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Research Article

Effective Use of Solar Energy with BIM Supported Parametric Methods: Case Study Al-Shaab Stadium

Filiz BAL KOÇYİĞİT[a,*], Abdullah ALLAWI[b]

[a] *Department of Architecture, Faculty of FAD&A, Atılım University, Ankara, TURKEY*
[b] *Department of Civil Eng. Faculty of Engineering Atılım University, Ankara, TURKEY*
* *Corresponding author's e-mail address: filiz.kocyigit@atilim.edu.tr*
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ABSTRACT

In this study, it is aimed to create an infrastructure that can contribute to the integration of parametric techniques and the joint work of construction and architectural science through an exemplary building design. The ability to respond to changes in data entry in algorithms gives architectural designers the opportunity to optimize structures and form at the same time. At the same time, replacing inputs with parametric techniques saves time in the design process. Otherwise, the design will have to be redesigned from the beginning, depending on the periodic change made in the design. In addition to this, it has been emphasized to build a building design and structure that will provide energy efficiency. In order to create low cost in profit-cost ratios, the possibility of minimizing the inefficient surfaces with the design method by analysing the floats with maximum energy gain due to creating solar plans. The algorithmic design used for this is modelled on the visual and optimizes the geometry to achieve maximum energy efficiency for the building form. To find solar panels suitable for the building geometry design, there is a need to model the actual effect of the sun's rays on the building. One of the key parameters that helped us reach the results of the study is to explore the possibility of using modern guidelines of exemplified stadium designs. This research is based on a method of comparing analysis between two prototype proposals tested to show the effect of the sun on geometry using parametric algorithms. In this case, "Grasshopper 3D" software was used for radiation, daylight hours and shadows to create parametric algorithms in the solar effect simulations process. The purpose of using parametric simulation was to increase energy efficiency for the stadium. Additionally, generative design was used for structural optimization. In this study, generative design was also used to optimize the stadium design structure, which helps to significantly reduce the amount of materials used in the formation of the structure and its costs. In this study, with the help of the Buiding Information Modelling (BIM) program used, solar energy gains affecting the building were investigated and energy gain-loss calculations were made by using environmental data. The obtained data and shell design samples were compared. In the study, Al Shaab stadium in Baghdad was evaluated as an experimental model for modelling the reality.

Keywords: *Parametric design, Energy efficiency, Grasshopper, Solar panels, Structural optimization, Building Information Modelling (BIM)*

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YBM Destekli Parametrik Yöntemler ile Güneş Enerjisinin Etkin Kullanım Analizi: Al-Shaab Stadyumu Vaka Çalışması

Öz

Tasarım alanında parametrik tasarım, çeşitli algoritmalar, değişkenler ve sayılardan oluşan farklı durumlara adapte edilebilen ve dinamik bir süreci tanımlar. Algoritmalardaki girilen verilerin değişimine cevap verebilme yeteneği, tasarımcılara yapıları ve formlarını aynı anda optimize etme fırsatı verir. Aynı zamanda girdilerin parametrik yöntemlerle değiştirilmesi, tasarım sürecine de zaman kazandırmaktadır. Aksi halde, tasarımda yapılan revizyonlara bağlı olarak tasarımın baştan yeniden tasarlanması gerekmektedir. Bununla birlikte, özellikle enerji verimliliği sağlayacak bir yapı tasarımı ve strüktürünü inşa etmek ön plana çıkartılmıştır. Kar-maliyet oranlarında düşük maliyet oluşturmak amacıyla güneş planları oluşturulmuş, dolayısı ile maksimum enerji kazançlı yüzerlerin analizini yaparak, verimsiz yüzeylerin tasarım yöntemi ile minimuma indirgenme olanağı analiz edilmiştir. Bunun için kullanılan algoritmik tasarım, binanın görselini modeller ve bina formu için maksimum enerji verimliliği elde etmek amacıyla geometriyi optimize eder. Bina geometrisi tasarımına uygun güneş panellerini tespit etmek için, güneş ışınlarının bina üzerindeki gerçek etkisini modellenme ihtiyacı oluşmuştur. Çalışmanın sonuçlarına ulaşmamıza yardımcı olan temel parametrelerden biri, örnek alınan stadyum tasarımlarının modern talimatlarını kullanma olasılığını keşfetmektir. Bu araştırma, parametrik algoritmalar kullanarak güneşin geometri üzerindeki etkisini göstermek için test edilen iki prototip önerisi arasındaki analizlerin karşılaştırması yöntemine dayanmaktadır. Bu durumda, güneş ışığı simülasyonları sürecinde parametrik algoritmaları oluşturmak için radyasyon, gün ışığı saatleri ve gölgeler için "Grasshopper 3D" yazılımı kullanılmıştır. Parametrik simülasyon aracı kullanılmasının amacı, stadyum için enerji verimliliğini artırmaktır. Bu çalışmada, stadyum tasarım yapısını optimize etmek için üretken tasarım da kullanılmıştır, bu da yapının oluşumunda kullanılan malzeme miktarını ve maliyetlerini önemli ölçüde azaltmaya yardımcı olmuştur. Bu çalışmada, kullanılan Yapı Bilgi Modellemesi (YBM) programı yardımıyla binayı etkileyen güneş enerjisi kazanımları araştırılmış ve çevresel verilerden yararlanılarak enerji kazanç-kayıp hesaplamaları yapılmıştır. Elde edilen veriler ve kabuk tasarım örnekleri karşılaştırılmıştır. Bu çalışmada, örnek bir yapı tasarımı üzerinden, parametrik tasarım tekniklerin entegrasyonu, inşaat ve mimarlık disiplinlerinin ortak çalışmasına katkıda bulunabilecek altyapı oluşturulması amaçlanmıştır. Alan çalışması olarak Bağdat'taki Al Shaab stadyumu, deneysel bir model olarak ele alınmış, optimizasyon çalışmaları bu model üzerinden yürütülmüştür.

