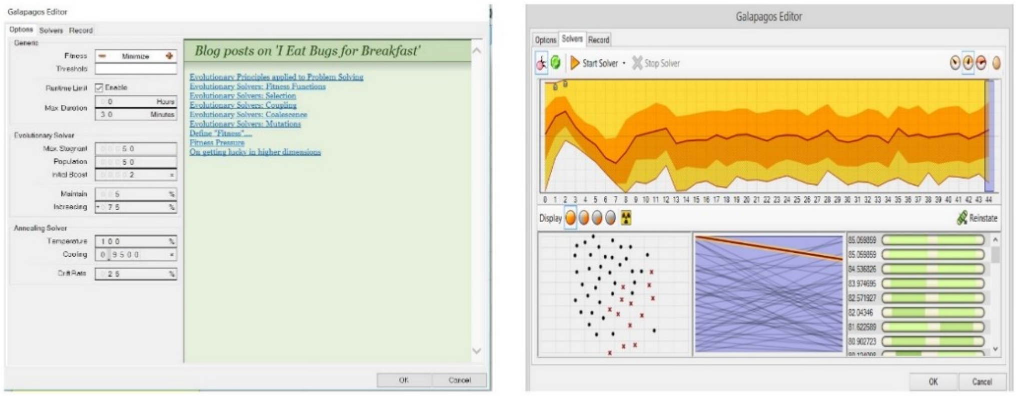


Figure 4.7 : Galapagos interface.

In Galapagos, which is based on the Non-dominated Sorting GA, fitness functions can be defined for maximizing or minimizing. Galapagos can analyze only one parameter for optimization. In the first part of example, solar radiation is a single-parameter. Figure 4.8 shows the genome map, which displays all the Individuals. Every genome has a unique graph that shows the applying mutation to a genome. A mechanism that exchanges the gene to create a new population is crossover operation (Rutten, 2010).

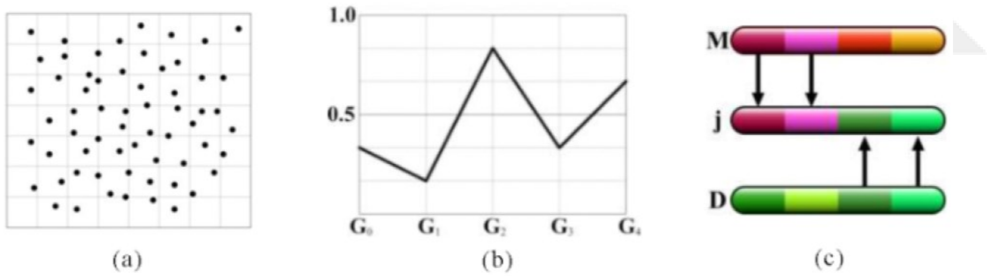


Figure 4.8 : (a) Genome map , (b) Genome graphs (c)Crossover coalescence (Rutten, 2010).

This study includes two variables such as movement and rotation that must be defined to optimize the placement of blocks. Initially, the point in the middle of the blocks for movement and rotation is found. The blocks move along the x-y axis and the magnitude of displacement of each block is (-1.00, 1.00). Depending on the placement of the blocks, different numbers can vary the magnitude of the displacement. In addition, a user can define angle limits for each block. For this test, there was no limit to the angle of rotation of the blocks. Figure 4.9 demonstrates the flowchart of the SOGA process for solar radiation. This loop continues until the objective function value is reached or maximum production is reached (Yi and Malkawi, 2012).

The overall process such as geometric representation, Ladybug simulation, and GA optimization are shown in Figure 4.10. This process is explained in detail in the fifth chapter. Table 4.2 demonstrates three outcomes from several optimizations of maximizing solar radiation for each block by using Galapagos in the Grasshopper component.

Table 4.2 : Outcomes from several optimizations of maximizing solar radiation for each block

Location Change From Base Case	Block 1	Block 2
Moves Along X Axis	-1	0.6
Moves Along Y Axis	-0.3	-0.7
Angle of Rotation	341	-273

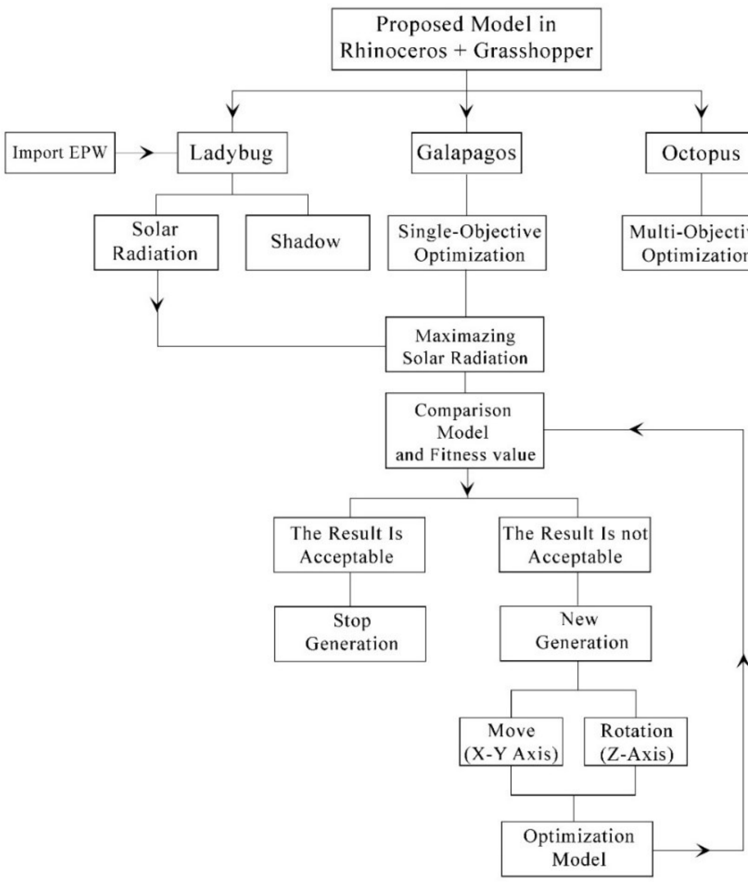


Figure 4.9 : Flowchart of GA for Single-Objective solar radiation(Drawn by the author).

The result of solar radiation optimization shows that block 1 rotated 341 degree, displaced to the (-1.00,-0.30) position, and block 2 rotated -273 degree and displaced to the (0.6,-0.7) position. The solar radiation value after optimization for block 1 is

40.59 kWh/m^2 and for block 2 is 43.74 kWh/ m^2. The solar radiation value for block 1 increased by 3.46% and block 2 increased by 7.76% (table 4.3). The result of optimization shows that total solar radiation can increase up to 8.71 %, which leads to energy saving in winter semester.

Table 4.3 : The result of solar radiation optimization

Measurement of solar radiation (kWh/m2)	Before Optimization	After Optimization	Percentage
Block 1	39.23	40.59	3.46%
Block 2	38.33	43.74	7.76%
Total Radisation	77.57	84.33	8.71%

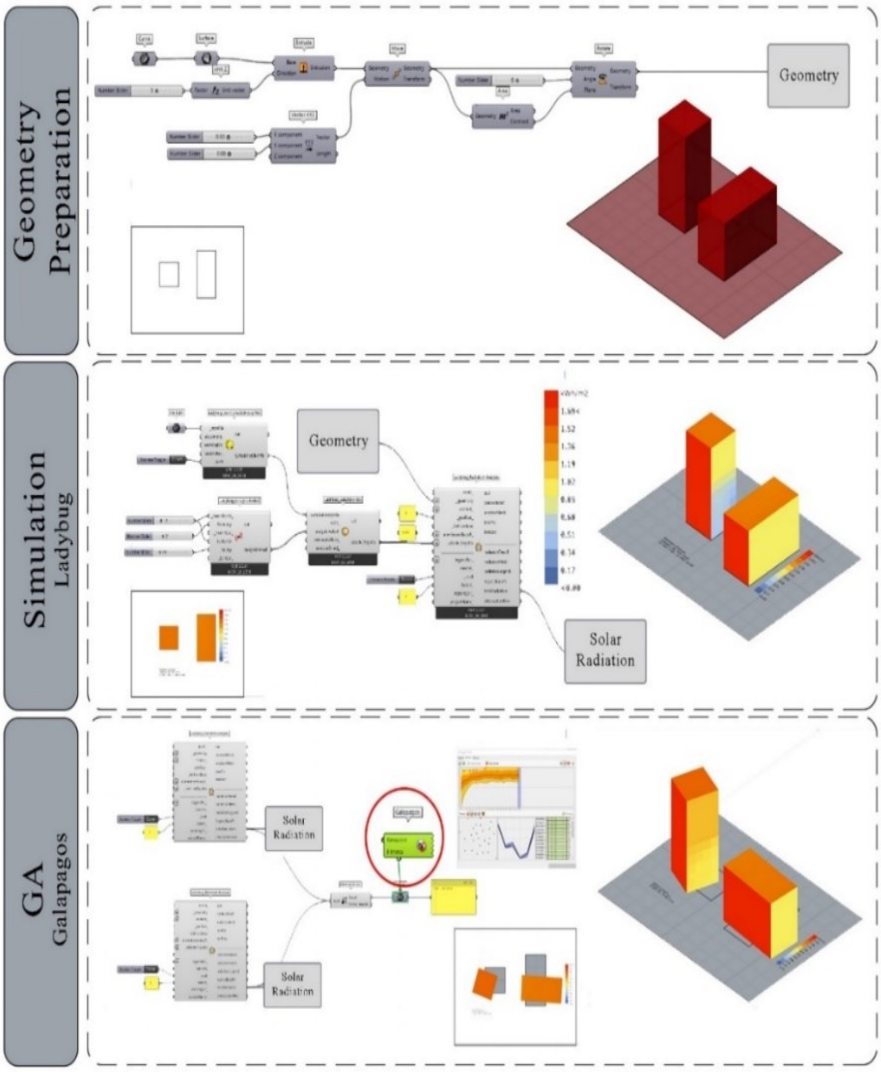


Figure 4.10 : Single objective GA optimization for Solar Radiation process(Drawn by the author).

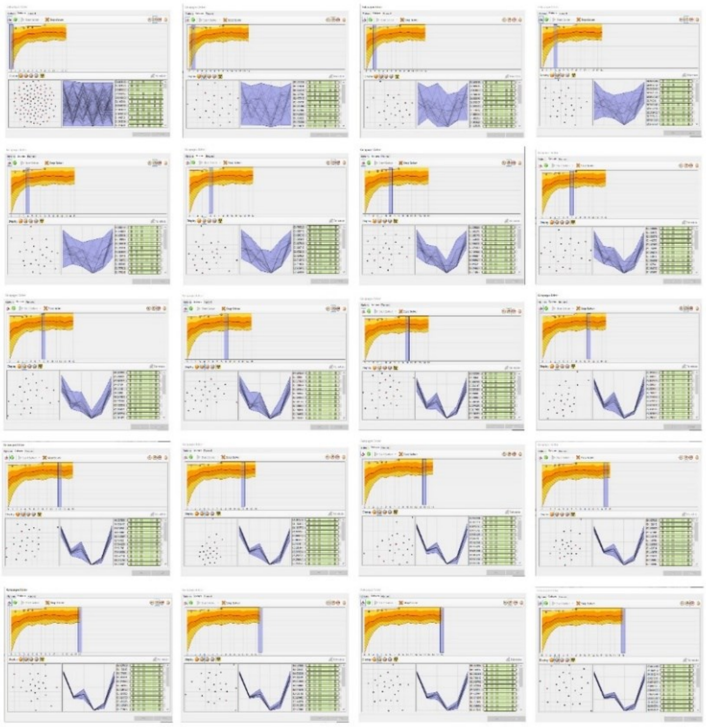


Figure 4.11 : Solar Radiation optimization process in Galapagos plugin.

4.2.2 Optimization via GA for single-objective: shadow

In Energy Plus weather data, which is imported to ladybug, there is a shadow study by utilizing ladybug's sun path and sunlight hours to identify the shadow on vertical surfaces of blocks. As to be expected, the Sun is lower in the sky during the winter semester, which creates larger shadows that leads to making energy consumption of buildings for heating (Nikoofard et al., 2011). In this section, the shadow area for each block is calculated by using shadow studies in the ladybug component for Istanbul weather on December 21st. The total Shadow area for two blocks is 14.30 m^2.

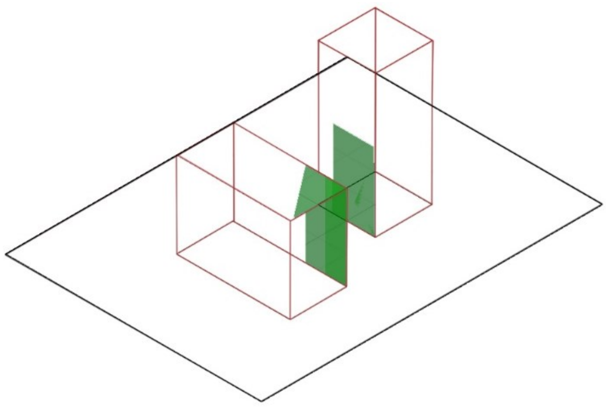


Figure 4.12 : Shadow area for each block for İstanbul weather on December 21st.

In this part of the study, the main purpose of using the Genetic algorithm is minimizing the shadow for the winter semester. Therefore, single-objective optimization is applied in the Galapagos plugin for minimizing fitness function. The variables for minimizing shadow are the same as previous optimization. The first variable is movement along the x-y axis with displacement of (-1, 1) for each block. The latter is a rotation without any limiting angle around the z-axis. The optimization result shows that the total shadow area for these two blocks has been reduced to 0.12 m^2.

