Architecture and Planning Journal (APJ)

Volume 30 | Issue 1
ISSN: 2789-8547

Article 2

March 2024

PARAMETRIC DESIGN AS A TOOL TO REDUCE SOLAR PENETRATION BY OUTDOOR SHADES IN HOT ARID CLIMATE

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Abstract

Conventional design methods and current tools infrequently link performance with the geometry of the design. These methods rarely enable backtracking through the design process and can't achieve full performance criteria. In this context, using both procedural geometry and information from numerical assessments and performance simulations should be discussed to support the search for effective solutions. Architects have gained control over the process of design by utilizing parametric methods to generate a sustainable design that interacts with sustainable, climatic, and environmental restrictions, particularly in hot arid zones where outdoor life is overlooked. This paper will discuss the performance-oriented design and a specific workflow empirical methodology that explores design alternatives of outdoor solar parametric shades for urban spaces with the aim of merging performance assessments in the initial phases of the design process to achieve maximum thermal comfort. This workflow includes parametric modelling using (Grasshopper) along with genetic algorithms (Galapagos), and the environmental tool (Ladybug). The design solutions were generated by evolutionary algorithms in accordance with the thermal performance requirements and simulations to evaluate their shading and thermal comfort efficiency. This will be illustrated through a case study of a bus stop static shade concentrating on the cladding of the geometry, especially on the solar radiation parameter. The study that will be discussed in this paper is a simulation study that will combine simulation techniques with a parametric approach and genetic algorithm optimization in a generative evaluation methodology for reducing the radiation under outdoor shades in hot dry climate areas. The optimum alternative /was determined based on the fitness value of incident radiation, and the process was iterated for a particular date and time.

Keywords

Performative design, Evolutionary algorithms, Passive strategies, Outdoor parametric solar shades

1 INTRODUCTION

According to the United Nations' most recent estimations, the world's population may reach 8.5 billion people in 2030, 9.7 billion in 2050, and 10.4 billion in 2100. More than half of the anticipated increase in worldwide population up to 2050 will be concentrated in eight countries: the Democratic Republic of the Congo, Egypt, Ethiopia, India, Nigeria, Pakistan, the Philippines and the United Republic of Tanzania. The percentages are increasing, especially in developing countries with hot dry climates (UN, *World Population Prospects, 2022)*. This will lead to frequent use of outdoor areas, so scientific studies must concentrate on designing urban areas that achieve optimum thermal comfort in hot arid.

A number of climate events have been characterized, Since the middle of the last century. However, the most obvious change in the global climate is the increase in surface air temperature. According to the worst scenario of the Intergovernmental Panel on Climate Change's (IPCC) 5th assessment report (IPCC, Climate change, 2014) the global mean temperature of surface is anticipated to raise by 2.6°C to 4.8°C between 2081-2100, which will undoubtedly have an impact on pedestrians' outdoor thermal comfort. As a result, design based on prediction of thermal performance for built environment has gained significant importance to both building and urban scales (Fahmy, 2017).

Urban scale models are not the best choice for iterative initial design processes because they are consuming time and resource to simulate a limited number of days (Salata, 2016). Consequently, the creation of representative maps that accurately demonstrate the thermal performance at spatial scales larger than individual buildings such as street canyons, requires the use of smart urban design workflows.

In the same context, the past decade was evidenced by the emergence of parametric tools which have become an integral part of the workflow for architecture design. Computational models have been validated for their ability to simulate the urban microclimate of outdoor spaces numerically with an acceptable level of agreement with field measurements (Forouzandeh, 2018). Having the concept of the visual representation as well as comparative assessment of design options at the initial design stage.

This paper will present an approach for the design of outdoor solar parametric shades for urban spaces in hot arid with a specific focus on the design of the cladding of the shades, assuring the significance of the initial integration of performance evaluations in the design procedure, with the aim of improving thermal comfort.

2 CLIMATIC COMFORT OF OUTDOOR AREAS

While indoor climate comfort has received great attention, less scientific attention and consideration of design has been provided to outdoor climate comfort in urban hot dry environment. However, this is an important consideration that should be considered in the process of urban design and at the diverse scales of design. This relates to new developments and the potential to improve the case of existing urban settlements.

The attraction of spaces to users is significantly influenced by their climatic comfort. According to specific studies, thermal comfort has a considerable impact in the rate of utilization for urban environments and in the users behaviour (Nikolopoulou, 2001). The impact of temperature on the number of people using an outdoor public space emphasises the necessity of taking thermal comfort into consideration when designing such areas. Turning to the topic of thermal comfort, multiple studies indicate that occupants of urban environments are able to tolerate a wider range of temperature than the one anticipated for indoor thermal comfort (Nakano, 2004).

3 PASSIVE DESIGN STRATEGIES FOR CLIMATIC COMFORT

Strategies for passive climatic comfort are based on the interaction between the outdoor climate and areas that required thermal and lighting comfort. These strategies aim at passive heating or cooling based on requirements of thermal comfort by using of local climate conditions, and use natural daylight to meet the requirements of lighting.

3.1 Thermal Comfort Passive Strategies

Nicol and Roaf discussed the form physics, the location and the amount of its mass, the size and direction of the openings, the shading, the properties of material and the impact of any passive technology all affect the temperature in spaces designed using passive strategies (Nicol, 2012).

Passive systems are the focal point of this study. The reason is the critical role of such strategies in reducing energy use specially in hot dry climate areas. Reductions of energy usage can be accomplished by decreasing the demand for energy, reducing consumption, recuperating cold and heat and using energy from environment (Omer, 2008). Passive systems enable a decrease of the demand for artificial energy requirement, which is an important goal in view of rational energy usage. The following two sections illustrate some of the key factors that affect the level of comfort which can be particularly managed by passive outdoor solar shades.

3.2 Thermal Comfort and Built Environment

The popular definition of thermal climatic comfort is the one provided by ASHRAE , that describes thermal comfort as the "State of mind that expresses satisfaction with the surrounding environment". Depending on the taken approach, there are many different thermal comfort formulations. There are three various approaches: psychological, thermo physiological and the one depending on the human heat balance (Höppe, 2002). The ASHRAE definition involves subjective factors and refers to psychological aspects (Nikolopoulou, 2003). Considering thermo physiological aspects, definition of thermal comfort is “based on the firing of the thermal receptors in the skin and in the hypothalamus. Comfort in this sense is defined as the minimum rate of nervous signals from these receptors” (Höppe, 2002). Concentrating on the human body heat balance a definition of comfort can be provided according to exchanges of energy. Comfort sensation “is reached when heat flows to and from the human body are balanced and skin temperature and sweat rate are within a comfort range, which depends only on metabolism” (Fanger, 1972). Several models of heat balance for the human body consider the large variety of interrelated variables among them the physiological equivalent temperature (PET) and the predicted mean vote (PMV) (Höppe, 1999).

The topic of climate thermal comfort and its complicated definition and measurements is beyond the focus of this research. This paper will focus on the passive strategies in designing outdoor parametric solar shades that use interactions between climatic variables and the built environment to affect the heat balance equation of the human body with the goal of creating thermal comfort. This indicates that interaction with the design's elements is expected to control air velocity, temperature, humidity, and mean radiant temperature. Generally, this can happen by using air flow (velocity and exchange), thermal mass, solar radiation and daily and patterns of wind , in addition, in case of cooling, as well adiabatic cooling (direct and indirect evaporative cooling). Use of thermal mass is intended to decrease the temperature variations. This can consist in shades cooling at evening to absorb the daytime temperature and decrease the load of cooling, or saving the radiant temperature to decrease the load of heating. Finally, a component of adiabatic cooling is water evaporation, which results in a decrease of the air temperature as a result of absorbing energy in the process of evaporation (Artmann, 2007).

This paper will concentrate on designing a solar shade for a bus stop in hot arid using parametric tools and simulations. The parameter that this study will focus on is minimizing incident radiation to reach the optimum shape of a bus stop shade to achieve maximum thermal comfort.