Anahtar Kelimeler:*Parametrik tasarım, Enerji etkin mimari, Grasshopper, Güneş panelleri, Strüktürel optimizasyon, Yapı Bilgi Modellemesi (YBM)*

I. INTRODUCTION

Al-Shaab Stadium was incipiently designed to be an Olympic stadium; thus, it has the features to be a multi-purpose space. For example, besides Football, it can host other sports types that help expand the stadium uses and grow its financial viability. Football fields can also host amusement events, including concerts, festivals, theatrical glamor, and commercial / consumer shows[1].Therefore, Stadiums need to increase the area of spectators. However, making the pitchlarger for another sport or adding a running track around the field can cause the football spectator's seats to be far from the field. It reduces their sense of participation and interaction with the game and decreases their enthusiasm. Stadium developers often have to increase the size of the stadium regarding clients' requests. Occasionally, these requirements are inevitable.Unfortunately, this would result in a much less successful facility than a football field explicitly built around a football field's dimensions [2].The consequence of increasing stadium area is the increasing of the stadium roof. Solar plans can be used to cover the stands, but to know where the solar radiation will on roof surfaces, there is a need to simulate the solar effect on geometry[3]. In this research, two-hypotheses for comparing the pros and consof developing Al-Shaab stadium were done. These are:

Hypothesis (H0): The effect and value of using shell form on the energy efficiency design.
Hypothesis (H1): The effect and value of using the cylindrical form on the energy efficiency design.

Mainly represents the parametric analysis as the subject.

P. Caponi [4] presented the techniques of Luigi Moretti's parametric theory in architecture. Also, shows Moretti's recommendations by leaving the empiricism thinking in the design, and using the parametric method include procedures, tools, and objectives.

M.S. Roudsari [5] has research presenting the ladybug tool features in comparison with environmental tools. Also, showing the instant response of environmental information behaviour changing on a building through the design process.

Atsushi Shiota and Ayumi Tada, [6] had shown a new manner in converting raster data simulation's results to vector data. Also, presented how to analyze the solar radiation amount and the correction of these data.

P. Shepherd, R. Hudson [7] shows the success of new technology of design by integrating parametric technique to model design across all disciplines. Also, the collaboration between architects and structural engineers by the response to immediate changes without re-designing or re-analyzing the structure.

II. STADIUM MASS

Before putting the solar plats for the roof, knowing which part of the geometry is mostly affected by the sun and the temperature variation throughout the year in Baghdad city. To know the weather information, we used a "Grasshopper 3d" plugin called "Ladybug." This tool allows us to simulate and visualize the radiation and the sun hours per day on the geometry.

Two masses were created to simulate, one is a cylindrical shape, and the second is a shell shape to compare between them and see which one is better to get more hours and radiation. in simulation has been ignored the stadium's surrounding context because the area beside is an open area and no high-rise structures or buildings (Figure 1)[8].