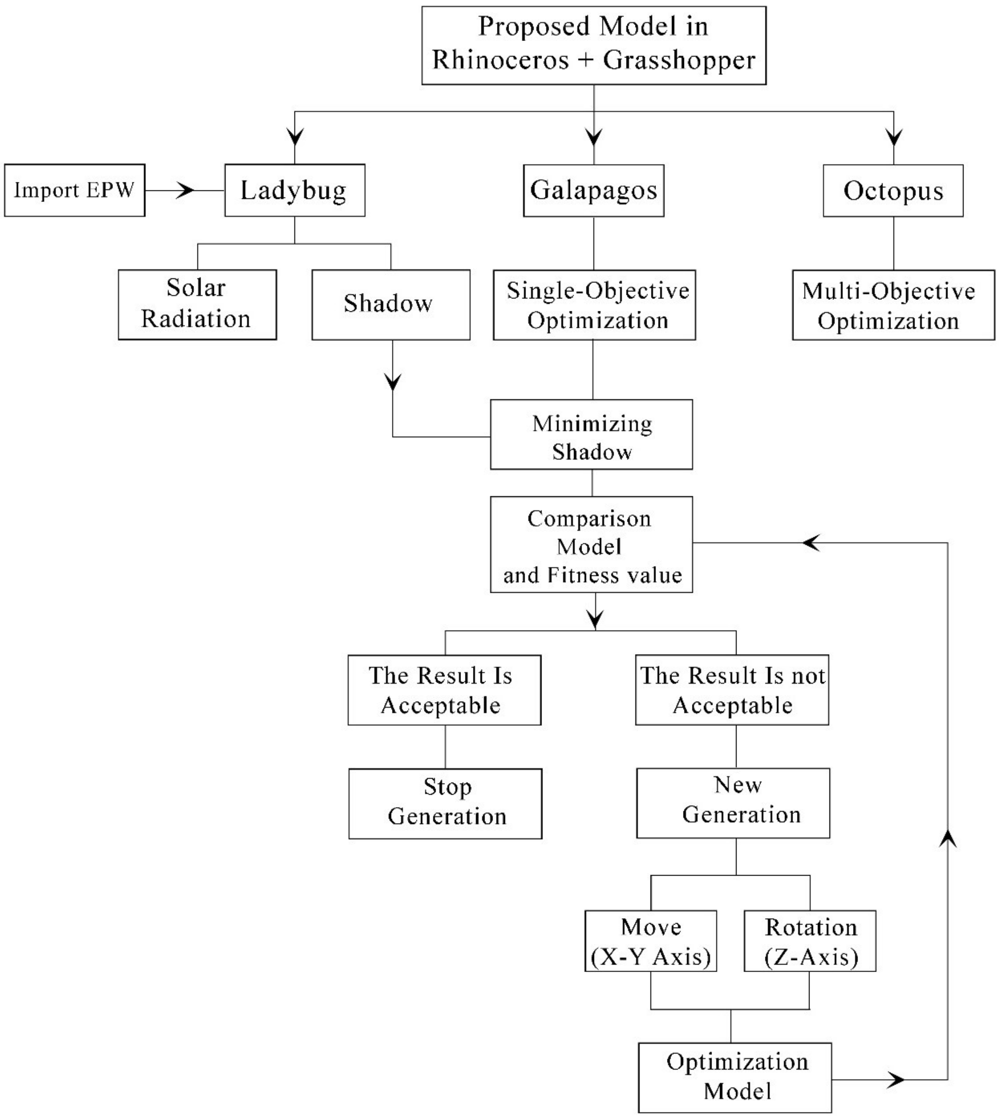


Figure 4.13 : Flowchart of GA for single objective shadow(Drawn by the author).

The result of Shadow optimization shows that block 1 rotated 125 degree, displaced to the (-0.95 ,0.07) position, and block 2 rotated -288 degree, displaced to the (0.92,0.46) position (table 4.4). The optimization result shows that the total shadow area for these two blocks has been reduced to 0.37 m^2 (97.41 %) which leads to affect the energy consuming for indoor spaces.

Table 4.4 : Outcomes from several optimizations of minimizing Shadow for each block

Location Change From Base Case	Block 1	Block 2
Moves Along X Axis	-0.95	0.92
Moves Along Y Axis	0.07	0.46
Angle of Rotation	125	-288

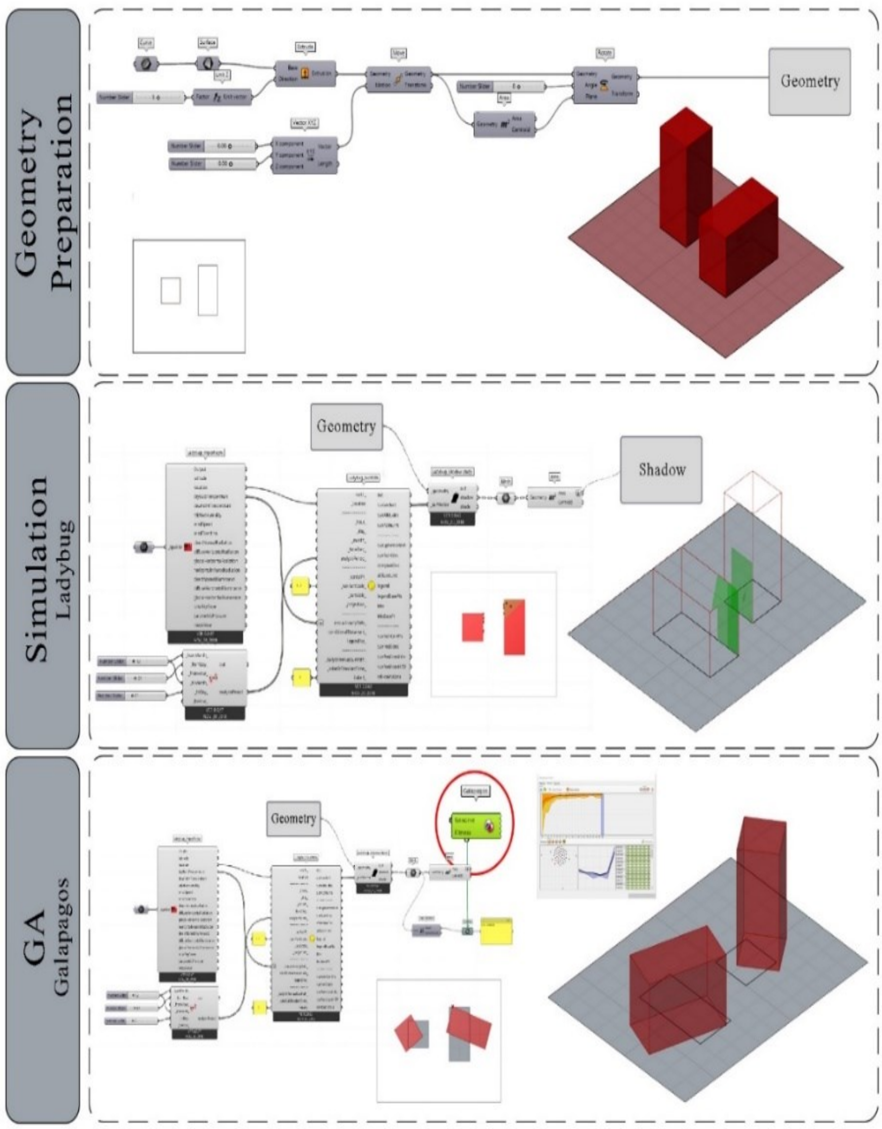


Figure 4.14 : Single objective GA optimization for Shadow process(Drawn by the author).

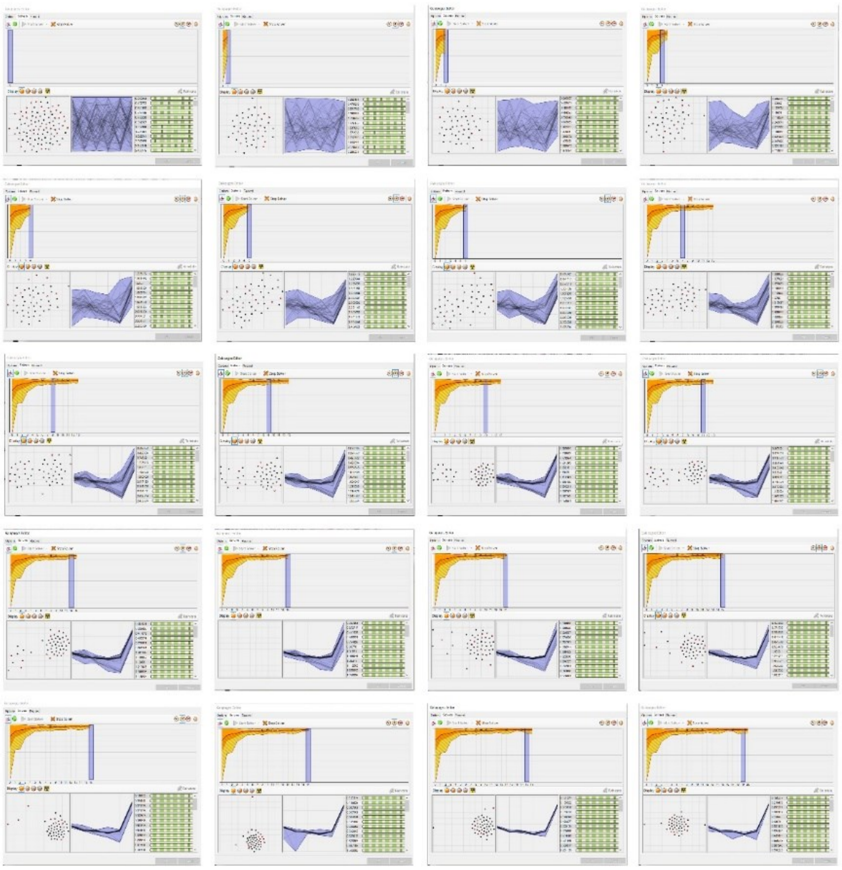


Figure 4.15 : Shadow optimization process in Galapagos plugin.

4.2.3 Optimization via GA for multi-objective:solar radiation and shadow

Unlike SOGA, MOGA is not a single point of form protection function, it's from the point family known as the pareto-optimal set (Obayashi, 1998). In this part of study, multi-objective GA is applied to obtain the trade-offs between shadow and solar radiation. Therefore, Octopus (version 0.4) add-on ,which Robert Vierlinger developed for Grasshopper, is utilized for applying Multi-objective GA (Vierlinger et. al, 2013) (http:// www.food4rhino.com/project/octopus). Octopus applies the evolutionary process for finding a solution that allows for the production of a set of trade-off solutions among each objective (Zhang et al., 2016). The first implementation of this mechanism was the work of Christoph Zimmel, who wrote a loop for Grasshopper. In addition, Octopus ensures that the entire optimization process to be visual, which creates a 3D model for each solution, and controls them. Unlike Galapagos, the Octopus plugin represents a solution space in a 3D environment in which the number of objectives can be two- to five-dimensional (Figure 4.16).

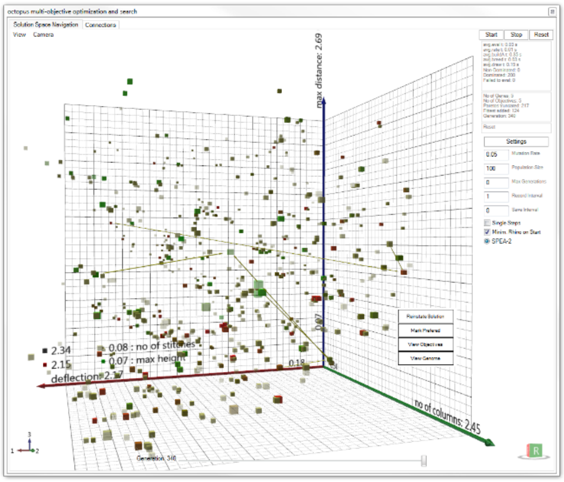


Figure 4.16: The interface of Octopus (url-1).

The first three objectives indicate different X, Y, and Z axis and for the fourth and fifth objectives are represented by the color and size of cubes in octopus interface (Figure 4.16). The bottom portion of the Octopus interface shows the objective axis that has been labeled in Grasshopper. In this example, solar radiation is located on the axis 1 and shadow is located on the axis 2. Such as the previous optimization for Single-objective optimization in Galapagos, variables like move and rotation are used for MOGA in the Octopus plugin (Figure 4.17).

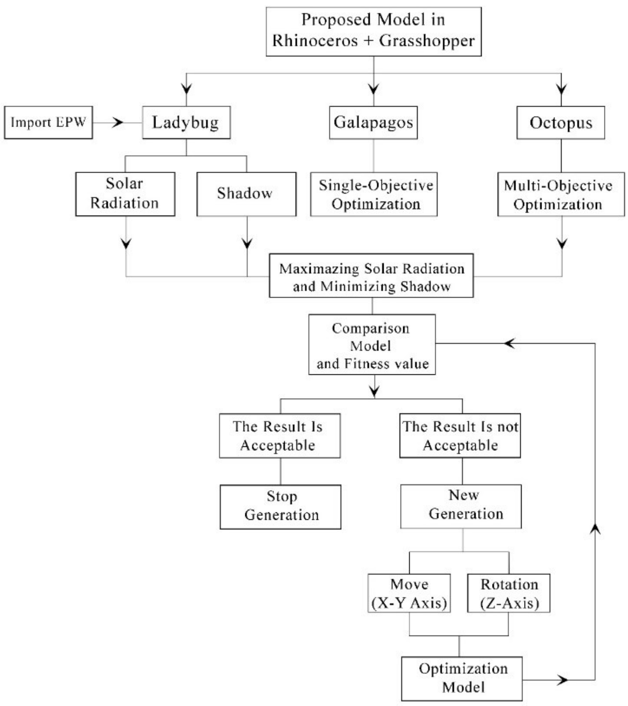


Figure 4.17 : Flowchart of GA for multi-objective optimization(Drawn by the author).