3.3 Performative Geometries Achieve Passive Thermal Comfort

When concentrating on outdoor passive solar shades, the penetration of solar exposure, that relies on the shape of the shade and its elements, also on the characteristics of its materials, affects air temperature of the space beneath the shade. The inner surface of the shades has an impact on the radiant temperature, which may be higher or lower than the air temperature of the areas beneath; this relies mostly on the absorption factor of the shade. Air fluctuation in the space under the shade depends on the receiving wind and on various air movements, like convective circulation. The shape and openings of the shade have a direct impact on air circulation patterns, while the second one is additionally impacted by regional temperature variations. Air humidity is related directly to the degree of moisture in the air and needs particular attention in balancing both adiabatic cooling and inconvenient degree of moisture, that reduces the maximum allowable temperature. The process of adiabatic cooling can be performed by spraying water on the passive solar shade, in order to decrease the heat of the shade moreover, as a result, the long wave radiation from the shade. Additionally, cooling can also be achieved by putting water features like fountains or ponds under the large shades. Using vegetation is also an additional option (Turrin, 2010). The controlling of the radiant temperature of the shaded areas relies on the solar transmission of the shade and generate the shape of its shading; the impact of the solar radiation on the shaded areas relies on the shade absorption factor and its distance from the ground; air speed beneath the shade relies on how the large shade affects the air movement (including wind) and the gradient temperature; the decrease of variations in temperature can be managed by incorporating adiabatic cooling as well thermal mass in the overall system as shown in fig. (1) (Turrin, 2010).

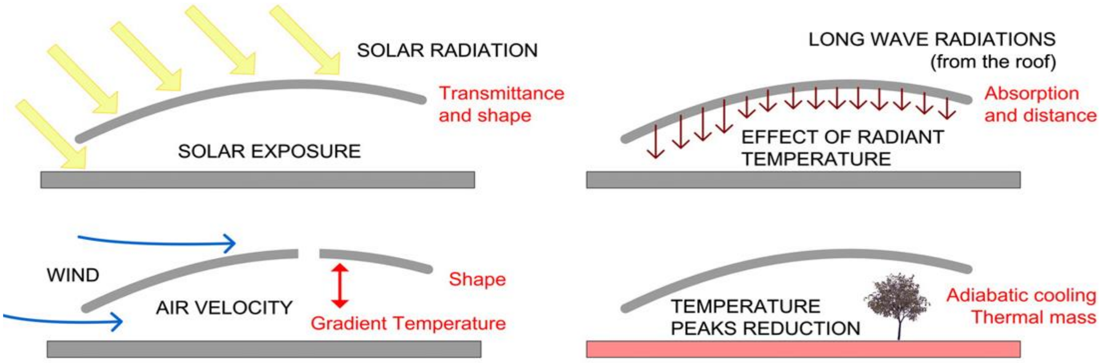


Fig.1: Shows the idea of passive solar shades. (Turrin, 2010).

The parameter that this study will focus on is minimizing incident radiation to reach the optimum shape of a bus stop shade to achieve the maximum thermal comfort.

4 THE RELEVANCE OF SHADE GEOMETRY TO THERMAL COMFORT

Outdoor shades are envelopes that partially cover areas, filtering and managing the environmental factors for daylight and thermal comfort in the space beneath. This action is depends on an integration of material characteristics and geometry, that are both equally significant. This paper will focus on the cladding of the shade geometry specially on one parameter which is solar radiation because the most sifnificant parameter that have an effect on thermal comfort of outdoor spaces is mean radiant temperature (MRT) and the most crucial parameter that affect human comfort in urban open spaces is solar radiation (Setaih, 2013).

4.1 A Case Study Showing the Effects of Geometry

In order to highlight the considerable contribution of geometry to thermal comfort, this paper will present a case study. The study implemented in this paper is a simulation study that incorporates simulation techniques with parametric approach and Genetic algorithms (GAs) optimization. Consequently, the simulation technique used here can be considered as a generative evaluation methodology for reducing the radiation under outdoor shades.

The case study was chosen to be placed in hot arid zone so Cairo, Egypt (30 6N, 31 24 E, alt. 75m) was determined as an example for this climatic zone. Cairo is the capital and major city of Egypt and regarded as one of the world's 15 largest cities in urban and population expansion and thus, contains large number of outdoor areas , parks and bus stops etc,... . On the other hand, according to Köppen's classification it relates to a hot arid subtropical desert which is characterized by high direct solar exposure and clear sky that requires particular outdoor shades to reduce solar radiation and achieve optimum thermal comfort under it (Peel, 2007).

In this study, a hypothetical outdoor shade was constructed as a base model to clarify that this approach can be applied on different geometries. The Energy Plus Weather (EPW) file of Cairo was used to analyse climate parameters.

The outdoor space selected for this study was Abd el Moniem Riad bus stop. The main aim was to propose an approach for outdoor shade for a bus stop to take it as a method for designing shades for bus stops reducing the incident radiation with the preservation of the presence of daylight. Figure (2) showed the current situation of the station.

Fig.2: The shades at Abd el Moniem Riad bus stop don't prevent the sun. Source: By Researcher

The context of this station is surrounded by bridges and exposed to the sun Fig (3). show the context of Abd El Moniem Riad station.

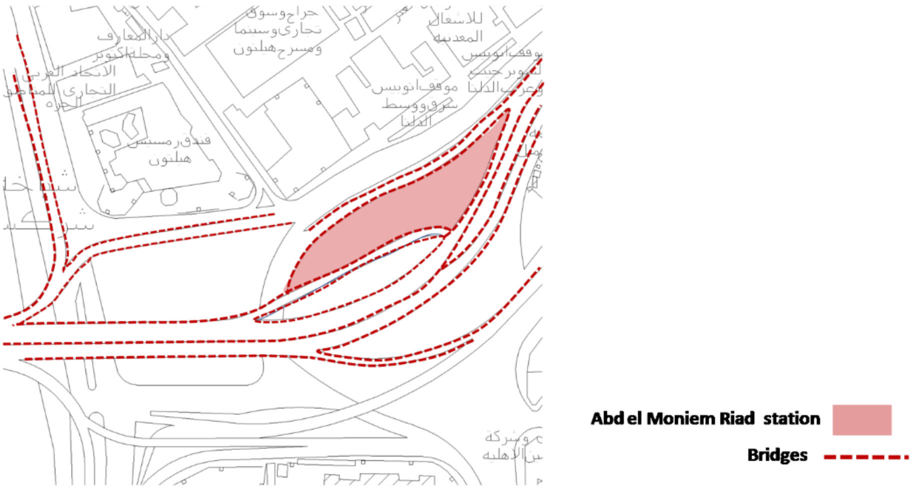


Fig.3: The context of Abd el Moniem Riad station. Source: By Researcher

The geometry of the proposed outdoor shade is not a concentrated point of this paper it's a neutral shape which is used in most of modern bus stop shades. This study neglects form parameter to concentrate on environmental parameters, this doesn't mean that parameters of more different shapes don't affect environmental results so the parameter of the shape should be taken in consideration in the future development of this research. The goal of this research is to reach a method for evaluating parametric outdoor shade that could balance daylight and thermal performance. One form was modelled to prove that this approach can be applied on any forms at any places. Rhino and Grasshopper have been selected as a computational platform to develop a parametric shade model and operate as a form generation tool to better understand the incident radiation under urban outdoor shade.

DOI: 10.54729/2789-8547.1243

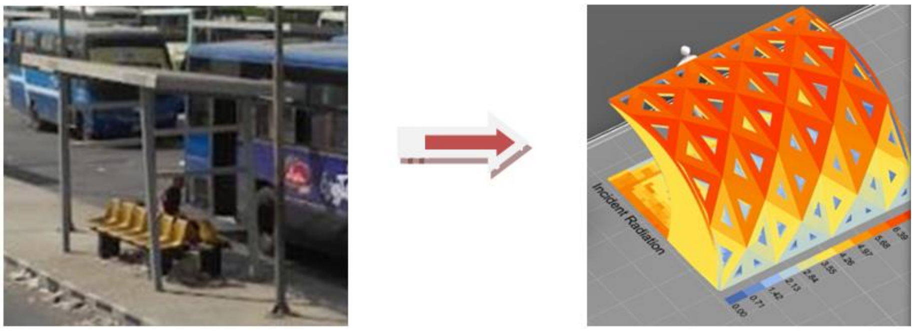


Fig.4: The main aim Converting the method for bus stops shades to a parametric approach. Source: By Researcher

4.2 Parametric Modelling Use

The shape of the shade has a significant impact, particularly on the reduction of incident radiation. Parametric methods were applied to explore geometrical design alternatives. Parametric modelling permits representation of geometric entities and their relationships, that are arranged in a hierarchical chain of dependents created through the initial process of parameterization. The independent characteristics of of the model are usually expressed via independent variables, and their variations create various model configurations as shown in figure (5).