Figure 1.*Stadium site and surrounding context. Source: (Google Earth)*

III. WEATHER DATA

Al-Shaab Stadium is located on the right side of Baghdad city near the Tigris River, and the city of Baghdad is located in the middle of Iraq in the alluvial plain of the Mesopotamian Valley. The climate in Baghdad is characterized by being hot and dry during the summer months. In winter, temperatures reach below zero on some days of the year although sunlight available most of the year [9].

As for the eco-friendly buildings, there is a newly completed project, which is the International Shuadaa Stadium, in which solar panels were used in some areas of its roof (Figure 2). More specifically, a small part of the roof includes solar cells with an area of approximately 7000 square meters installed on the roof of the stadium that will provide it with 1200 kV. This stadium is the only environmentally friendly facility in Baghdad[10].

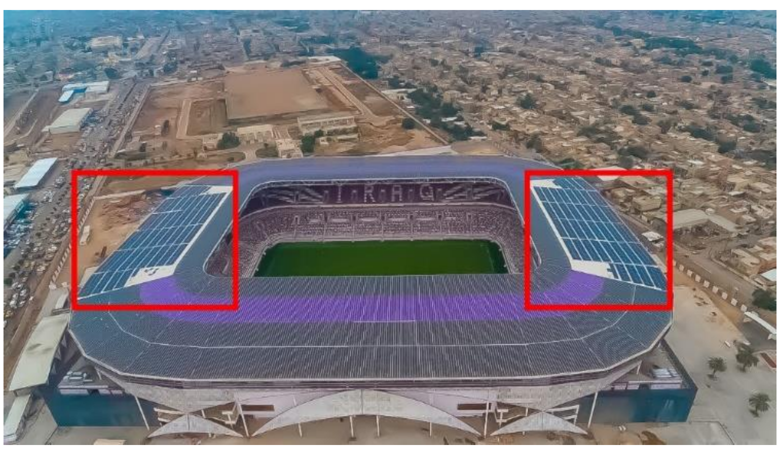


Figure 2 .*Solar plates- International Shuadaa Stadium, Baghdad[11]*

To find out the relationship between the temperature variation and its effect on the facilityin the city of Baghdad, the temperature variation must be known first, by extracting it using the Energy Plus Weather File (EPW) information in the “Grasshopper” through the tool “Ladybug” which provides temperature information according to the location of the building or the city geographically (Figure 3). Providing this information is essential to know if the site is suitable for using energy panels or not. Also, knowing the temperatures throughout the year qualifies us to conduct the radiological analysis of the sun in the coming stages (Figure 4) (Figure 5).