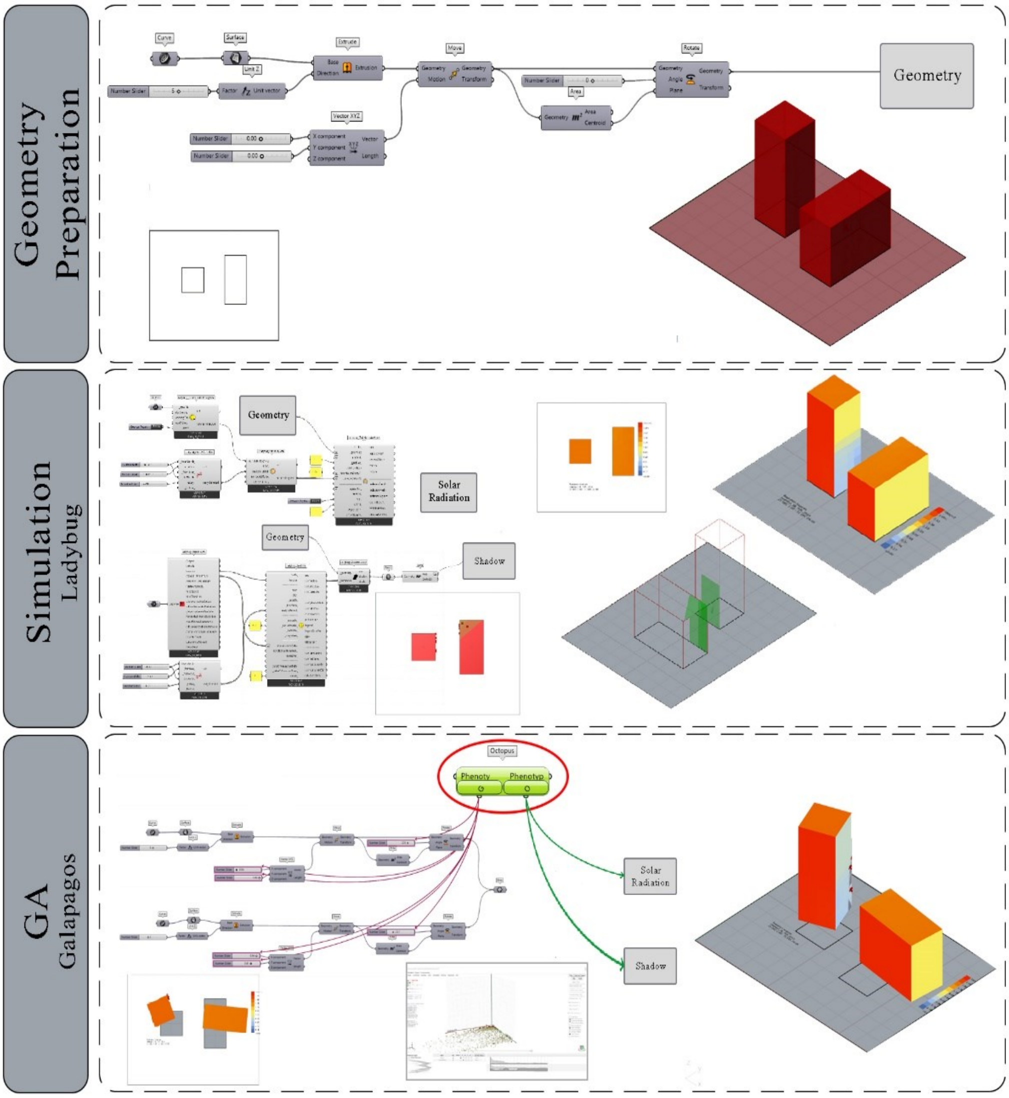


Figure 4.18 : Multi-objective GA optimization process(Drawn by the author).

The optimization result in MOGA optimization in Octopus plugin demonstrates that the total solar radiation has increased up to 84.09 Kwh/m2 and the total shadow area has been reduced to 1.11 m^2 for these two blocks (table 4.5). Figure 4.19 indicates the optimization process in octopus interface and in figure 4.18 shows the last position of blocks after optimization.

Table 4.5 : The result of multi-objective optimization.

Parameters	Before Optimization	After Optimization	Percentage
Solar Radiation	77.57	84.09	8.40% (increase)
Shadow	14.30	1.11	92.23% (decrease)

Figure 4.19 : MOGA Optimization process in octopus interface.

Table 4.6 : Outcomes from several optimizations of MOGA.

Location Change From Base Case	Block 1	Block 2
Moves Along X Axis	-0.94	0.94
Moves Along Y Axis	1.00	0.41
Angle of Rotation	210	-275

4.3Comparison Of SOGA And MOGA

In this example, Genetic Algorithm solvers such as Galapagos and Octopus plugins have been used to maximize solar radiation and minimize shadow. In this context, Comparison between SOGA and MOGA proceeds as follows:

Galapagos is a plug-in for SOGA optimization in which solution space is 2D. On the other hand, Octopus is a plugin for MOGA optimization in which solution space is 3D. In Galapagos, a single objective is chosen to maximize or minimize, but Octopus is chosen for multiple objectives, some of them for maximizing and others for minimizing. Galapagos and Octopus are optimization tools to find the best solution, but Octopus needs more optimization process time than Galapagos due to evaluating more than one objective. Octopus needs more generation than Galapagos to reach fitness function.

Table 4.7 : The result of GA optimization for Solar Radiation and Shadow.

Parameters	Before Optimization	SOGA For Solar Radiation (Galapagos)	SOGA For Shadow (Galapagos)	MOGA For Solar Radiation and Shadow (Octopus)
Solar Radiation	77.57	84.33	-	84.09
Shadow	14.30	-	0.37	1.11

5. USING OPTIMIZATION FOR SITE LAYOUT PLANNING: TOKI AS A CASE STUDY

TOKI is one of the public housing development institutions since 1984 in Turkey (Url-2). studies indicated that the majority of residents (70%) choose TOKI for economic reasons (Gür and Dostoglu, 2011). In addition, the goal of TOKI is to provide 5-10% of Turkey's housing needs through the rapid production of housing (Url-2). In addition, housing planning and design are based on standard plans repeated in many locations and environments in TOKI projects (Çalştay, 2009). The main reason for choosing TOKI as a case study is that similar block types in different locations are produced quickly and affordable to buy for low and middle-income target groups who cannot buy a house under current market conditions.

In this context, the placement of blocks is optimized in a site plan by using GA. In this study, two TOKI houses were selected for the optimization process. The reason for selecting Istanbul and Gaziantep TOK residential for the case study is that they have similar block types (B1 and C1) in different locations and climates. TOKI Ayazma which is located in Istanbul has 7 blocks; 5 blocks are B1 type and 2 blocks are C1 type. On the other hand, there are 18 blocks in TOKI Şahinbey located in Gaziantep; 10 blocks are B1 type and 8 blocks are C1 type. Table 5.1 indicates a brief description of the TOKI projects data. Case studies data files were obtained with DWG format from TOKI institutions in Istanbul. Figure 5.2 demonstrates the B1 and C1 plan types which have had minor changes with the passing of time such as slight differences in the style of the toilets.

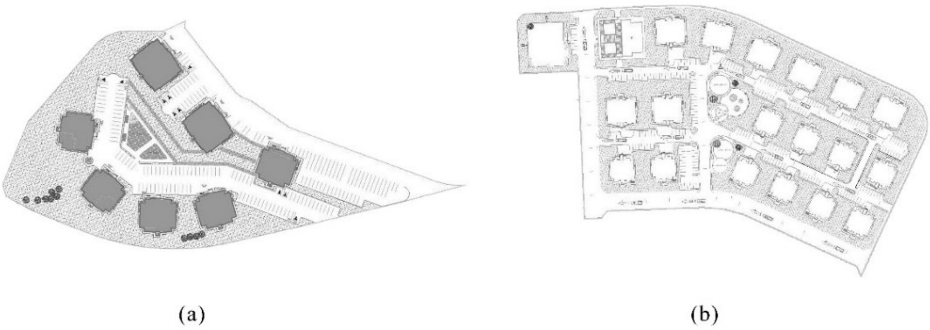


Figure 5.1 : Site plan of case studies , (a) : TOKI Ayazma / Istanbul-Başakşehir . (b) : TOK Şahinbey / Gaziantep (data files were obtained to DWG format from TOKI institutions in Istanbul, date retrieved 02.07.2019).

Table 5.1 : case study data.

TOKI projects	Location	B1 (block type)	C1 (block type)	Number of residences
Ayazma	Istanbul /Basaksehir	10	8	643
Sahin bey	Gaziantep	5	2	196

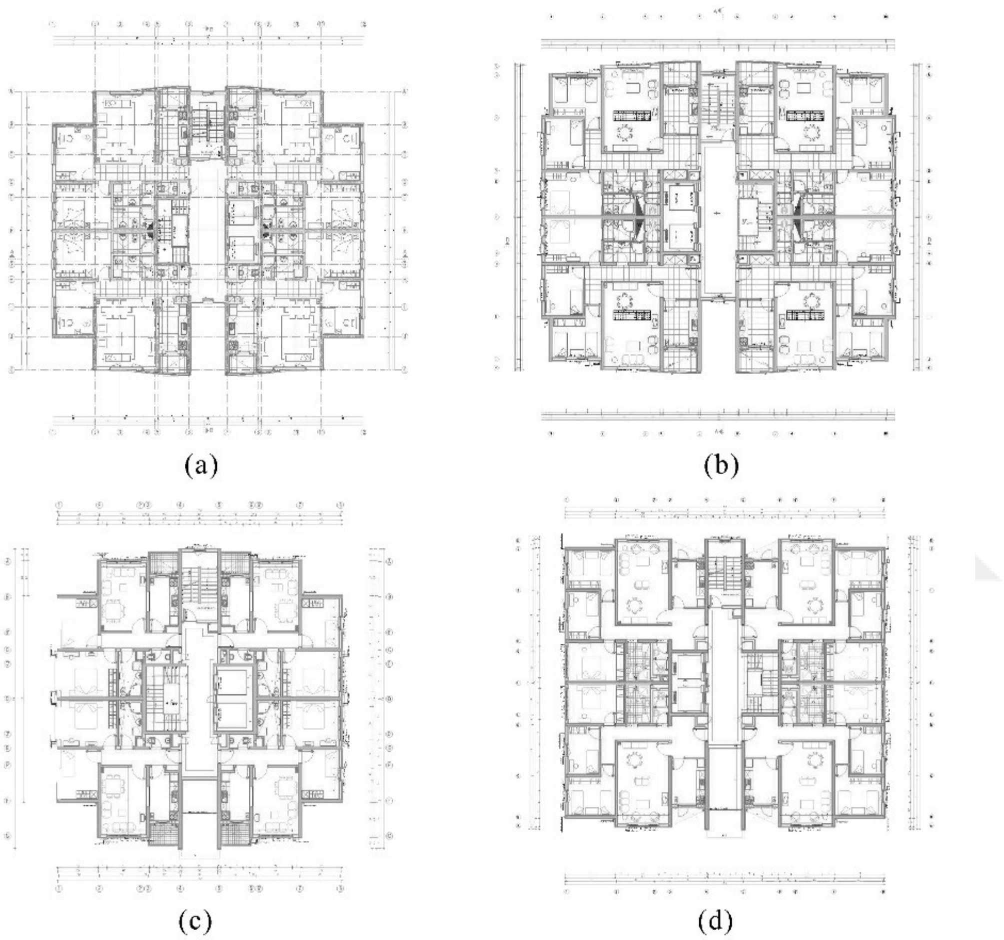


Figure 5.2: Plan types : (a) Ayazma B1 plan type , (b) Ayazma C1 plan type , (c) Şahinbey B1 plan type , (d) Şahinbey C1 plan type (data files were obtained documents with DWG format from TOKI institutions in Istanbul, date retrieved 02.07.2019).

In the first part of the study, AutoCAD files were imported to Rhino 6, and outlines of blocks were drawn as approximate shape polylines. Then a surface from curves was drawn, and extruded for simulation. Solar radiation and shadow were calculated for each block by using the Ladybug plugin in Grasshopper. After these analyses, variables such as move and rotation are defined in GA to optimize the placement of blocks for maximizing solar radiation and minimizing shadow(Table 5.2).

Table 5.2 : Site layout planning optimization process.

Input	Operation	Outcome
Curves (Blocks)	Extrude	3D Model
Import Epw	Ladybug-Solar Radiation	Solar Radiation (Kwh/m2)
Analysis Period	Ladybug-Shadow	Shadow (M2)
Move	Octopus (MOGA)	Relocation Of Blocks
Rotate		

In both case studies, the number and location of blocks were predetermined. On the other hand, the blocks are presented in approximate geometry, such as rectangles to minimize optimization time. In both case studies, change in time in site layout planning is static. Also, the location of blocks were predetermined and the blocks are presented in approximate geometry, such as 3D cube to minimize optimization time. On the other hand, the movement of blocks for the optimization process is vector-based. Table 5.3 indicates the case study parameters based on criteria which discussed in chapter two.

Table 5.3 : Case Study Parameters.

	Mobility in time		Shape Representation			Dimension Of Shape		Site Layout	
	Static	Dynamic	Meta Shape	Approximate	Analog	2D	3D	Matric	Vector
Case Study	•			•			•		•

5.1 TOKI Ayazma Başakşehir

TOKI Ayazma is one of the public housing developments which has 7 blocks and 196 apartments in Istanbul, Turkey. Istanbul is a major and old city in Turkey where Europe and Asia intertwine. Also, Istanbul has been focusing on migration since the 1950s (Demir & Yilmaz, 2012). Figure 5.3 shows Istanbul on the map of Turkey and the location of TOKI AYAZMA project. The location of TOKI Ayazma is at Istanbul which is close to both Olympics Park and the biggest organized industrial zone of Turkey.