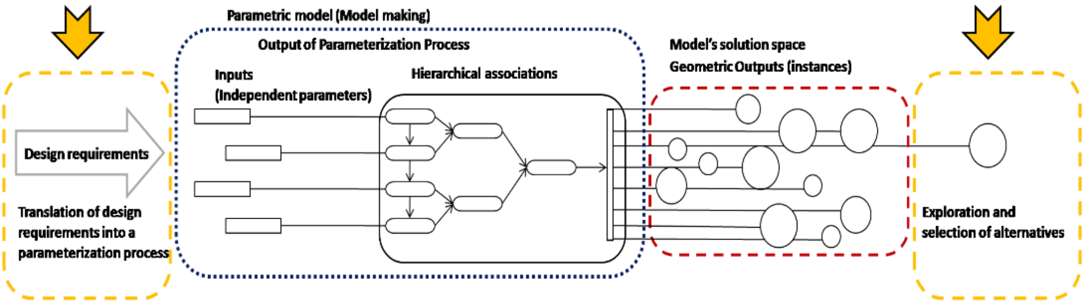


Fig.5: The process of parameterization results in several independent variables (inputs) as well as in a hierarchical structure (representing a dependency chain of relations in the parametric model). The combination of parametric model instances represents its solution space. Source: By Researcher

Three project scales were parametrically explored (Overall shape, Structural system, and cladding system). This paper will concentrate on cladding system. At this scale different options for the cladding system were explored, to decrease the direct solar radiation while still preserving the income of indirect light. This aspect is discussed in the next section. The infrastructure consisting in initial parameterization in which the factor of the geometry resulting from the analysis can be incorporated as shown in Figure (6).

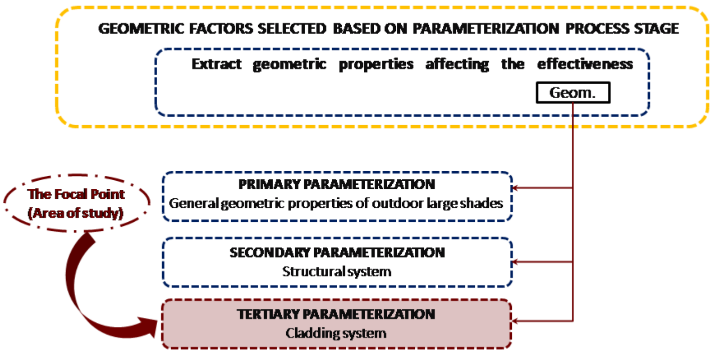


Fig.6: The three project scales that were parametrically explored. Source: By Researcher

5 PERFORMANCE ORIENTED DESIGN OF THE PARAMETRIC CLADDING SYSTEM

Initial calculations have shown the essential of decreasing the direct solar exposure penetration of the shade to decrease the summer thermal discomfort. The initial exploration for the cladding of the shade geometry was executed in the Rhinoceros 3D modelling environment. But the creation of different parameters that control the shade cladding required the geometry to be created in Grasshopper as a mean to parametrically control each variable. Ladybug for Rhino, a highly optimized energy modeling plug-in for Grasshopper and Rhino, was utilized to carry out the simulation process. The simulation results were analyzed to understand and assess the incident radiation, and energy performance behaviour of the proposed shade geometry.

The overall definition was generated in Grasshopper and can be divided into four main sets as shown in Figure 7:

1) Parametric modeling which includes parametric outdoor shade model with its various variables; size, scale and number of divisions in U and V directions.
2) Environmental parameters simulation by using Ladybug tool.
3) Optimization of the shape geometry using evolutionary algorithm.
4) Environmental validation of the outcomes.

The next sections will present an overview of each step for the shade geometry.

5.1 Simulation Workflow of The Shade Geometry

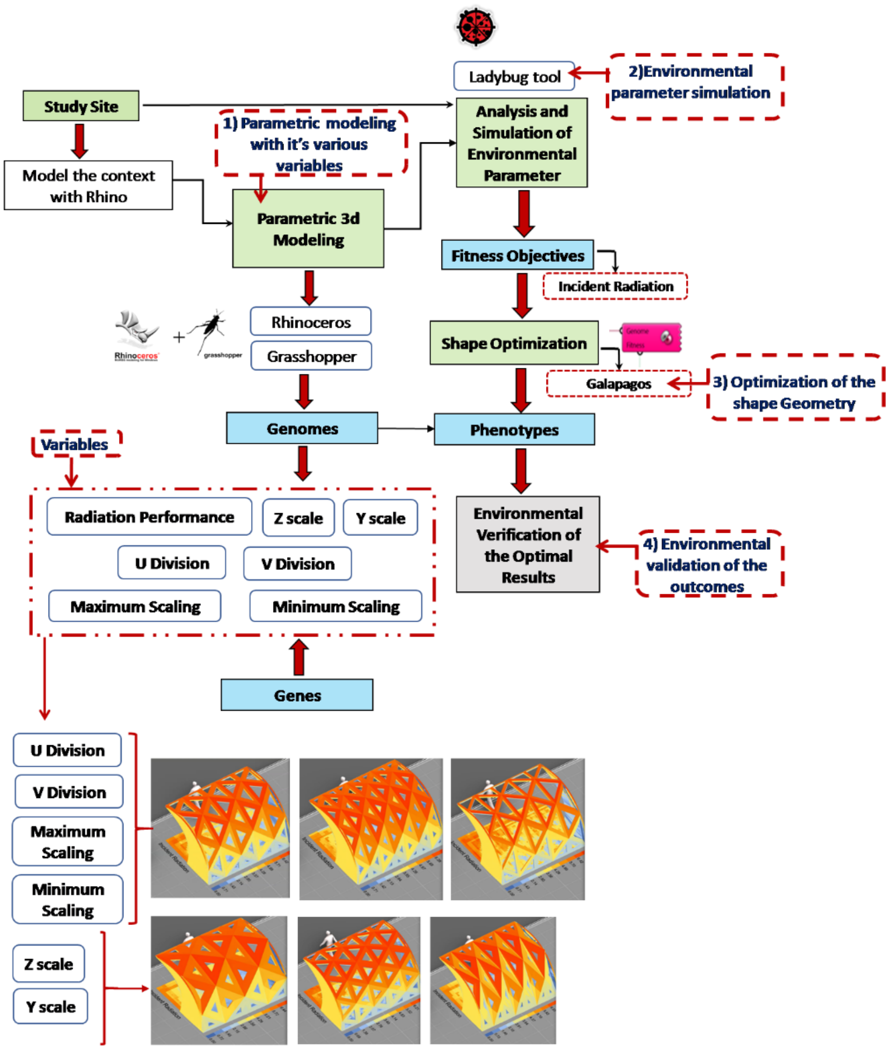


Fig.7: Workflow used for the optimization of bus stop static shade. Source (By Researcher)

DOI: 10.54729/2789-8547.1243

5.2 Definition of The Shade

- Shade Geometry Definition

Grasshopper is used to model the structure of the shade in a parametric way. This model includes six parameters that were defined as variables:

1. Y scale and Z scale of the shade shape.

2. U Division and V Division of the triangulated patterns on the surface.

3. Maximum and minimum scaling of the openings in each cell. Various scale configurations ranging from 20% to 70% of the main cell.

Fig.(8) indicates the steps and components that was used to create the shade geometry and two variables Y & Z scale