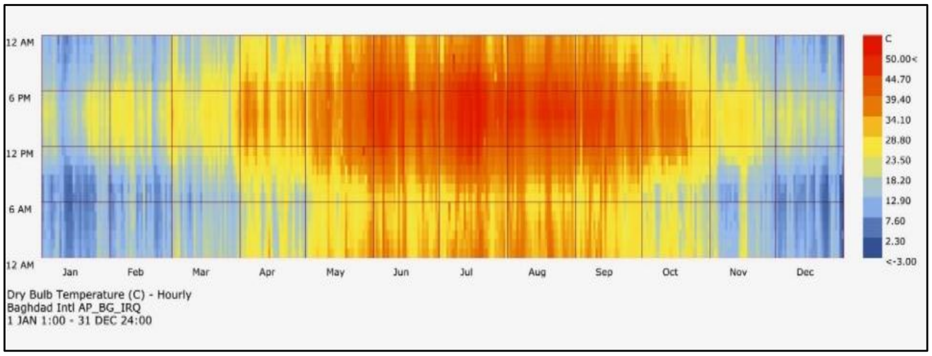


Figure 3.*Baghdad's temperature hourly variation, (1 Jan – 31 Dec, 2020)*

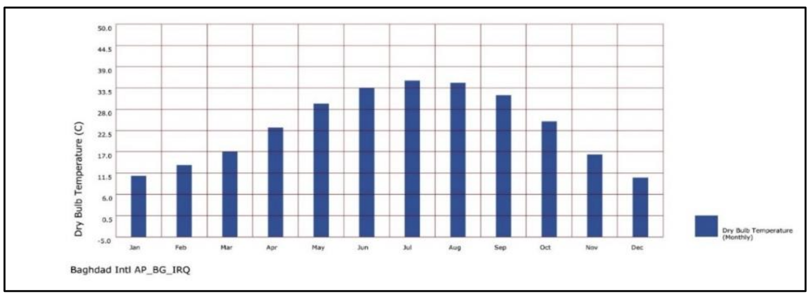


Figure 4. *Baghdad's dry temperature monthly variation, (1 Jan – 31 Dec, 2020)*

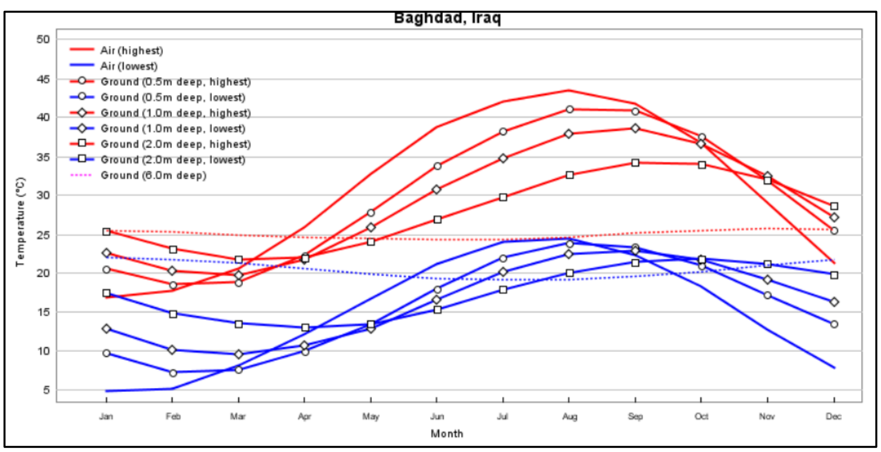


Figure 5.*Baghdad's temperature hourly variation, from “Energy 3D” software, (1 Jan – 31 Dec, 2020)*

IV. METHODOLOGY

A. ANALYSIS

The methodology used in this research depends on the comparing between two prototypes for three different simulations; Radiation simulation analysis, sunlight hours, and the shadows. Also, reviewing topology optimization tools, to compare parametric tools for architecture and structure.

A. 1. Solar Radiation Analysis

An essential aspect of the analysis process is solar radiation analysis. The experiment for two prototypes (shell form) and (cylindrical form) has used the algorithmic design of the "Ladybug" tool, one of the Grasshopper environment plugins. Solar radiation analysis improves the eco-friendly buildings in case of using solar plates system as major electric supply. Equinox times have been chosen for analysis[9].As for illustrating the mechanism of the algorithm (Figure 6) simply shows the workflow for this algorithm. First, link the weather data from the "Ladybug" tool website with the algorithm and link it with the "Import" parameter. Second, by using the number slider determine the simulation duration time and dates for the simulation. Third, link the data with the "colour" parameter to the "Ladybug Sun path" parameter to calculate the data and process it before links it with " Ladybug Radiation analysis"parameter to simulate the radiation of the geometry.