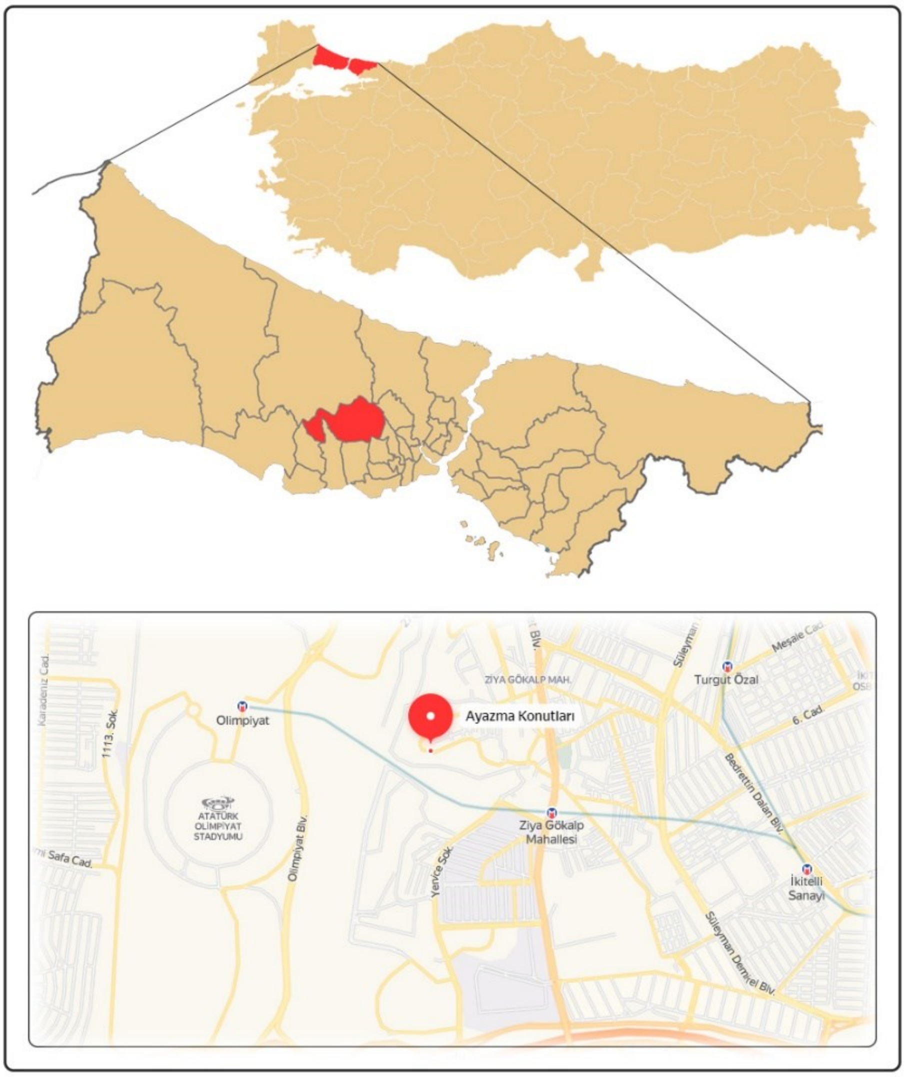


Figure 5.3 : Toki Ayazma on map.

5.1.1 TOKI Ayazma’s solar radiation and shadow study

Solar radiation is an important factor for thermal comfort and energy consumption of buildings (Roudsari, & Smith, 2013). In this study, the weather file of Istanbul was downloaded from the Energy Plus website (.EPW) and imported to Ladybug for information of the weather and of the location and to calculate the solar radiation and shadow (figure 5.5). Figure 5.6 indicates several components of Ladybug in Grasshopper / Rhino.

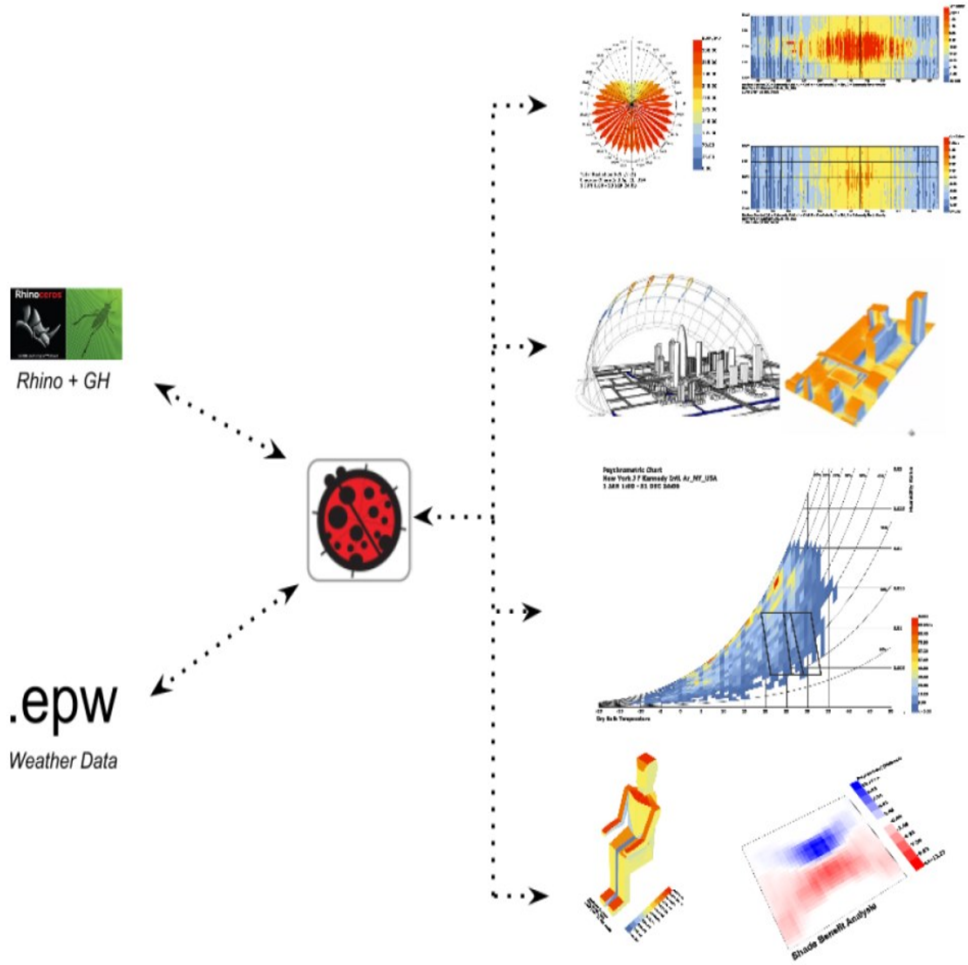


Figure 5.4 : Ladybug Plugin For Grasshopper (Url- 3).

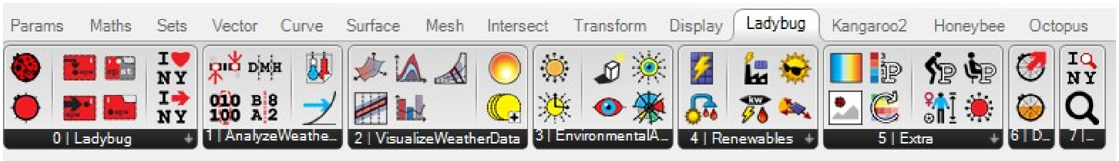


Figure 5.5 : Ladybug Components.

The first step of sun analysis, defining the total solar radiation and sun path by using Ladybug components. Ladybug provides different diagrams for radiation such as Sky Dome, Radiation Rose, etc. Figure 5.6 indicates the Radiation Rose diagram in ladybug on 21 December by utilizing different components of ladybug such as Gen Cumulative SkyMtx, SkyMtx, Radiation Rose and Analysis Period for a specific period of time.

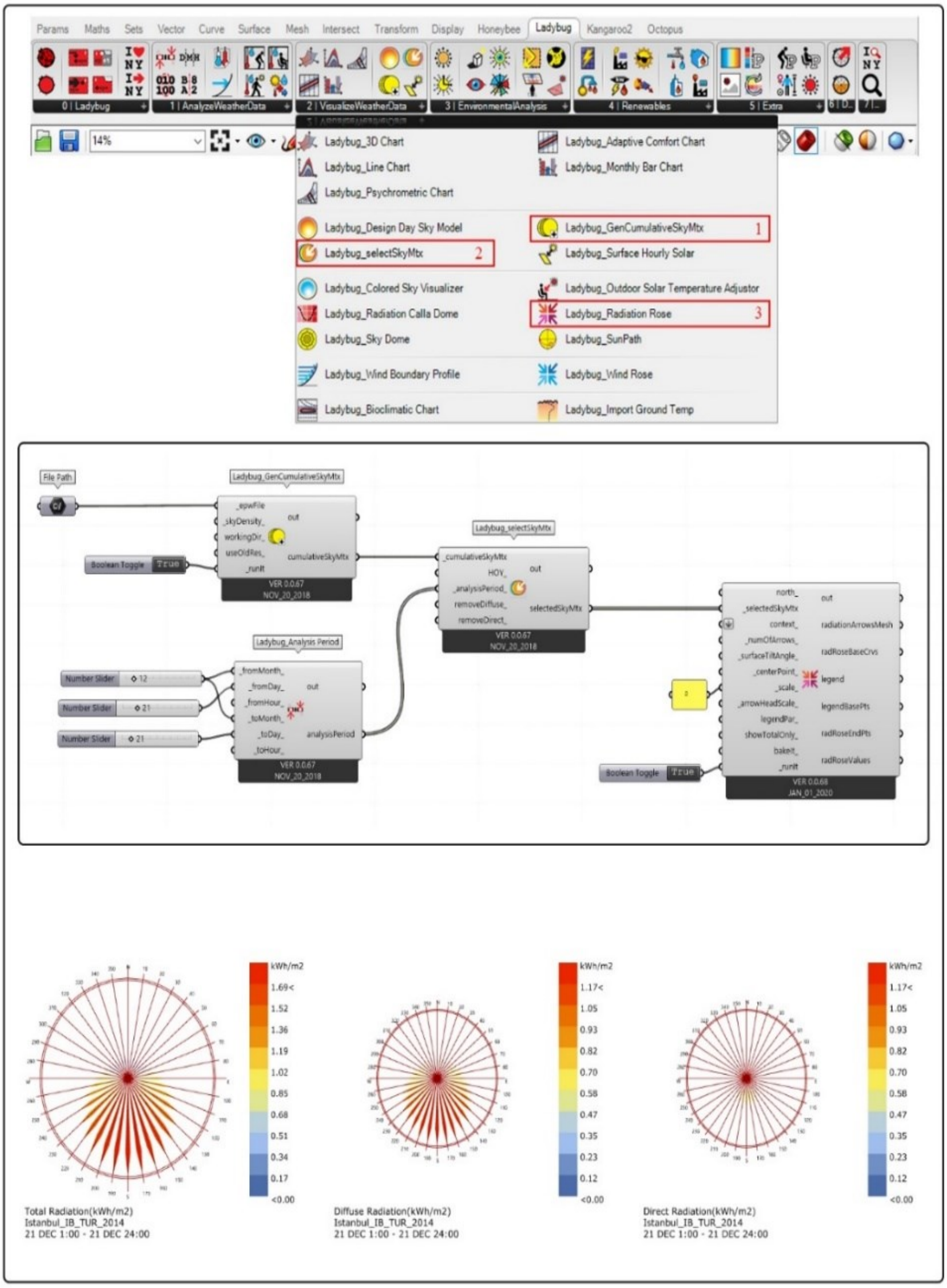


Figure 5.6 : Ladybug Radiation Rose.

Ladybug Radiation components create 3d graphs of radiation on a surface of blocks and calculate the total solar radiation for each block. Figure 5.7 indicates the calculation of solar radiation for one of the blocks of TOKI Ayazma.

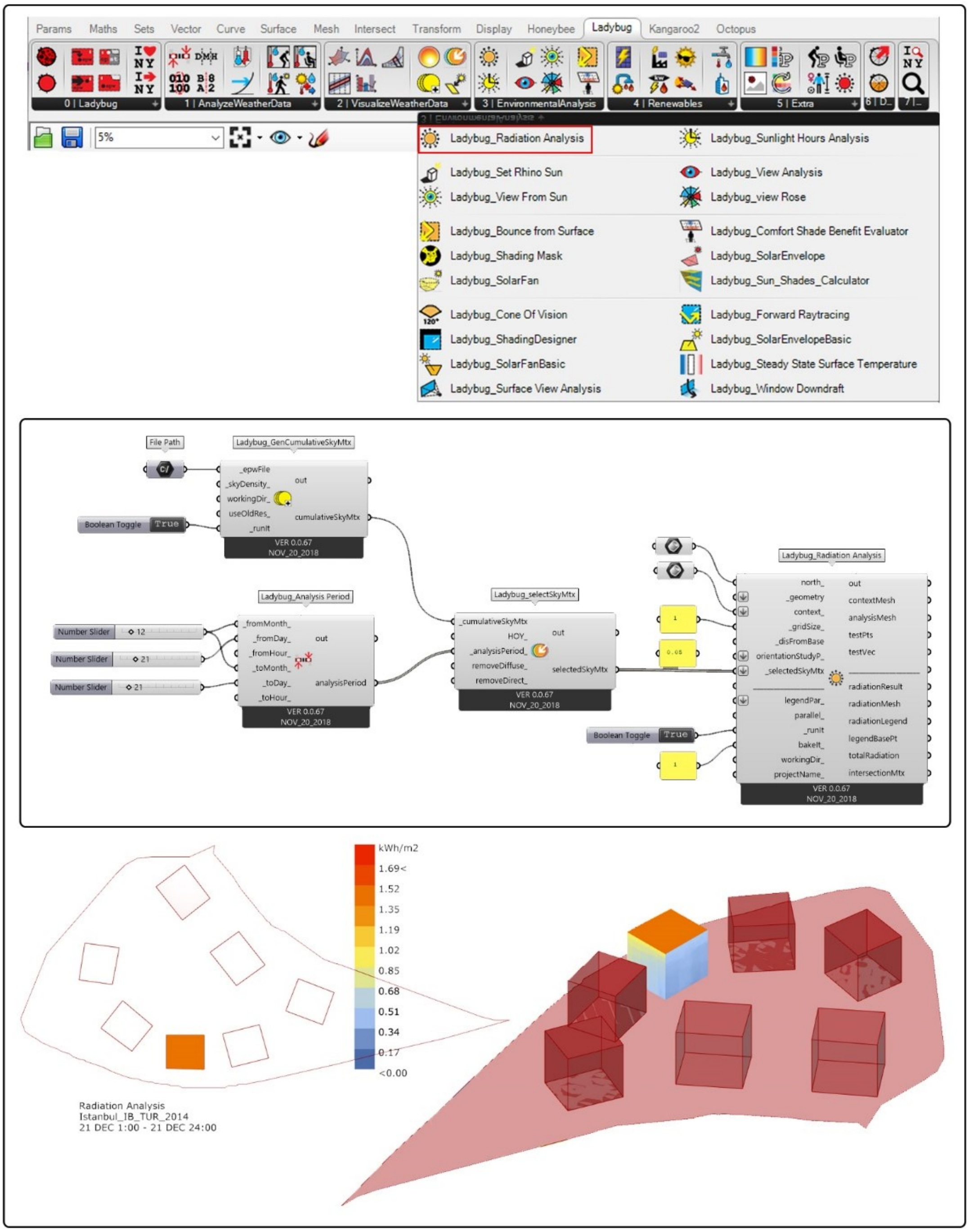


Figure 5.7 : Solar Radiation of one of the Ayazma blocks.