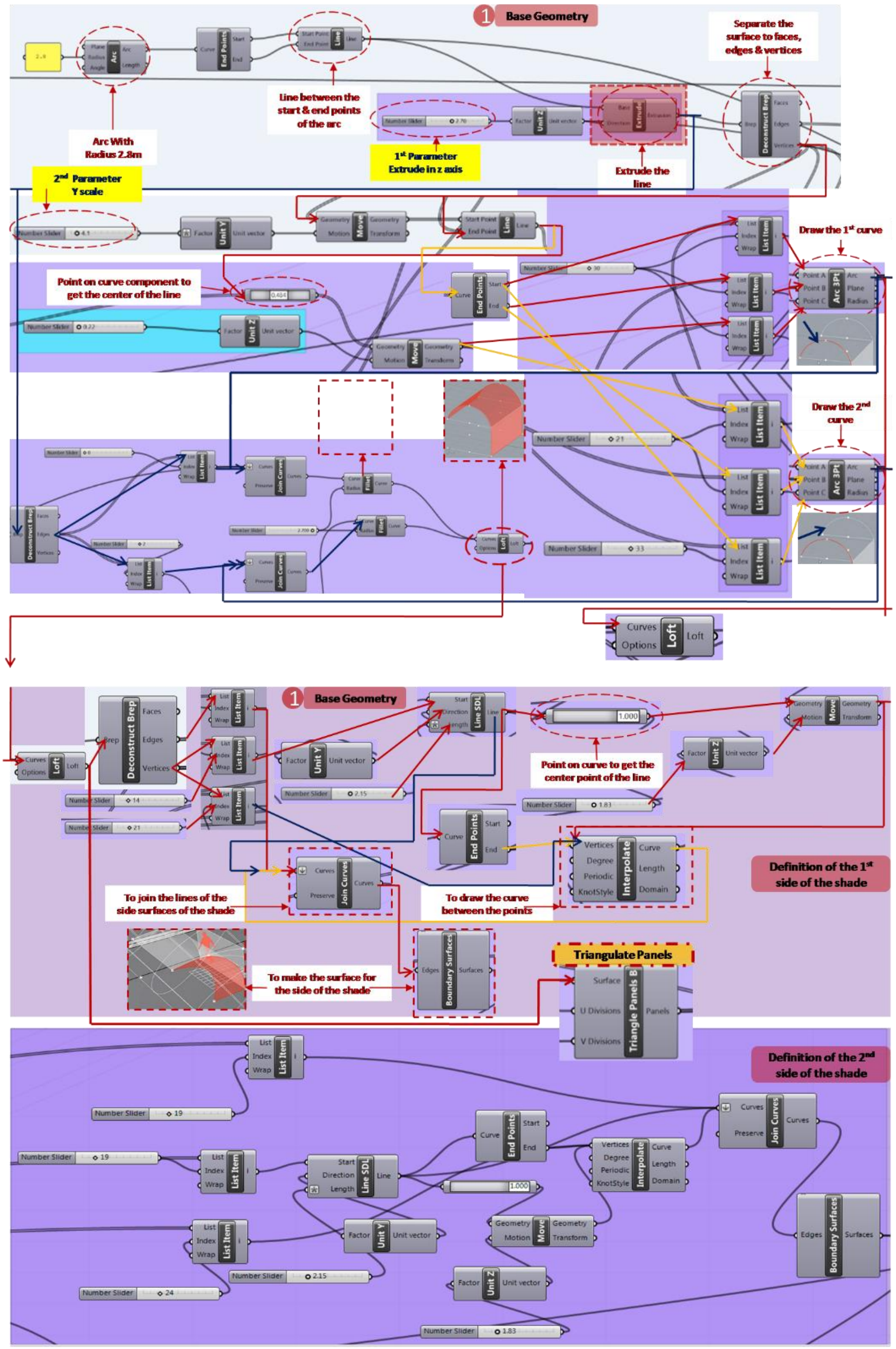


Fig.8: Definition of Base Geomtry (By Researcher)

➢ Panelling Definition and Sun Attractor (Problem Definition)

It is crucial to notice that the scale range of each cell varies based on the attractor point (the sun) to penetrate optimum radiation through the shade opening. These parameters are defined as the ‘variables of parametric design’ or ‘genes’ that will be altering depending on the target indices and varied positions of the sun during the year. The following definition in fig.9 indicates the components used to make the sun as an attractor point that affect minimum and maximum scaling of triangle panels and other two variables (U & V divisions) that change till reaching the optimum alternative.

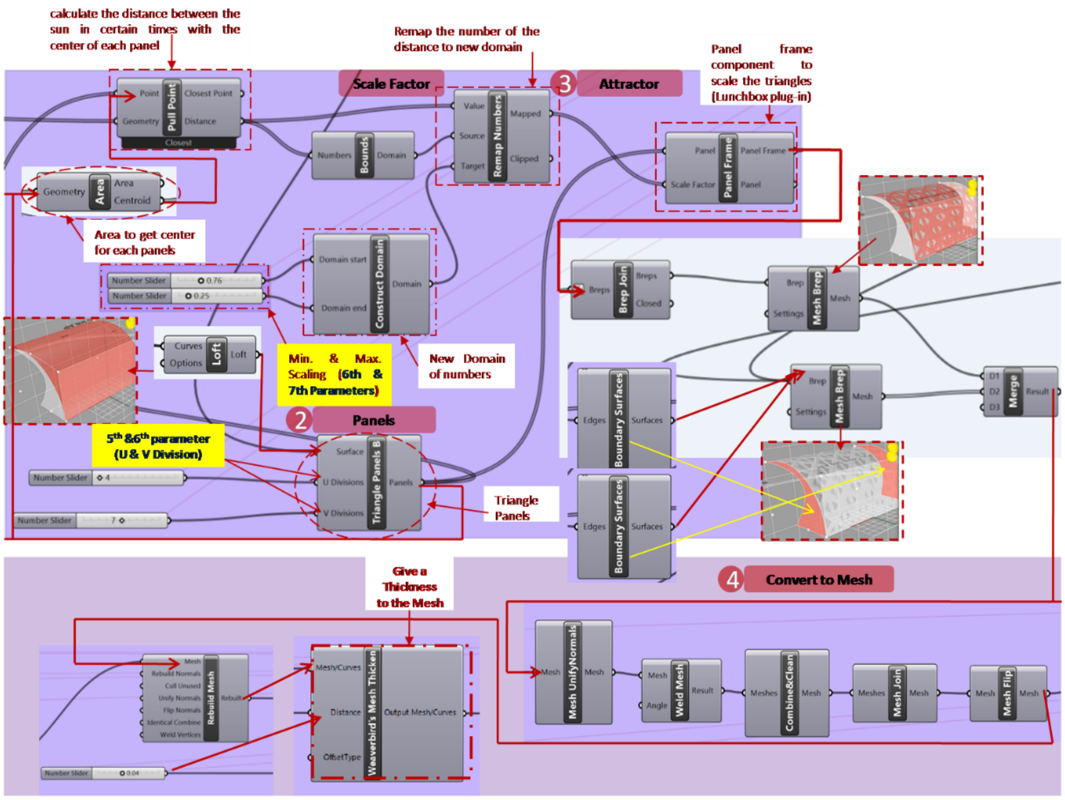


Fig.9: Problem Definition (By Researcher)

➢ Analysis for solar Radiation (Ladybug)

Ladybug is used to perform extensive evaluations of climatic data by importing the energy plus weather (EPW) file of Cairo. To capture the site-specific interaction of the incident radiation under the shade, representative days and hours were selected: December, January, February for winter and June, July, August for summer both at 7a.m, 12 p.m. and 16 p.m.

Investigate the thermal performance was the aim of these thermal simulations to reach the optimum radiation under the optimum shape to achieve thermal comfort as shown in fig. (10) that indicates the components used from ladybug to reach the evaluation part to calculate the incident radiation results in each option.

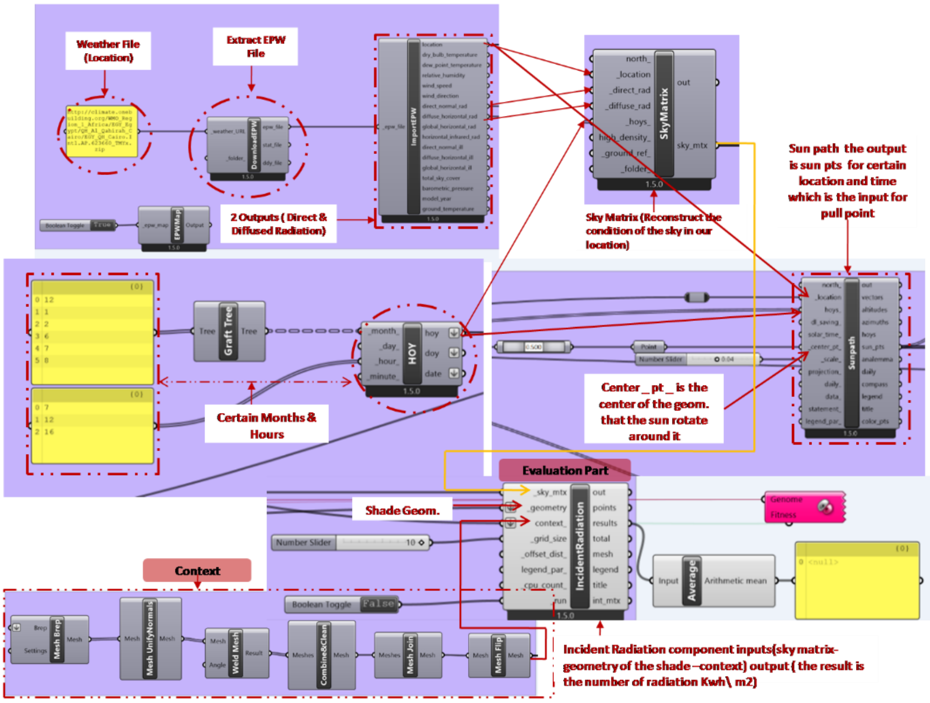


Fig.10: Definition of solar Radiation (By Researcher)

- Evolutionary Algorithm Definition

This section concentrated on using evolutionary algorithm (EA) aim to define the "near optimum" all six variables that could achieve the optimum radiation under the shade. Genetic algorithms (GAs), the most popular type of EA was shown to be an effective optimization approach in exploring new solutions that matches desired performance goals. Thus, in this section, Galapagos Evolutionary Solver, GAs component contained within Grasshopper had been used to find the optimal solutions by optimizing single objective optimizations of the proposed shade. The numerical simulations implemented in this research produced a population of shades claddings that have developed to one fitness value (Incident Radiation).