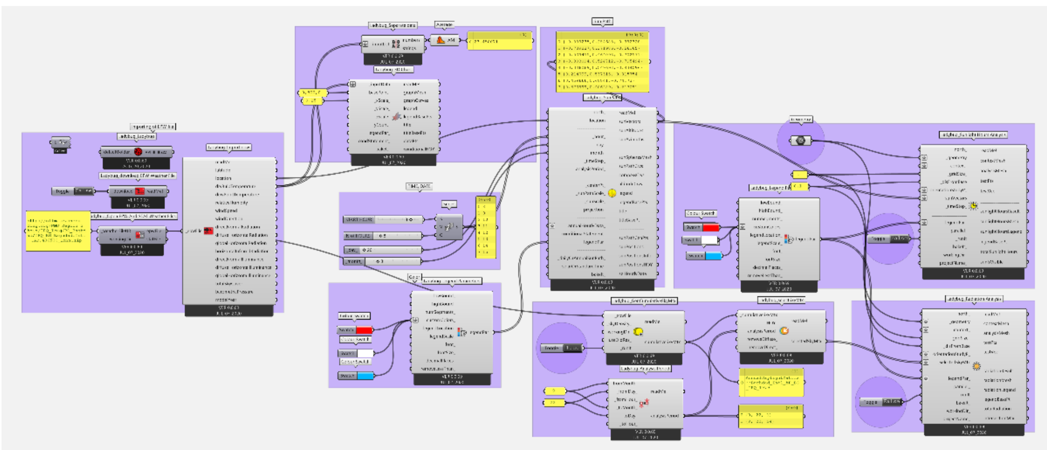


Figure 6.*Radiation algorithm Using "Ladybug"*

A. 2. Hours of Sunlight

Another aspect after solar radiation analysis is analysing the number of hours to determine solar radiation's time during the day where the surfaces have hours of exposure to the sun. The same tool, "Ladybug," for analysing the sun's radiation, is also used to analyse the hourly sunlight for different times of the year, equinox time.The same algorithm in (Figure 6) was used in radiation analysis was used to simulate hours of sunlight too, but the difference with selecting the last parameter " Ladybug Sunlight Hours Analysis " to did the simulation [12,13].

A. 3. Shadow Analysis

To optimize the ceiling surfaces that will use the solar plates, shadow analysis will be the final key factor for this stage. Nevertheless, the shadow analysis will be showing in the black and white abstract view from using the "DIVA" tool. DIVA tool is another environment Grasshopper plugin used to analyse environmental data[14](Figure 7) shows the illustrating mechanism of run the DIVA algorithm. To run it, First, determine the geometry for the experiment. Second, select the weather data from a file path, then by using the number slider determine the simulation duration time and dates, after preparing all data link it to "solar arc" to provide the shadow simulation.

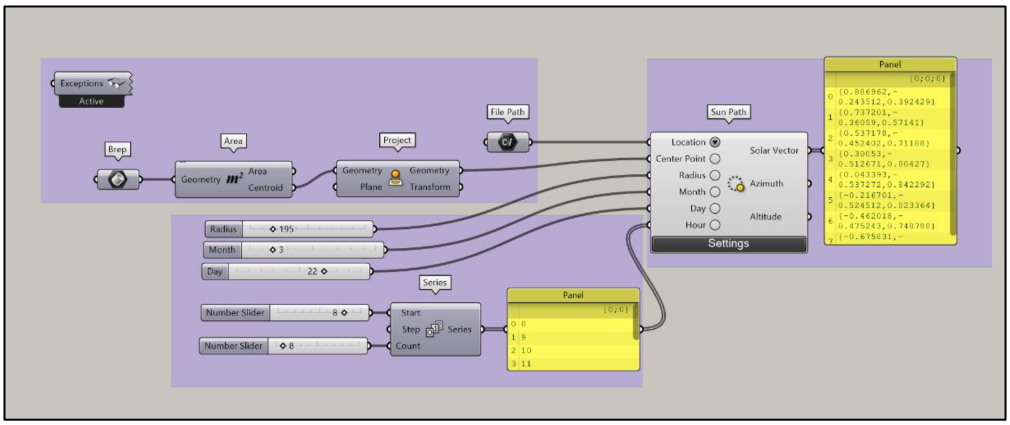


Figure 7.*Shadow analysis algorithm*

B. STRUCTURE ENHANCEMENT

As another application of algorithmic design is topology optimization. Which is a mathematical process to determine the maximum material that gives a better performance for a body, mass, or shape. Topology optimization's importance is to minimize materials used to the applied load and extract the structure's unnecessary volumes. Therefore, it is directly related to reducing the costs of construction.

First, a section of the stadium mass has been prepared by the "LunchBox" tool in Grasshopper. This tool allows to modify the geometry and extract the experimented section(Figure 8). The purpose of using the Lunchbox tool is to prepare the section shown in (Figure 9) without redrawing manually. If any change in geometry in the future, the algorithm will be a better solution for saving design time.