Figure 5.8 shows the site layout planning of the TOKI Ayazma project and table 5.4 demonstrates the type of plans, floors and solar radiation for each apartment block. The solar radiation gain is calculated by Ladybug's Radiation Analysis component in grasshopper, that the total solar radiation in TOKI Ayazma blocks is 15609.40 Kwh/m^2 on 21^{st} of December.

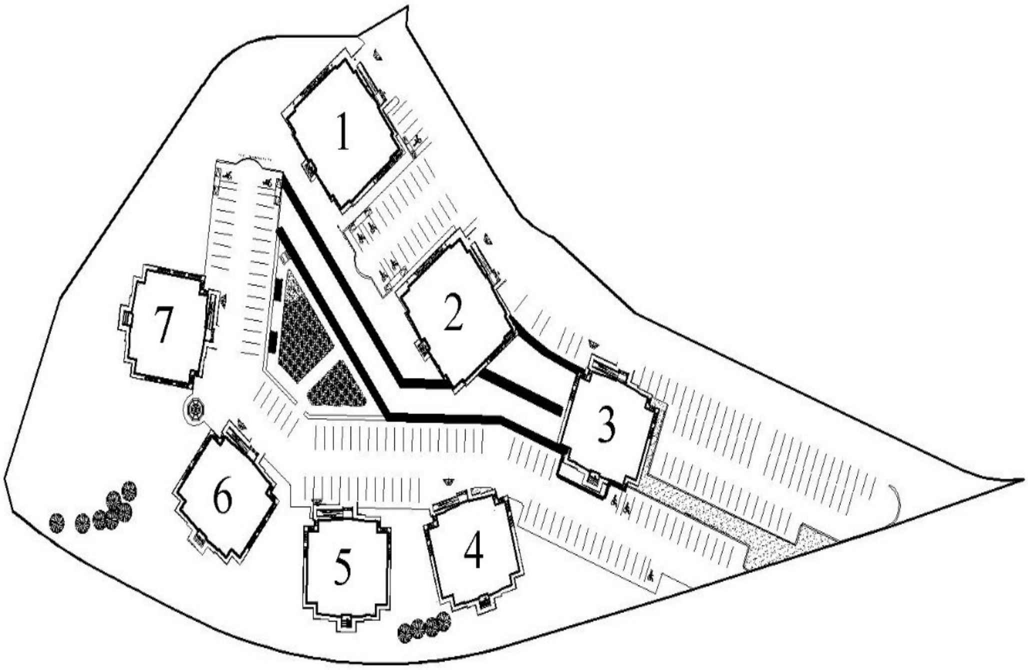


Figure 5.8 : Site layout planning of TOKI Ayazma

Table 5.4: A brief description of the TOKI Ayazma projects data.

Blocks	Type	Floor	Solar Radiation
Block 1	C	6	2472.23
Block 2	C	6	2380.11
Block 3	B	6	2435.32
Block 4	B	5	2129.81
Block 5	B	5	2118.35
Block 6	B	5	2127.13
Block 7	B	5	1946.43
Total			15609.40

Shadow is another significant factor for using solar energy as a renewable resource for reducing energy consumption during winter. The sun vector in Ladybug is used to analyze sunlight period and calculate shadow areas on vertical surfaces with the other components. Figure 5.9 shows the Sun path component, which needs the Epw file and analysis period inputs to make a three-dimensional sun path into the Rhino scene.

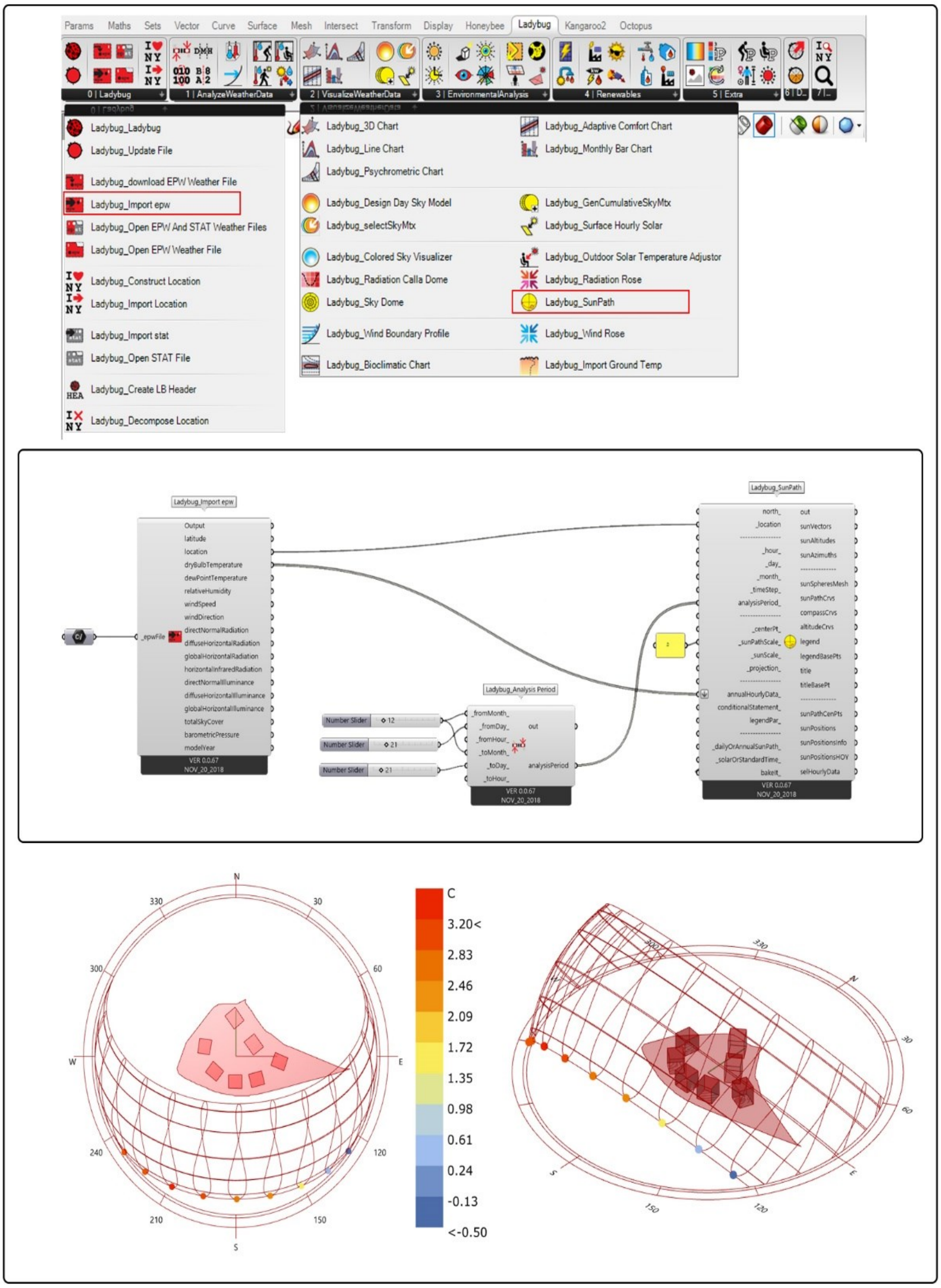


Figure 5.9 : Ladybug Sun Path(Drawn by the author).

Ladybug Shadow study component calculates shadows by inputting geometry and sun vector which is the output of ladybug's sun path component. Shadow output in the Shadow study component represents the shadows cast by the individual input Breps on other input Breps. The total shadow area on the vertical surface of the TOKI Ayazma blocks on 21st of December is 10736.71 m^2 (Figure 5.10).

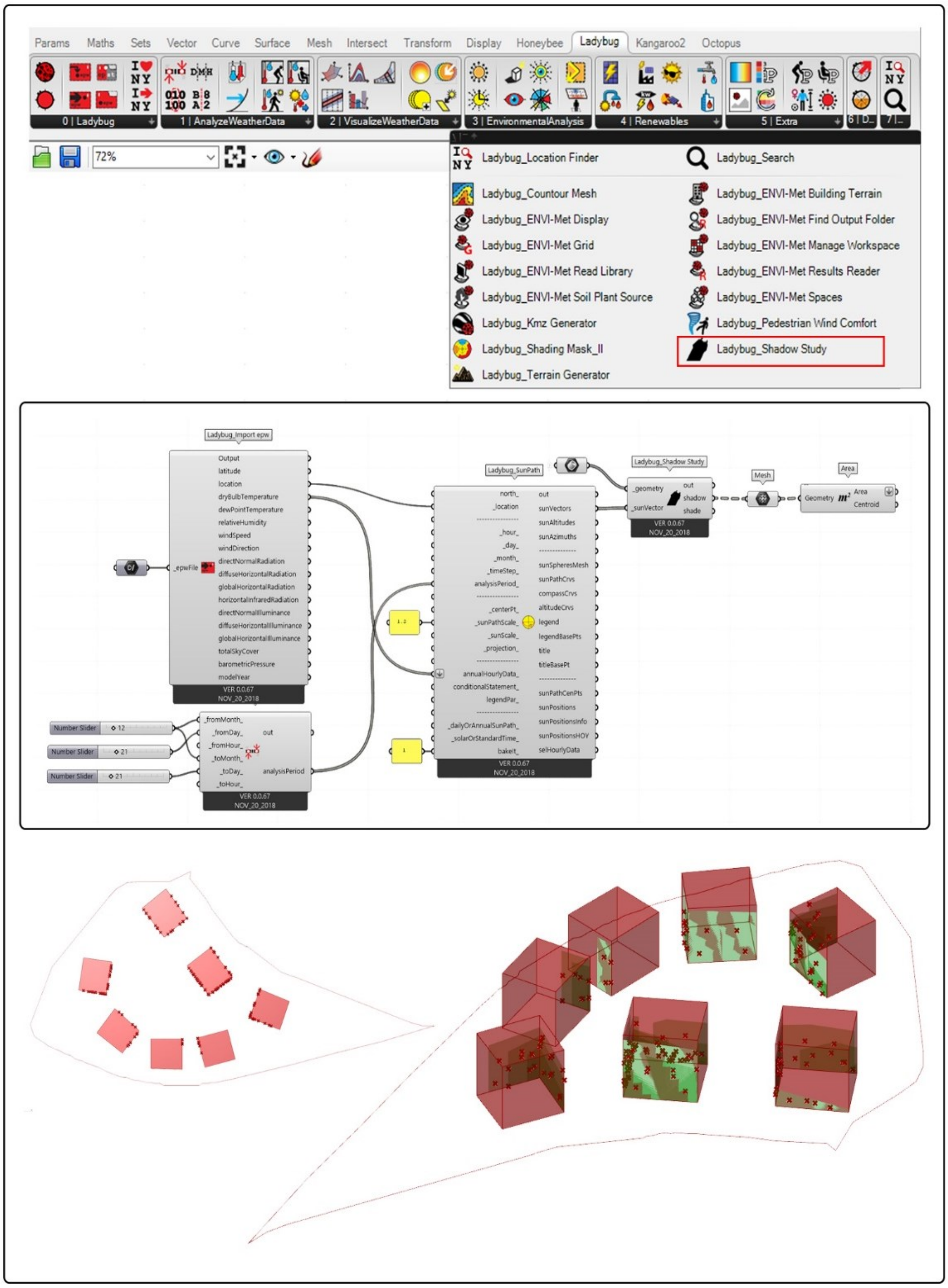


Figure 5.10: Ladybug Shadow Analysis for TOKI Ayazma Blocks(Drawn by the author).

5.1.2 Optimization of site layout planning in TOKI Ayazma

Octopus, which is a Multi-Objective GA Component in Grasshopper plugin was utilized to optimize the position of building blocks in site layout planning. In this part, two structure parameters were selected to optimize the placement of blocks: (1)

maximizing solar radiation (2): minimizing shadow on 21st of December. On the other hand, two variables are defined for multi-objective optimization. Figure 5.11 indicates the Octopus plugin in grasshopper in which variables connect to the genome input. The first one is a move that is transformed in the x-y axis and the magnitude of the displacement of each block is (-3.0, 3.0). The latter is rotation, that rotates every 5 degree. The main purpose of limiting movement and rotation data is to reduce the optimization time. The structure parameters connect to the fitness input (Figure 5.12).

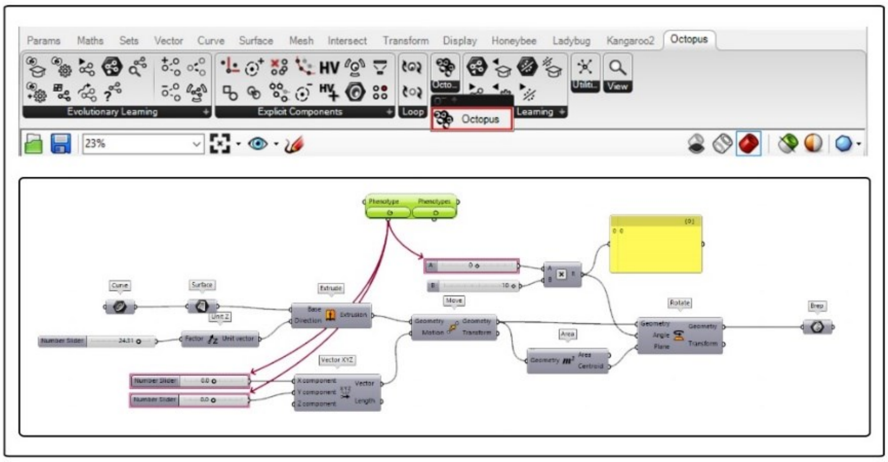


Figure 5.11 : Octopus Component in Grasshopper.