However, Galapagos is considered as a Single-Objective Optimization tool that aims to find the "best" alternative, that relates to the minimum or maximum value of a single objective function (Rutten, 2010). Hence, fitness function here is minimizing incident radiation. Moreover, to guide the genomes efficiently to the optimal results, the difference between the resulted fitness values needs to be clearly identified. Fig (11) indicates Galapagos component the first input for this component is Genome that means all variables that will be altering till reaching the optimum and the second input is fitness which is here incident radiation that was calculated via Ladybug environmental tool then the engine can be start producing alternatives.

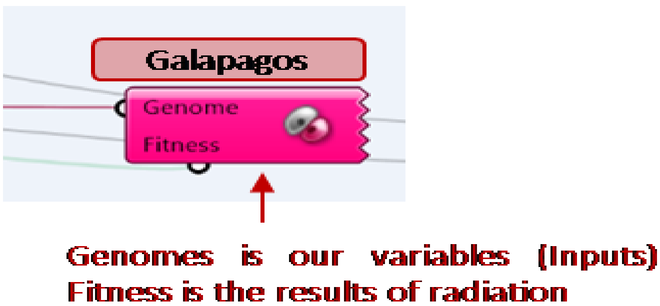


Fig.11: Galapagos component that used as a genetic algorithm tool (By Researcher)

5.3 Shape Optimization with Evolutionary Algorithm

In this phase, it is essential to define the meaning of some particular expressions to improve understanding the process of optimization. The genomes are the individuals of the generations of each optimization. The ultimate genes in this model (the X scale, the Z scale, U division, V division, Maximum scaling, Minimum scaling) are assembled. The phenotypes are the chosen solutions from each optimization that are reproduced as ultimate shadings.

The following exercise was performed with Galapagos as part of the optimization process.

- A population size of 50 generations was used to perform the optimization. Generation 1 contain 40 individuals and from generation 2 to generation 50 each of them contain 20 individuals. Figure (11) show the setting for the evolutionary, it will make iterations till the incident radiation reach 1.8 KWH/m2

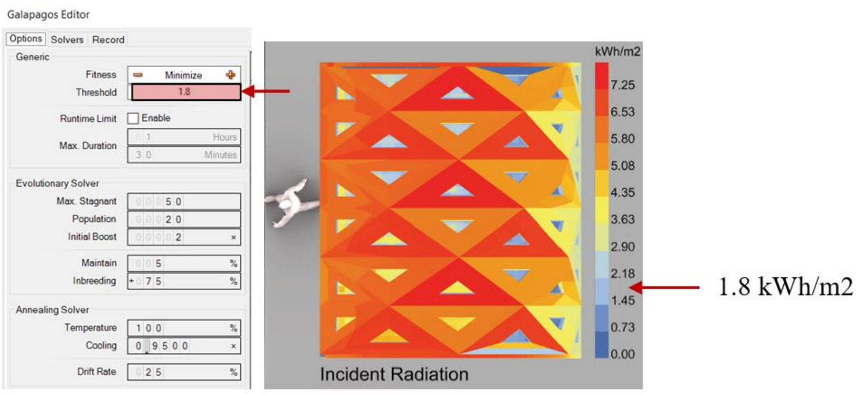


Fig.11: The settings for Galapagos (By Researcher)

A total population size of 1020 genomes (design options) were considered. with 16 optimum design solutions. The process took approximately 2.5 h. Figure (12) show the relations between the 1020 alternatives.

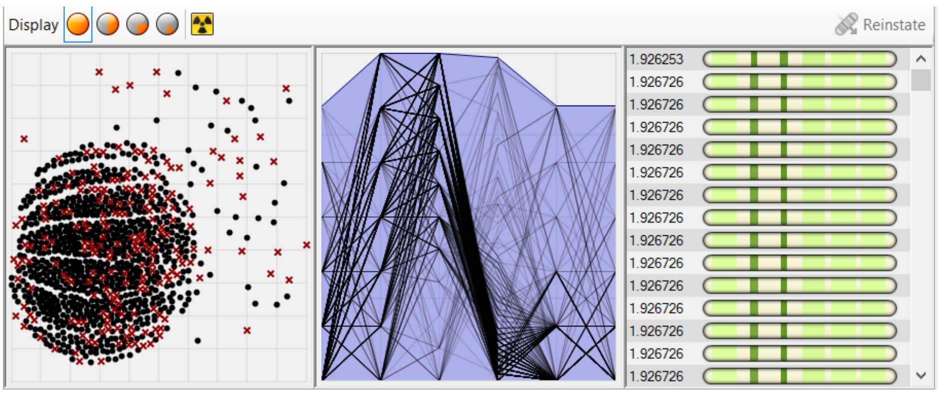


Fig.12: The variation of the 1020 alternatives. Source (By Resersher)

Defining the population size to perform the optimizations was the objective. Consequently, it was noticed a stability for the fitness of the genomes after the 15th generation as shown in figure (13).

DOI: 10.54729/2789-8547.1243

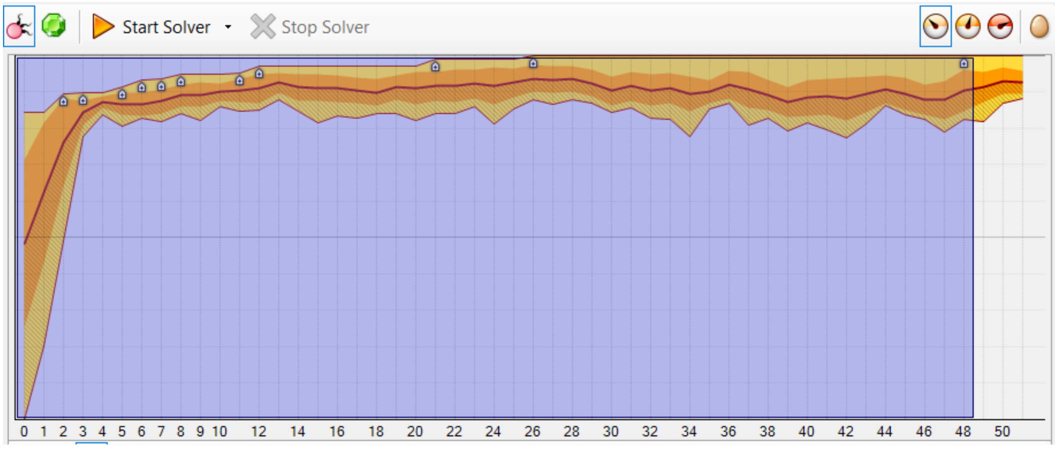


Fig.13: A stability after generation 15. Source (By Resersher)

5.3.1 Environmental verifications for the optimum alternatives

The best genomes for each fitness objective (at the particular timeframes investigated) were selected from the complete population of the Pareto Front Solutions (phenotypes) after the optimization using Galapagos. The non-dominance value for any generation in the population is calculated by using the Pareto Front. (Makki, 2021).

When the best genomes had been determined, their particular genes were identified to evaluate performance of the shades. Thus, to sum up 3D shades geometry repetitions were modelled with the genes' information in order to run environment-based simulations using Ladybug. The main goal is to evaluate the outcome results (Incident Radiation) from the resultant phenotypes.

5.4 Discussion of the Results

5.4.1 Optimization results as well as fitness values

There is 50 generations produced in this case study, table 1 includes the best 8 generations which numbers are (5,6,8,11,27,34,42,50) and generation 1 as an example for the worst generation each generation contain genomes table 1 contains the best genomes in each generation such as the best genomes in generation 1 are (0,2,33). The genes are the variables that changes in each alternative to achieve the optimum fitness value. The percentage of its gene (variable) expresses the extent of its effect in the genome. The initial generation is produced then an iteration process for generations generated till reaching the optimum solution keeping the history for each generation.