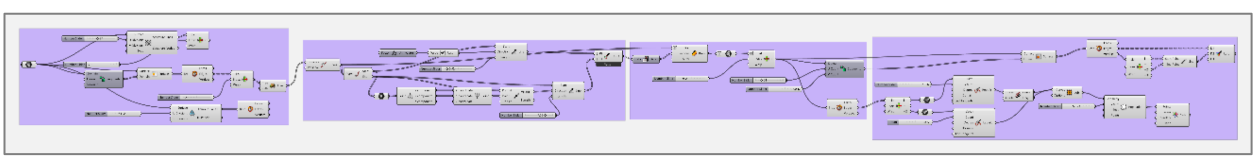


Figure 8 *.Lunchbox algorithm*

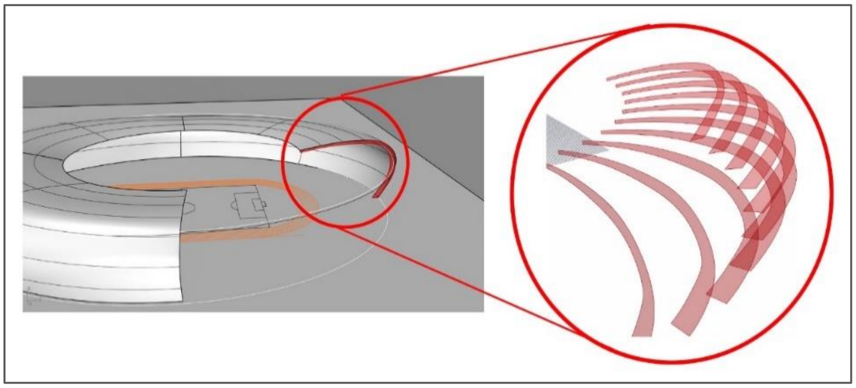


Figure 9. *Section extracting by Lunchbox algorithm*

After extracting the experimental section from the cylindrical form shapes surface, topology optimization was done using the "TOPOS" plugin in Grasshopper (Figure 10)[15]. The tool workflow considers the load, supports, boundary conditions, and boundary properties. The algorithm's applied load was 1.1 KN/m2 (solar plats weight, live load, and dead load), without considering wind loads.