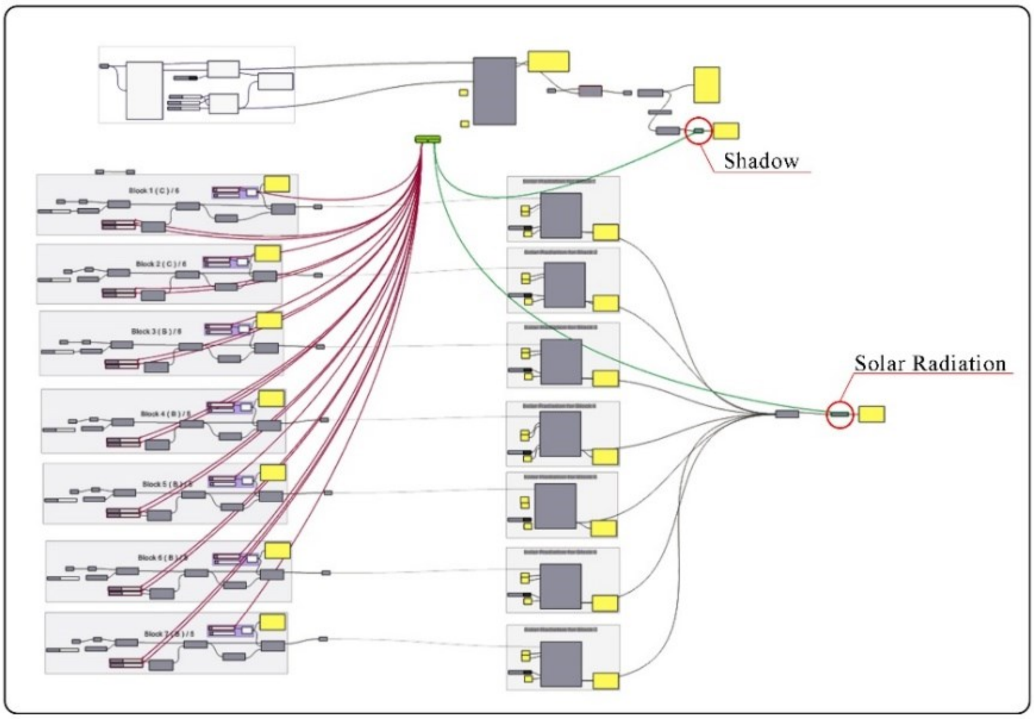


Figure 5.12 : Connecting parameters to the fitness input.

During this process, to implement the multi-objective GA optimization, we use the Octopus plug-in in Grasshopper, Rhino. Fig. 5.13 demonstrates four screen-captures of Octopus' interface for 1, 15, 20 and 24 generations, with a population size of 100. Integrating Ladybug with Octopus helps users to constitute and run a multi-objective performance form optimization in Grasshopper. The multi-objective GA optimization after 24 generation results indicate that the total solar radiation has increased up to 15973.76 Kwh/m^2 (+2.33 %) and the total Shadow area has been reduced to 5202.87 m^2 for each block (- 51.54 %). Table 5.15 shows the movement, rotation and solar radiation of each block after optimization in Octopus plugin.

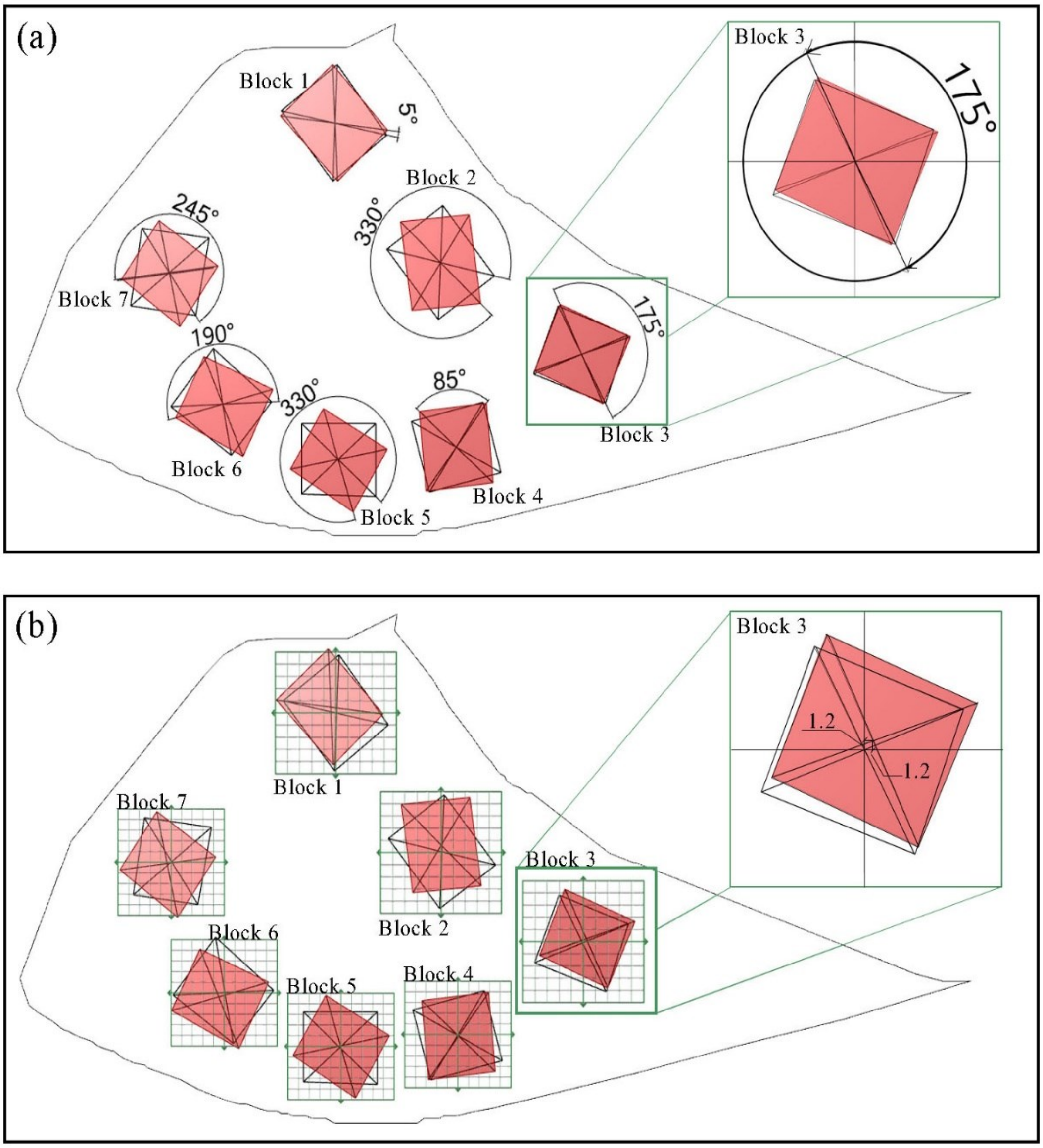


Figure 5.13 : GA optimization process for Toki Ayazma; (a):Rotation, (b): movement(Drawn by the author).

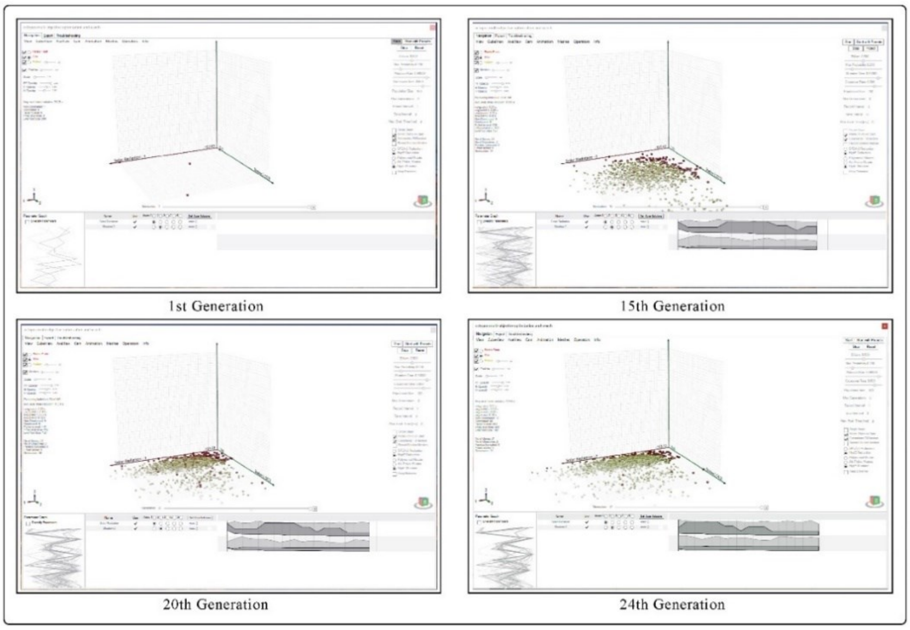


Figure 5.14 : GA generations for TOKI Ayazma.

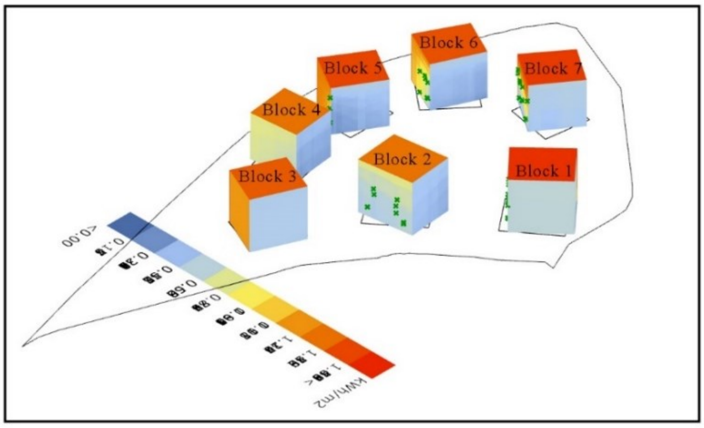


Figure 5.15 : Site layout planning after optimization for TOKI Ayazma.

Table 5.5: Movement, rotation and solar Radiation of each block after optimization.

Blocks	Move X-Axis	Move Y-Axis	Rotate Z-Axis	Solar Radiation (Before Optimization)	Solar Radiation (After Optimization)
Block 1	-1.9	1.7	5	2472.23	2494.41
Block 2	-0.2	1.9	330	2380.11	2378.75
Block 3	1.2	1.2	175	2435.32	2441.11
Block 4	0.3	-0.2	85	2129.81	2130.24
Block 5	0.2	0.5	330	2118.35	2418.29
Block 6	-1.9	-1.2	190	2127.13	2158.54
Block 7	-1.3	-0.5	245	1946.43	1952.42
Total				15609.40	15973.76

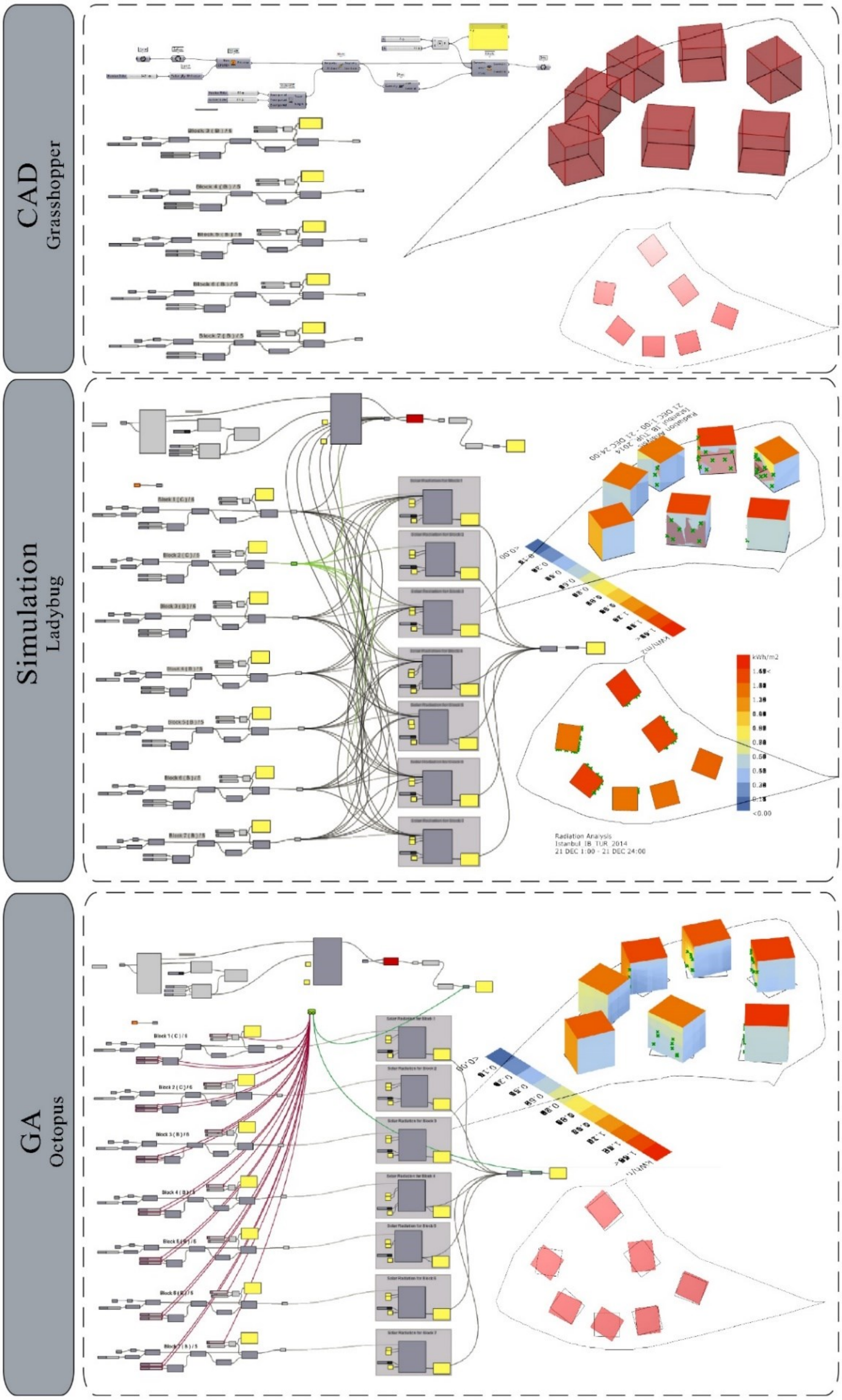


Figure 5.16 : Multi-objective GA optimization process for TOKI Ayazma(Drawn by the author).