The optimum alternatives for both winter and summer were chosen based on the fitness values and the process was iterated for each particular time and date. The simulated results for the incident radiation under the shade for the best 16 optimum design solution and generation 1 as an example for the worst solution to enable the comparison between the urban incident radiation under the shades to determine the best solution as illustrated in table (1).

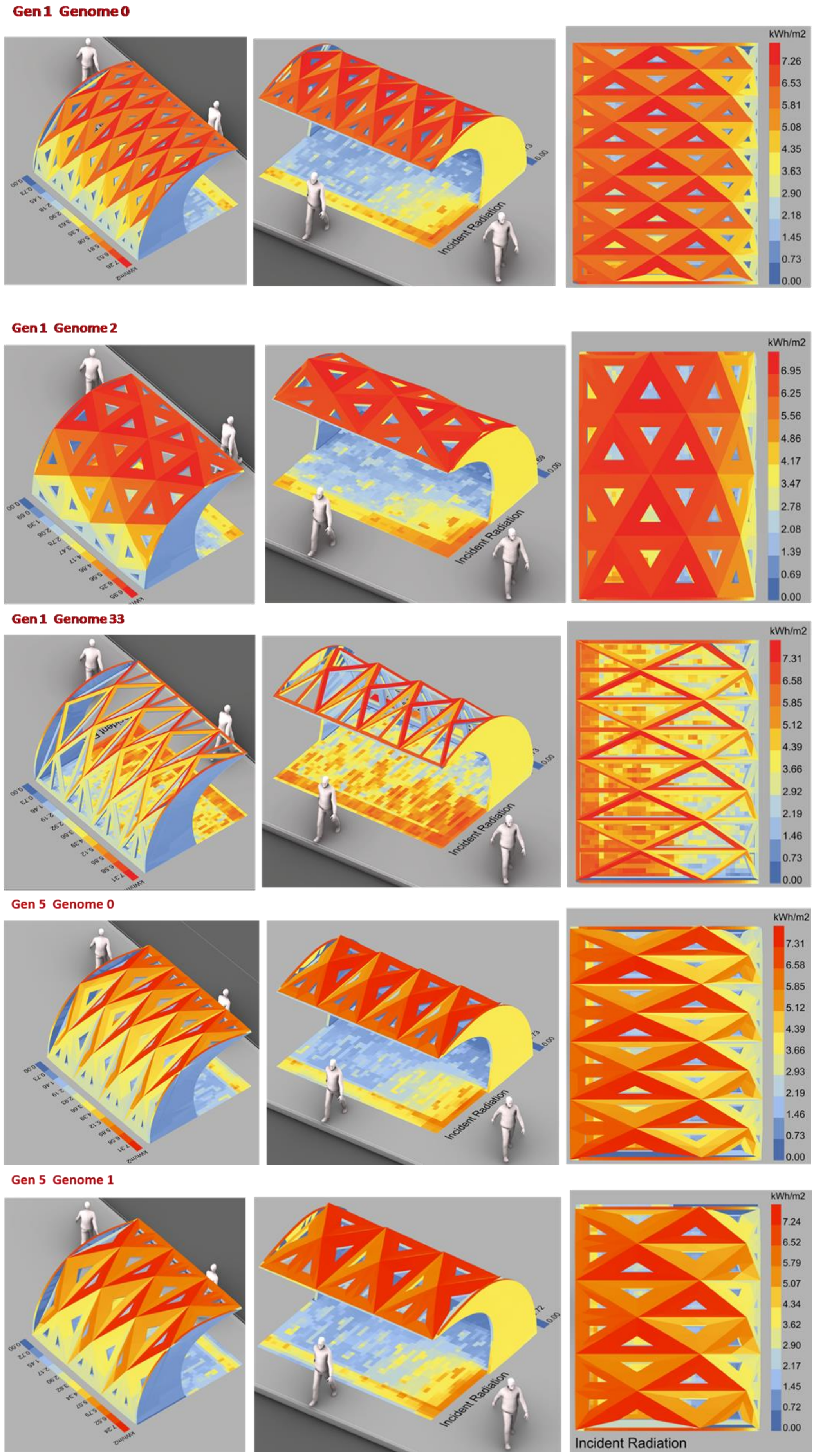
Table 1. The simulated results for the incident radiation under the shade for the best 16 optimum design solution and generation 1 as an example for the worst solution

Population		Fitness Values	Genes (Parametric Variables)					
Generation	Genome	Incident Radiation	Z Scale	Y Scale	V Division	U Division	Max. scaling	Min. scaling
1	0	2.14	33%	83%	40%	12%	0%	0%
	2	2.18	50%	0%	0%	38%	17%	0%
	33	3.00	17%	17%	70%	24%	33%	83%
Bio-Diversity: 0.866								
5	0	2.07	0%	50%	60%	22%	0%	0%
	1	2.07	0%	67%	50%	36%	0%	0%
	2	2.07	0%	50%	60%	12%	0%	0%
Bio-Diversity: 0.243								
6	0	2.04	0%	67%	60%	22%	0%	0%
	1	2.05	0%	33%	70%	12%	0%	0%
Bio-Diversity: 0.252								
8	0	2.01	0%	50%	80%	10%	0%	0%
	12	2.12	0%	50%	70%	14%	0%	17%
Bio-Diversity: 0.273								
11	0	2.00	0%	50%	90%	10%	0%	0%
	1	2.01	0%	67%	80%	12%	0%	0%
	2	2.02	0%	17%	80%	10%	0%	0%
Bio-Diversity: 0.281								
27	0	1.93	0%	83%	100%	4%	0%	0%
Bio-Diversity: 0.299								
34	0	1.93	0%	83%	100%	4%	0%	0%
	1	1.97	0%	83%	100%	6%	17%	0%
Bio-Diversity: 0.291								
42	**0**	**1.93**	**0%**	**83%**	**100%**	**4%**	**0%**	**0%**
	1	2.00	17%	50%	100%	4%	0%	0%
Bio-Diversity: 0.286								
50	0	1.94	0%	100%	90%	10%	0%	0%
Bio-Diversity: 0.478								

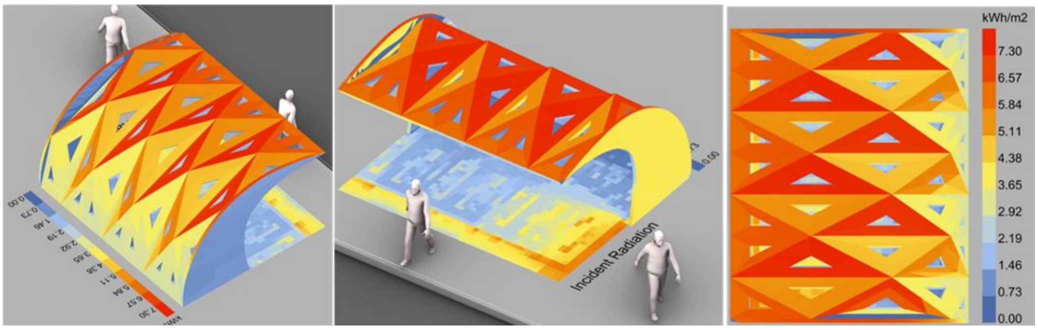
Source: By Researcher

It's concluded from table 1 that generation 42 genome 0 is the optimum alternative as it achieves the minimum incident radiation and bio- diversity value

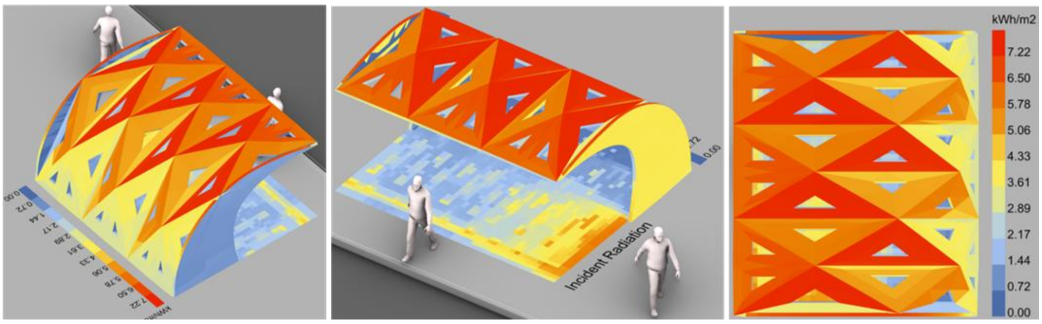
Following are visualization for each generation and genome illustrated in table 1 from layout and perspective view as shown in Figure (14).