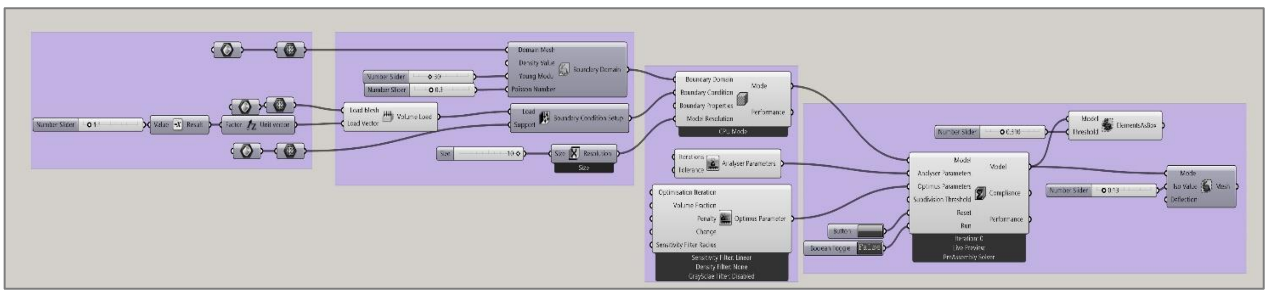


Figure 10. *TOPOS algorithm*

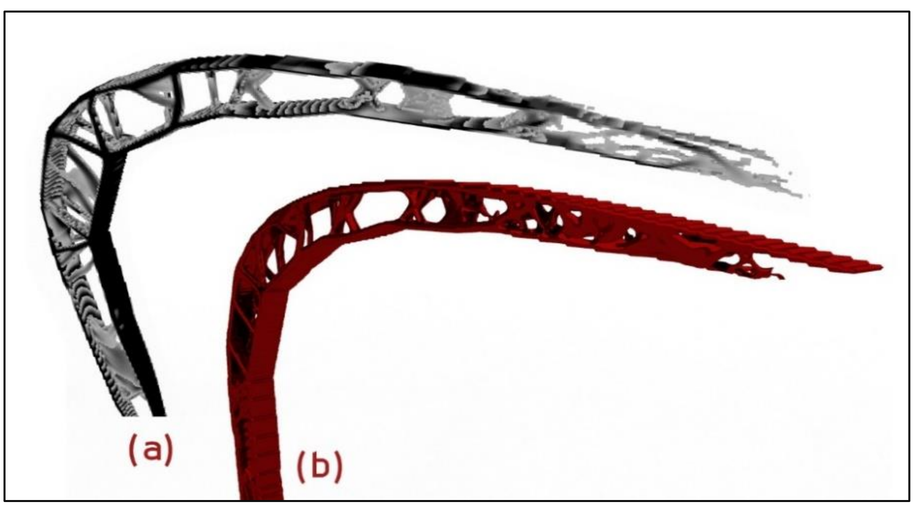


Figure 11.(a) *Closer image pixel result.* ***(b)****Final result*

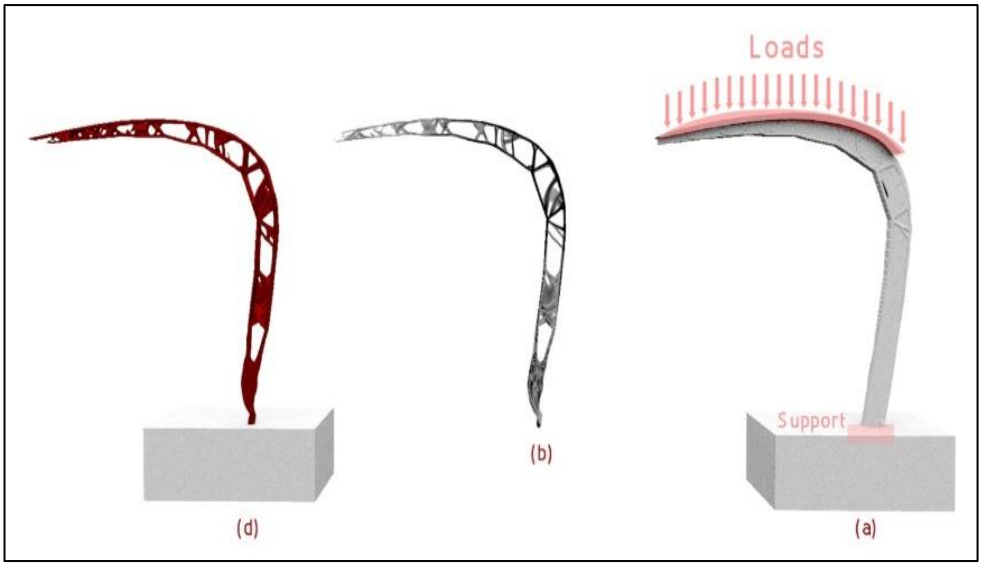


Figure 12.*Topology optimization for a section sample.* ***(a)*** *loads, and support.* ***(b)*** *pixel result.* ***(d)*** *Final result*

The outputs of this tool are two styles. First, pixel result (Figure 11 - a), which mainly refers to loads transferring from the applied forces to the support. Second, the soft mesh result (Figure 11 - b) is used to render the geometry, and it could be softer by using the "Weaverbird" tool. Finally, there is apparently torsion at the bottom of the column (Figure 12 - b), regards support only on the ground floor. The tool needs more options to input the data like structural software such as "SAAP, ETABS" to optimize the large-scale structure.

V. RESULTS

After exploring the algorithmic technique in different parametric tools, "Ladybug, DIVA 4.0, Lunchbox, TOPOS, and Weaverbird," the results were divided into two groups first the simulation analysis process results, and second the topology optimization tools review.

A. SIMULATION RESULTS

The simulation results show the analysis illustration and values for each prototype (01) and prototype (02) and compare between it as below:

A.1.Solar Radiation Analysis Results

Ladybug tool extracts the values of radiation shown in(Figure 13). These values are explained by unit "kWh/m2," and the colors change to the setting colors in the algorithm (Figure 6). According to the selecting experimenting times (Equinox time), the maximum value was 8.17 kWh/m^2 in June, and the lower value 0.17 kWh/m^2in December; (Table 1). The variation in the radiation values illustrated in (Figure 14).