5.2 TOKI Şahinbey Gaziantep

In this section, another case is examined with more blocks than TOKI Ayazma. TOKI Şahinbey has 18 blocks and 643 apartments in Gaziantep which is in southeastern Turkey near the border with Syria (Figure 5.15).

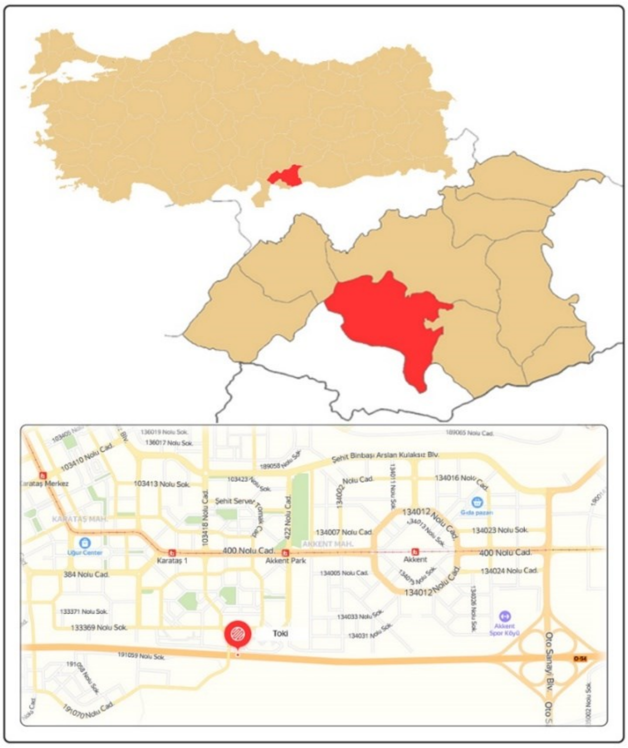


Figure 5.17 : Toki Şahinbey on map(Drawn by the author).

Figure 5.18 : 3D Render of TOKI Şahinbey (Url-4).

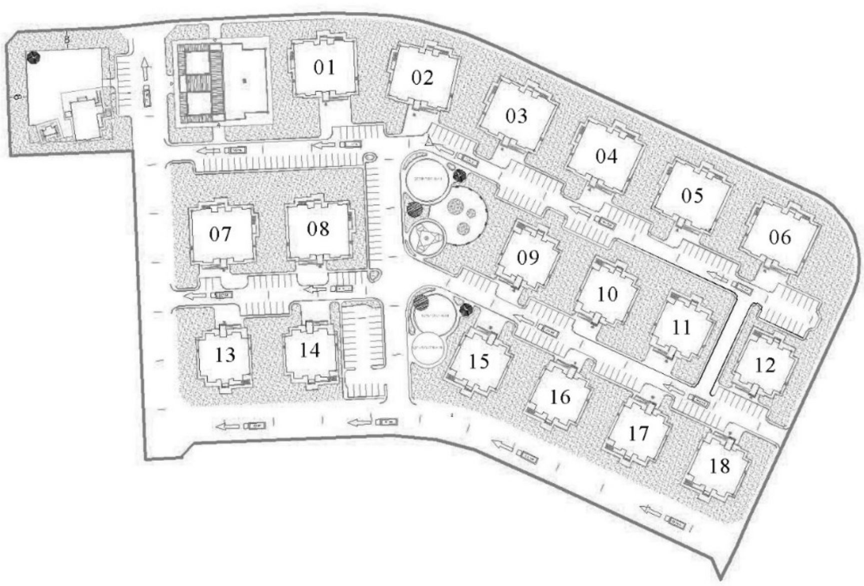


Figure 5.19 : Site layout planning of TOKI Şahinbey.

5.2.1 TOKI Şahinbey's solar radiation and shadow study

The site layout planning of TOKI Şahinbey which has 18 blocks (10 blocks are B1 type and 8 blocks are C1 type). Figure 5.17 indicates the sky dome diagram in ladybug on 21st of December by utilizing different components of ladybug in the case of Gaziantep's weather.

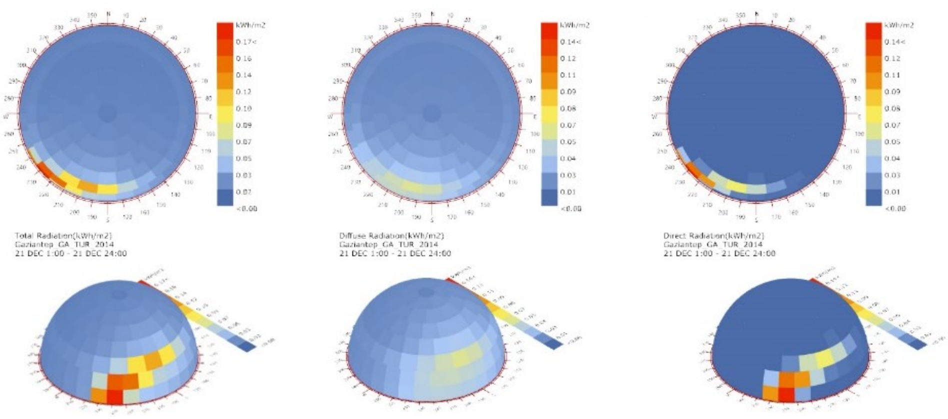


Figure 5.20 : Ladybug Sky-dome.

Figure 5.19 demonstrates the solar radiation calculation for one of the blocks of TOKI Şahinbey by utilizing Ladybug Radiation components. The type of each block, their floors, and solar radiation are shown in table 5.6.

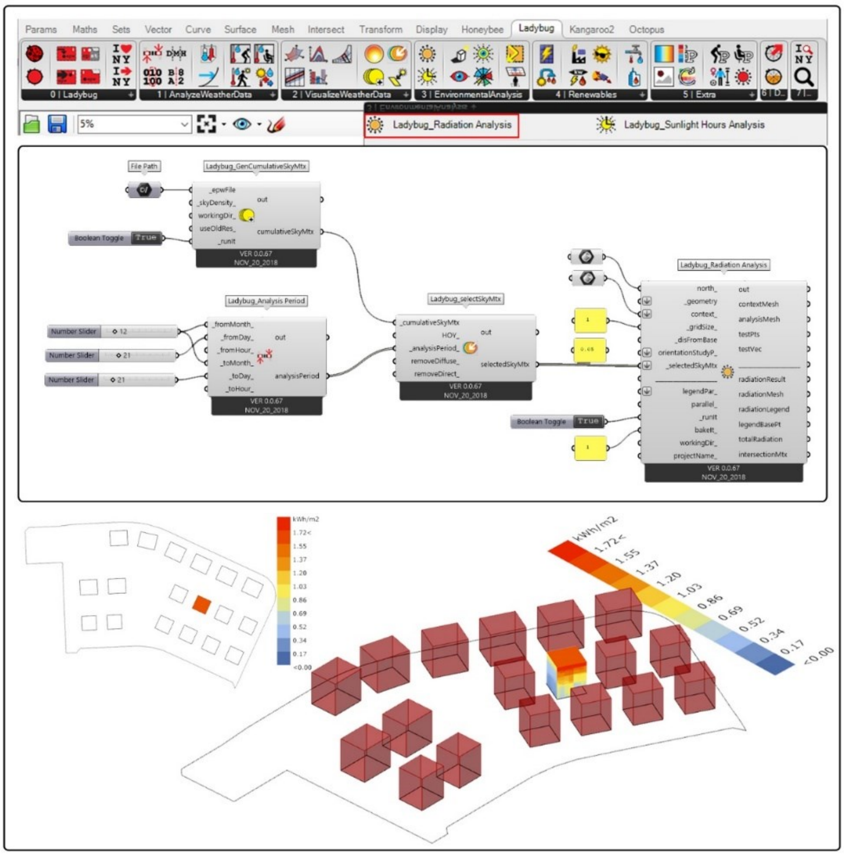


Figure 5.21 : solar radiation calculation for one of the blocks of TOKI Şahinbey.

Table 5.6 : A brief description of the TOKI Şahinbey projects data.

Blocks	Type	Floor	Solar Radiation
Block 1	C	8	2658.26
Block 2	C	8	2455.08
Block 3	C	8	2452.37
Block 4	C	8	2261.39
Block 5	C	8	2185.27
Block 6	C	8	2351.72
Block 7	C	8	2652.98
Block 8	C	8	2323.88
Block 9	B	8	1948.86
Block 10	B	8	1725.37
Block 11	B	8	1768.29
Block 12	B	8	1965.17
Block 13	B	8	2413.31
Block 14	B	8	2273.33
Block 15	B	8	2311.94
Block 16	B	8	2227.89
Block 17	B	8	2246.14
Block 18	B	8	2369.86
Total			40591.11

As demonstrated in Figure 5.20, 3D sun path is made by the sun path component in ladybug on 21st of December for the Gaziantep location. The total Shadow area which is calculated by Ladybug shadow component on vertical surfaces in TOKI Şahinbey at Gaziantep on 21st of December is 18407.74 m^2 (Figure 5.22).

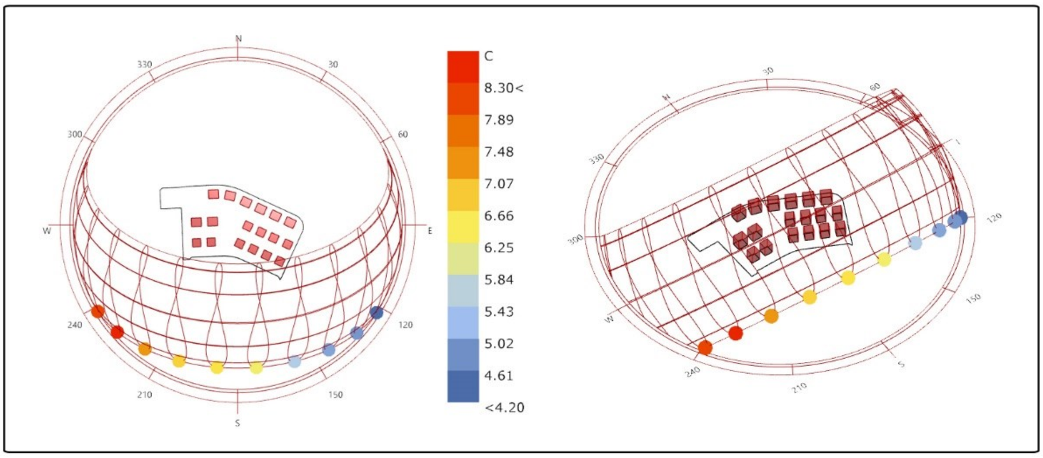


Figure 5.22 : Ladybug Sun Path for Gaziantep.

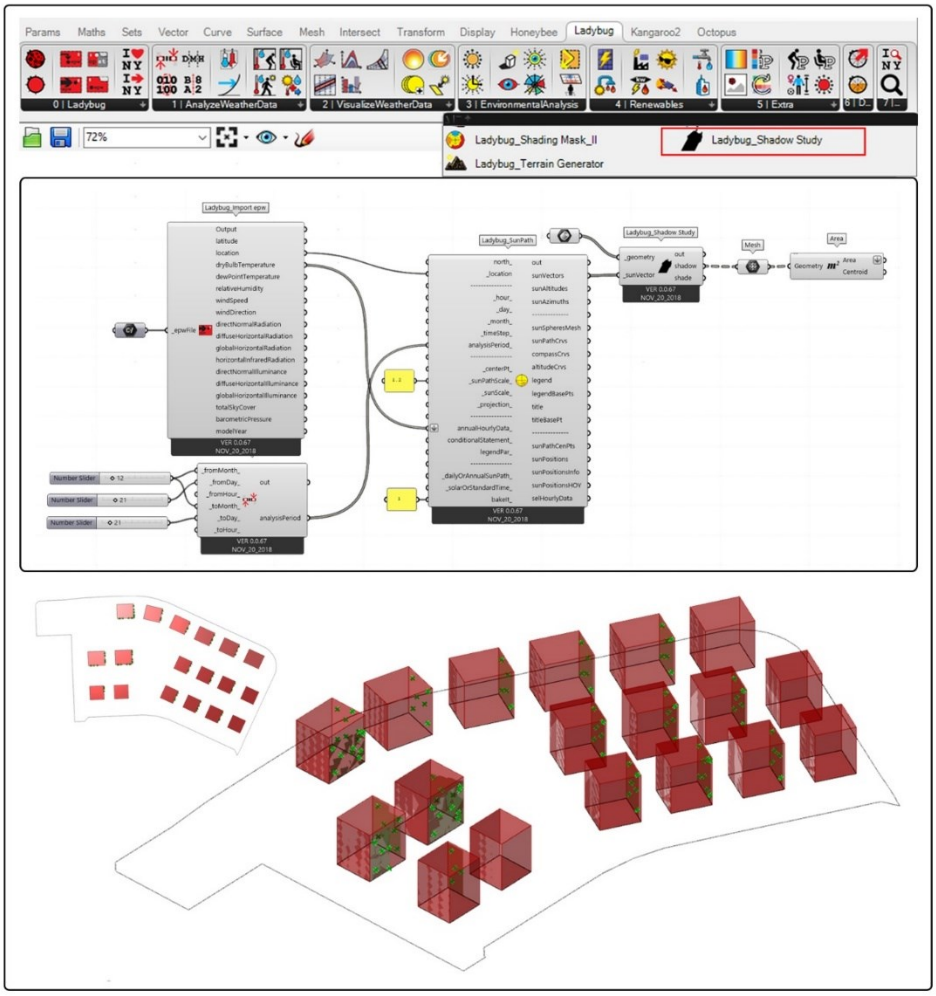


Figure 5.23 : Ladybug Shadow Analysis for TOKI Şahinbey Blocks.