Gen 1 Genome 0
kWh/m2
7.26
6.53
5.81
5.08
4.35
3.63
2.90
2.18
1.45
0.73
0.00
Incident Radiation
Gen 1 Genome 2
kWh/m2
6.95
6.25
5.56
4.86
4.17
3.47
2.78
2.08
1.39
0.69
0.00
Incident Radiation
Gen 1 Genome 33
kWh/m2
7.31
6.58
5.85
5.12
4.39
3.66
2.92
2.19
1.46
0.73
0.00
Incident Radiation
Gen 5 Genome 0
kWh/m2
7.31
6.58
5.85
5.12
4.39
3.66
2.93
2.19
1.46
0.73
0.00
Incident Radiation
Gen 5 Genome 1
kWh/m2
7.24
6.52
5.79
5.07
4.34
3.62
2.90
2.17
1.45
0.72
0.00
Incident Radiation
Incident Radiation

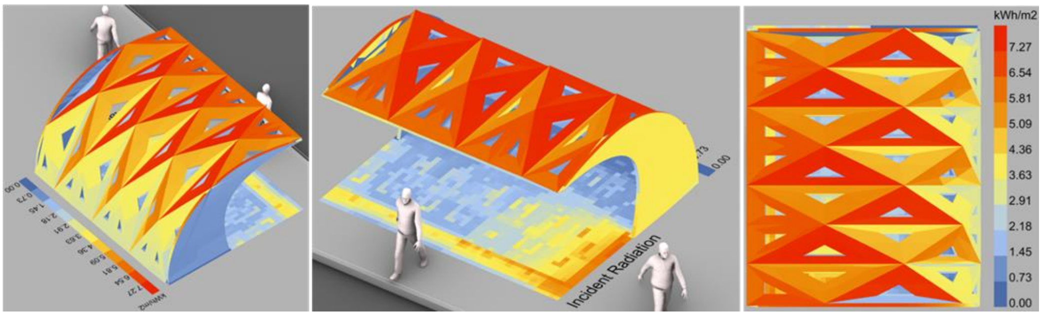
Gen 5 Genome 2



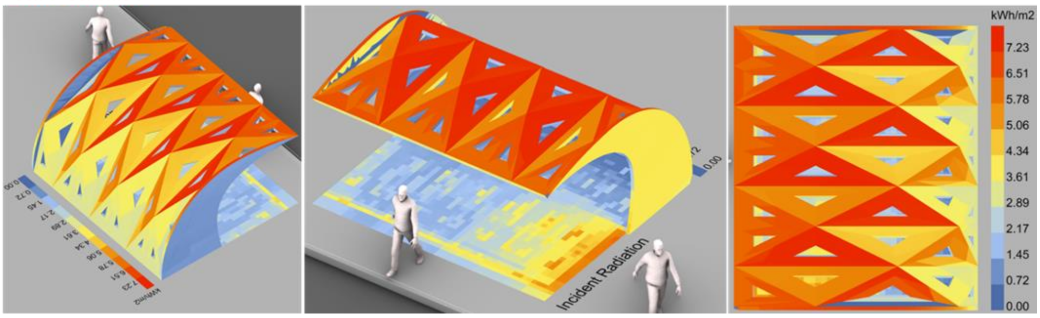
Gen 6 Genome 0



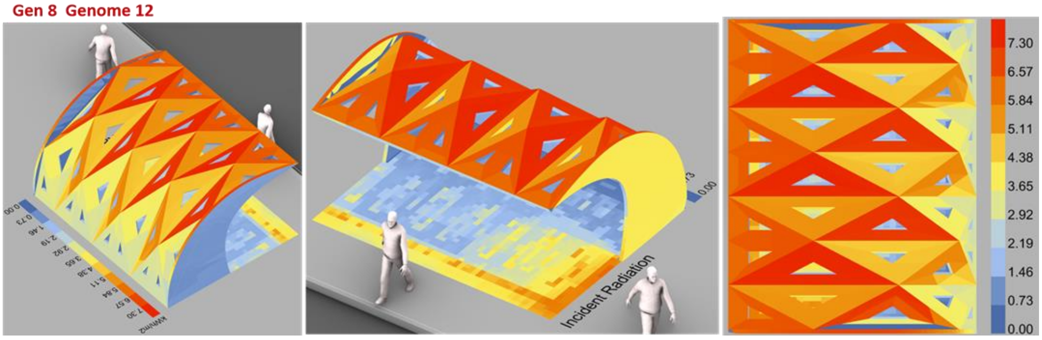
Gen 6 Genome 1



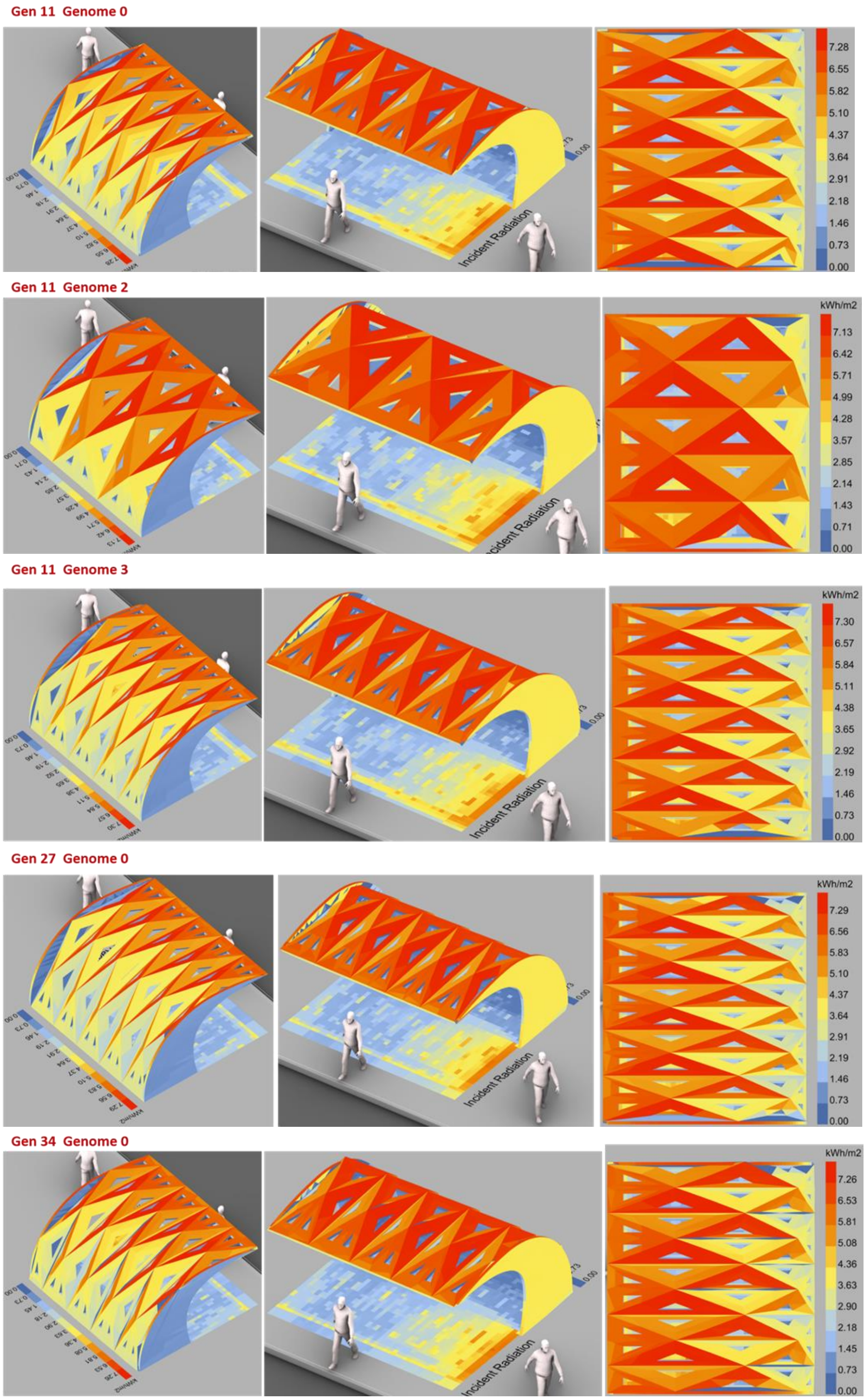
Gen 8 Genome 0



Gen 8 Genome 12



DOI: 10.54729/2789-8547.1243


Gen 11 Genome 0
Incident Radiation
7.28
6.55
5.82
5.10
4.37
3.64
2.91
2.18
1.46
0.73
0.00
Gen 11 Genome 2
Incident Radiation
kWh/m2
7.13
6.42
5.71
4.99
4.28
3.57
2.85
2.14
1.43
0.71
0.00
Gen 11 Genome 3
Incident Radiation
kWh/m2
7.30
6.57
5.84
5.11
4.38
3.65
2.92
2.19
1.46
0.73
0.00
Gen 27 Genome 0
Incident Radiation
kWh/m2
7.29
6.56
5.83
5.10
4.37
3.64
2.91
2.19
1.46
0.73
0.00
Gen 34 Genome 0
Incident Radiation
kWh/m2
7.26
6.53
5.81
5.08
4.36
3.63
2.90
2.18
1.45
0.73
0.00