5.2.2 Optimization site layout planning in TOKI Şahinbey

The main purpose of this optimization process is to maximize the solar radiation and minimize the shadow on the vertical surface for each block on 21st of December. In this proposed model, total solar radiation which is calculated by Ladybug plugin in grasshopper is 40591.11Kwh/ m^2. On the other hand, the total shadow of blocks on each vertical surface is 18407.74 m^2.

In short, the structure parameters and variables are the same as TOKI Ayazma. Also, the EPW weather file of Gaziantep was downloaded from Energy plus website. The result of Octopus with a population size of 100 and more than 42 generations are shown in figure 5.25. The total solar radiation has increased up to 41253.74 Kwh/ m^2 (+1.63 %) and the total shadow area on vertical surfaces of blocks has been reduced to 11118.14 m^2 (- 39.60%) in TOKI □ahinbey. The movement, rotation and solar radiation of each block after optimization are demonstrated in Figure 5.6.

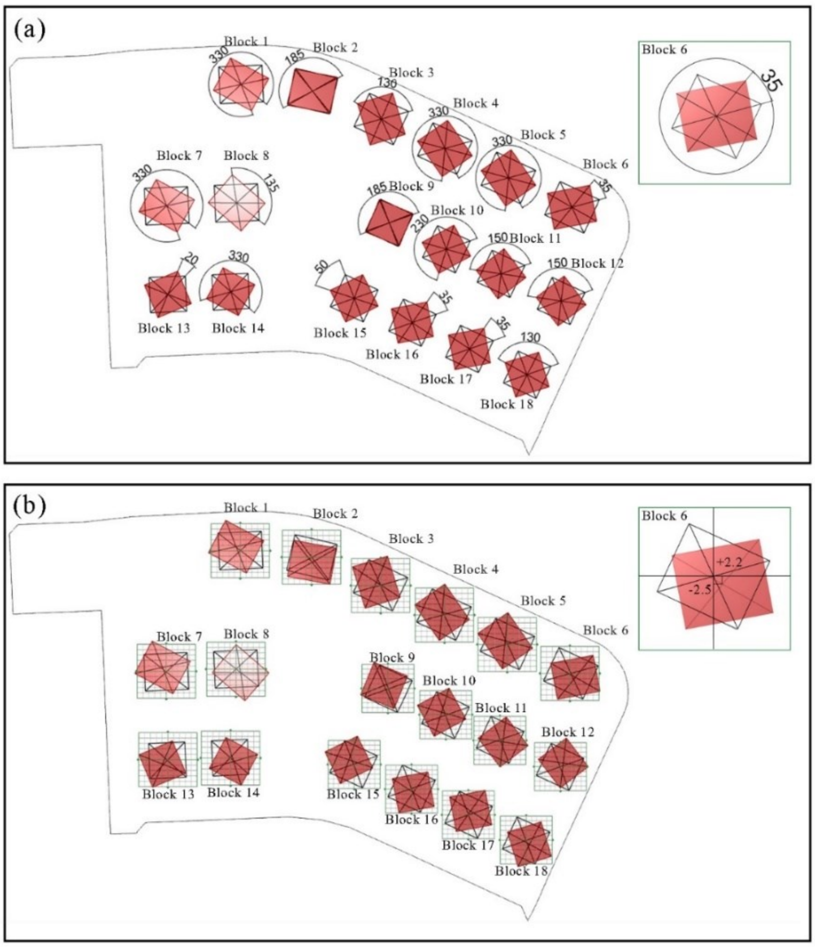


Figure 5.24 : GA optimization process for Toki Şahinbey; (a):Rotation, (b): movement.

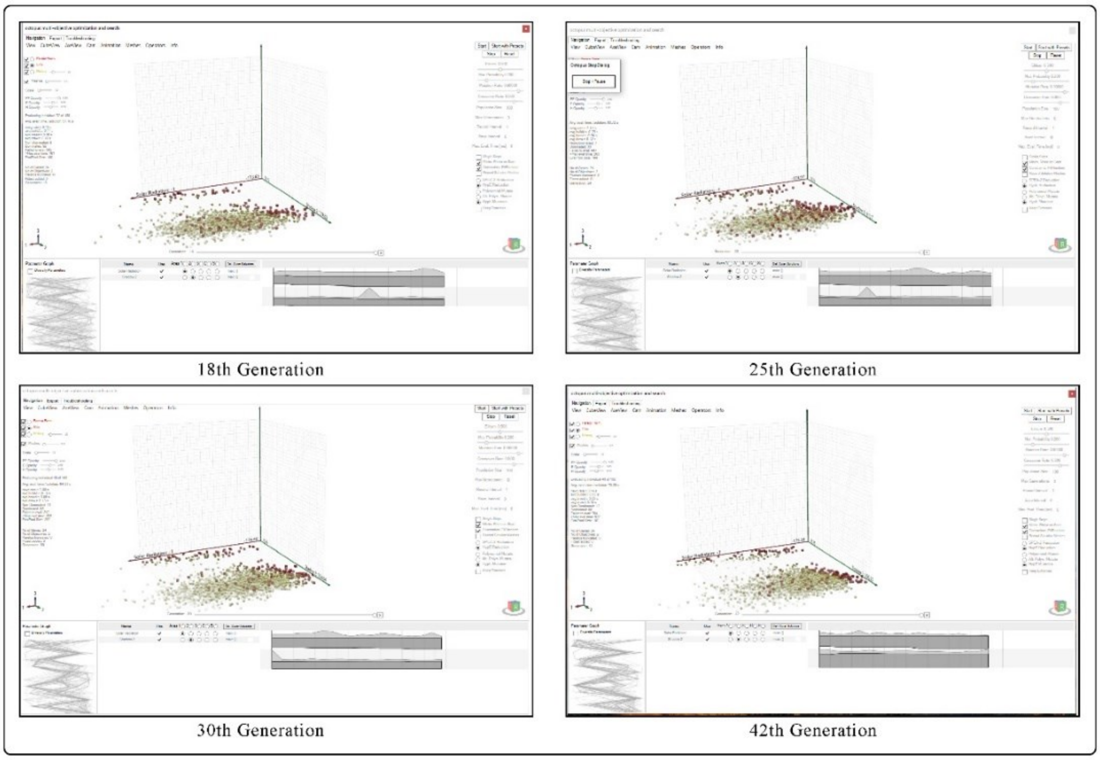


Figure 5.25 : GA generations for TOKI Şahinbey.

Table 5.6 : Movement, Rotation and Solar Radiation of each block after optimization in TOKI Şahinbey.

Blocks	Move X-Axis	Move Y-Axis	Rotate Z-Axis	Solar Radiation (Before Optimization)	Solar Radiation (After Optimization)
Block 1	-2.5	2.2	330	2658.26	2668.66
Block 2	0.1	-2.8	185	2455.08	2477.11
Block 3	-2.4	1.7	130	2452.37	2453.54
Block 4	-1.1	1.3	330	2261.39	2263.79
Block 5	-1.3	1.8	330	2185.27	2243.25
Block 6	2.5	-2.2	35	2351.72	2372.69
Block 7	-2.1	2.5	330	2652.98	2682.81
Block 8	2.5	-2.1	135	2323.88	2401.37
Block 9	-2.5	1.9	185	1948.86	1955.51
Block 10	-2.2	1.7	230	1725.37	1869.04
Block 11	1.7	-1.2	150	1768.29	1765.09
Block 12	1.8	2.2	150	1965.17	2014.13
Block 13	-2.8	-2.1	20	2413.31	2427.91
Block 14	1.9	-2.1	330	2273.33	2316.77
Block 15	-2.6	2.5	50	2311.94	2331.20
Block 16	1.0	-2.2	35	2227.89	2303.08
Block 17	1.2	2.2	35	2246.14	2288.64
Block 18	1.9	-2.1	130	2369.86	2419.15
Total				40591.11	41253.74

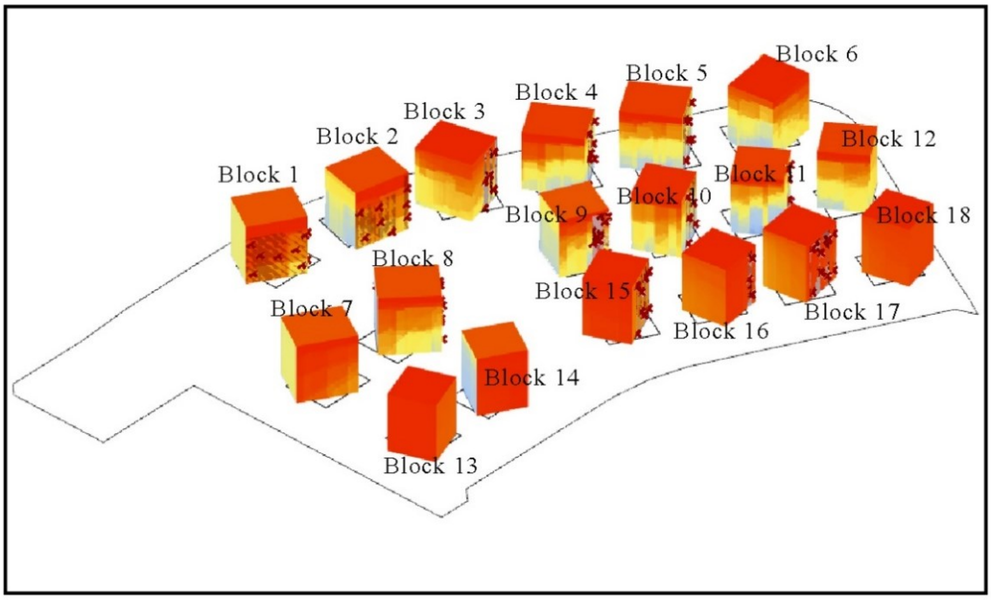


Figure 5.26 : Site Layout Planning after optimization for TOKI Şahinbey.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Presenting The Result

In this thesis, GA optimization is used for block settlement in site layout planning. In the beginning, the computational approaches of site layout planning are presented in chapter 2. In addition, different constructions of site layout planning were discussed, which these constructions were utilized for this study. As an example, the approximate shape of blocks was used in the case study for reducing the run time of GA optimization. In this research, graphical programming languages such as Grasshopper are selected for the optimization process. The main reason for choosing grasshopper is that it has a visual programming environment that makes it easier to learn and use without any coding experience.

Two solution methods in GA optimization are described in chapter 4; SOGA and MOGA. In this study, MOGA was selected for site layout planning optimization. The number of structural parameters for MOGA in the octopus plug-in can be set to a maximum of five and a minimum of two. In order to reduce the processing time, two structure parameters are selected in this thesis; maximizing solar radiation and minimizing shadow on vertical surfaces of blocks. GA's main goal is to find the best solution among a range of possible solutions. In this thesis, a simple methodology is described to optimize site layout planning by considering solar radiation and shadow at an early design stage. Overall, solar radiation and shadow in site layout planning is useful for reducing energy use in buildings during the winter semester.

Two TOKI projects were selected for finding the best locations for blocks by using MOGA in Rhinoceros/Grasshopper CAD modeling environment. Chapter 5 presents solar radiation and shadow analysis of two case studies on 21st of December. This chapter also discusses two variables for MOGA optimization. The first one is movement along the x-y axis and magnitude of displacement of each block is (-3.00, 3.00). The other variable is a rotation every 5 degree around the Z-axis. Limiting movement and rotation is the main reason for reducing computation time in optimization.

The first case study is TOKI Ayazma which has 7 blocks in Istanbul, Turkey. Solar radiation and shadow analysis in TOKI Ayazma blocks are calculated for Istanbul weather data on 21st of December by using the ladybug component in grasshopper. The optimization result of MOGA in TOKI Ayazma after 24 generations presents that the total solar radiation increases 2.33% and shadow area on vertical surfaces of blocks decreases 51.54%.

The other case study is TOKI Şahinbey which has 18 blocks in Gaziantep Turkey. According to Gaziantep weather data on 21st of December, solar radiation and shadow were calculated successfully for TOKI Şahinbeys blocks. The MOGA optimization process in TOKI Şahinbey was successful for 18 blocks and results indicate that the total solar radiation increased 1.63% and shadow area on vertical surfaces of blocks decreased 39.60 %. Table 6.1 demonstrated the result of MOGA optimization for TOKI case studies.

Table 6.1 : The result of the MOGA optimization for TOKI case studies.

	Measurement of solar radiation (kWh/m2)			Measurement of shadow (m2)		
	Before Optimization	After Optimization	Percentage	Before Optimization	After Optimization	Percentage
TOKI Ayazma	15609.40	15973.76	2.33 %	10736.71	5202.87	-51.54%
TOKI □ahinbey	40591.11	41253.74	1.63%	18407.74	11118.14	-39.60%

The duration for optimization in TOKI Şahinbey took much more time than TOKI Ayazma because of an excessive number of blocks. The result of the optimization demonstrates that some blocks reduce solar radiation instead of increasing. For example, block 2 of TOKI Ayazma and block number 11 of TOKI Şahinbey decreased solar radiation after the optimization process.

The results of MOGA optimization indicate that even small block displacements in site layout planning will have an important impact on energy savings. In this thesis, MOGA optimization is applied only to residential buildings, however, this optimization can be used for another architectural project, such as commercial buildings, hospitals, universities, etc. to reduce energy consumption in the winter period.

According to the result of this thesis, it has been shown that MOGA optimization can be successfully applied in site layout planning. Also, it might be useful in the early stage of the design. In this study, various alternatives have been proposed to reduce computational time in trial and error process, such as (1) Number of structure parameters ; (2) Shape of blocks ;(3) Limiting movement and rotation of each block; (4) Analysis period. Two structure parameters have been selected in this study to reduce run time optimization, but different environmental parameters such as noise, indoor thermal comfort, Outdoor Thermal Comfort, etc. can be added for future studies. Rectangular approximate shape without entrance and windows is chosen in this research for optimization, but future research could include the actual shape by considering window size for indoor thermal comfort. The limitation of movement and rotation can be changed depending on the project. Also, variables such as height of buildings and number of floors can be defined in MOGA to maximize the utilization of the solar energy incident on the building. Solar radiation and shadow analysis were calculated for only one day, but future studies analysis period can be changed to the winter months. In future research, it is hoped that the parametric analysis of site layout planning will further include the more parameters and variables. It is also possible to implement a web service to optimize the best location of blocks in site layout planning.

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