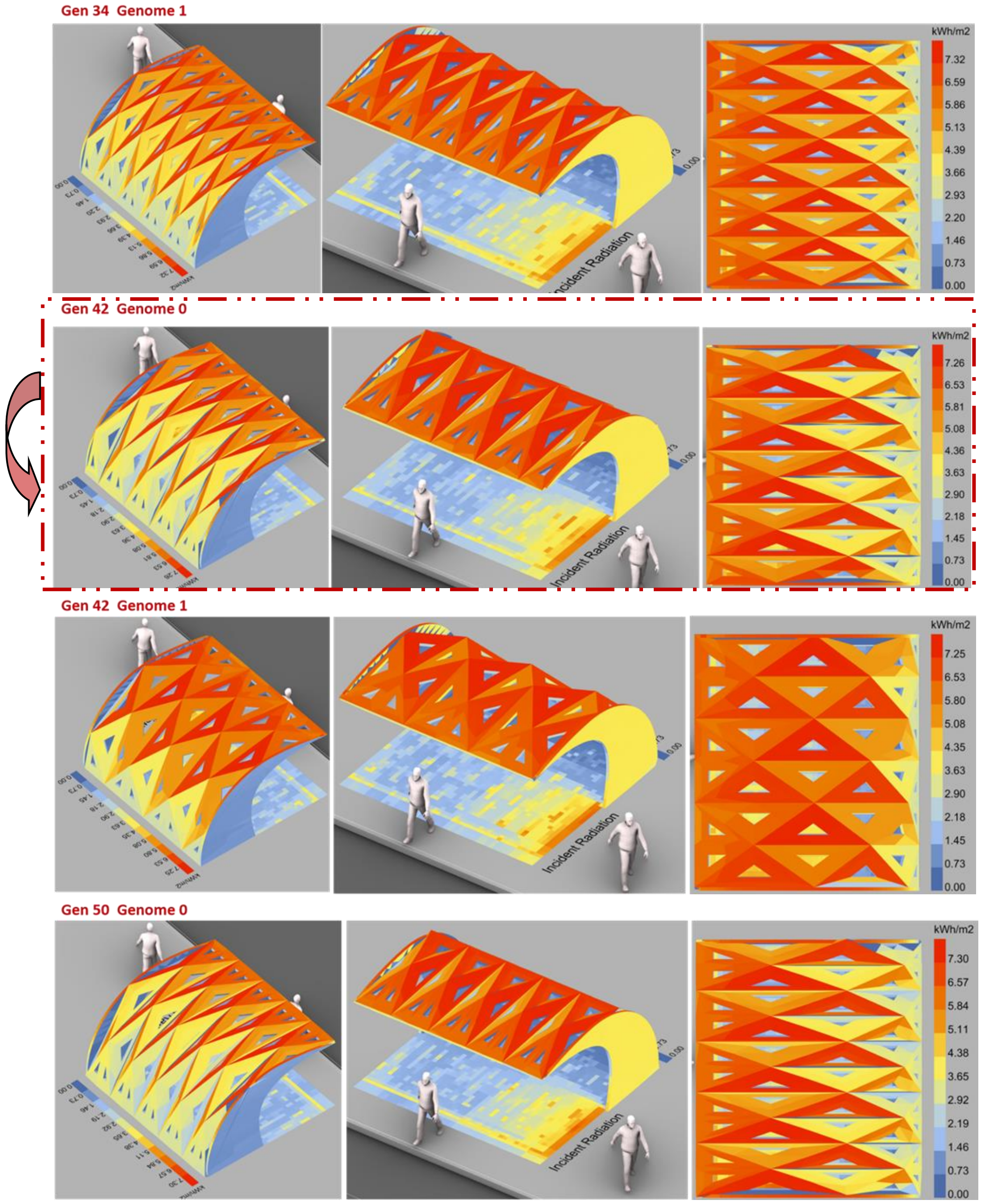


Fig.14: A visualization of the phenotypes mentioned in table 1 indecating that genaration 42 genome 1 is the best solution Source (By Resersher)

5.4.2 Validation of the optimum results

Particular phenotypes were selected from the Pareto Front alternatives to assess the environmental effectiveness of the results Fig. (12) that showed that the total population size contains 1020 genomes only 16 optimum solutions were extracted from them . Table 1 illustrated the chosen phenotypes that were simulated with the genes' information obtained from the Pareto Front. It's concluded from table 1 values that generation 42 genome 0 is the optimum as it achieves the minimum incident radiation. On average, the fitness optimization outcomes indicated a satisfactory agreement with the repeated shades results. It is observed that shades affected the average of incident radiation from Table 1. From here, it is confirmed that shadings play an essential role in enhancing human comfort in urban spaces, that consequently affects the pedestrians satisfaction and perception. Consequently, it's anticipated that the existence of outdoor shadings additionally participates to the urban thermal comfort because of the reductions in emitting ground long wave radiation and obscure the direct radiation with the preservation of the presence of daylight.

Regarding the environment-based outcomes, a particular shades alternatives were shown in Figure (14) and table 1 (the optimum solution). Therefore, the simulation's outcomes for the average of months in summer (June, July, August) and winter (December, January, February) in specific hours 7a.m, 12 p.m and 16 p.m are represented as a visualization of a chosen performance of phenotype. From results generation 42, genome 0 is the optimum solution as it achieved a minimum number of incident radiation 1.93 kwh\m2 which is in the comfort zone and a minimum number of bio-diversity 0.286 shown in table 1.

6 CONCLUSION

This paper introduces a workflow that includes parametric modelling use (Grasshopper) along with genetic algorithms (Galapagos) and environmental tool (Ladybug) through the preliminary process of design for static shading used in outdoor areas. The ultimate design aims to reach optimum shades shape which assist in improving urban thermal comfort by reducing solar penetration.

The simulations were conducted for outdoor shade in Cairo, Egypt. The shade variable parameters are X scale, Z scale, U Division, V Division, Maximum scaling and Minimum scaling. The simulation results were analyzed to understand and evaluate the incident radiation, and energy performance behavior of the proposed shade geometry.

The problem definition was generated in Grasshopper and can be divided into four main sets:

- Parametric modeling for the geometry of the shade
- Environmental simulation using ladybug tool
- Using evolutionary algorithm to optimize shade geometry
- Environmental validation of the results

The process of work has shown to be multilateral in specifying the assessment sample size, that leads to savings of time through the process of optimization. This flexibility additionally enables evaluating the phenotypes as well as putting the results in a fast and friendly interface (Phyton in Grasshopper). The particular data of the genes and genomes extracted from the chosen phenotypes was then saved for a future repetition and assessment of the environment-based goals. This is a significant benefit of the executed algorithm in contrast to others that are currently available and don't permit saving the information data.

Regarding the optimum phenotypes, they participate in decreasing thermal stress by producing shaded spaces with optimum incident radiation which responded to the investigated latitude's sun directions. The outcomes presented in this paper are related to the selected case study. Thus, the current work represents a start in the right direction toward responding to the urgent need for climate-specific solutions to enhance urban thermal comfort. Nevertheless, it is expected that this proposed workflow could be expanded to evaluate various geographic regions with greater variety of climates where the geometries are formed depending on the particular latitude and climate circumstances as this paper tested only hot arid zone. More assessments should be further developed to study the effect of the material of the shade on outdoor thermal comfort, involve another complex parameter such as humidity, air velocity and ventilation . It's advisable to work on the generalization of the shape, so as to be able to operate on more complex geometrical configurations so the parameter of geometry should be taken in consideration in the future development of this research .

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