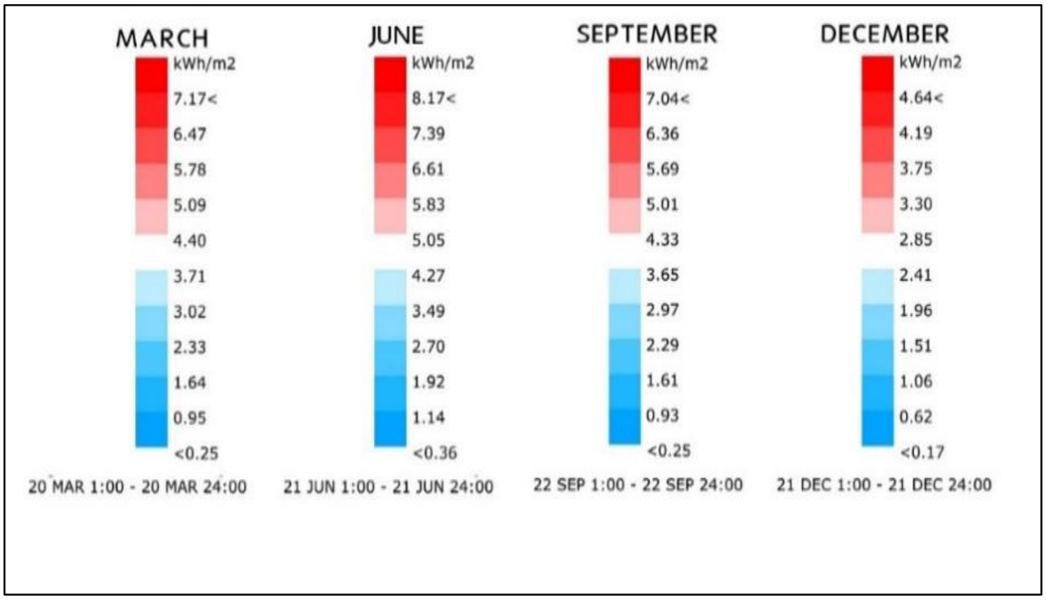


Figure 13. *Solar Radiation Values (kWh/m2)*

Table 1. *Maximum and minimum solar radiation values (kWh/m2)(1 Jan – 31 Dec, 2020)*

Radiation Values (kWh/m^2) - Equinox Time			
March	June	Septemper	December
7.17	8.17	7.04	4.64
6.64	7.39	6.36	4.19
5.78	6.61	5.69	3.75
5.09	5.83	5.01	3.3
4.4	5.05	4.33	2.85
3.71	4.27	3.65	2.41
3.02	3.49	2.97	1.96
2.33	2.7	2.29	1.51
1.64	1.92	1.61	1.06
0.95	1.14	0.93	0.62
0.25	0.36	0.25	0.17

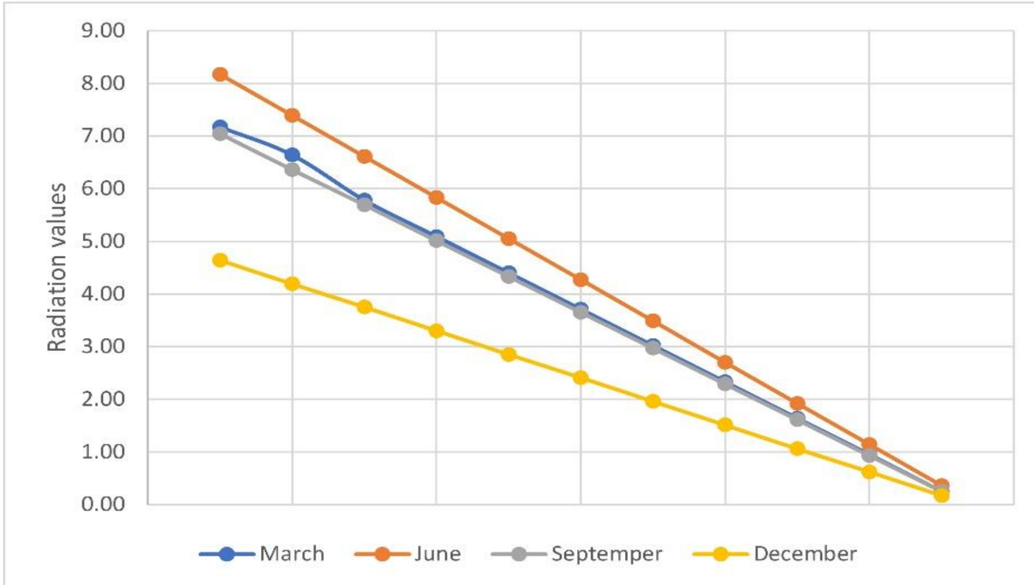
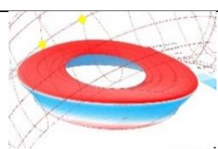
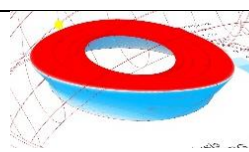
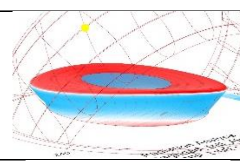
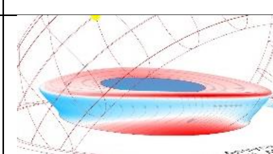
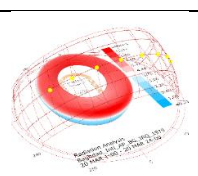
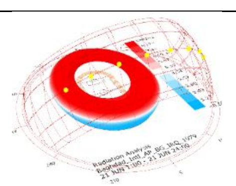
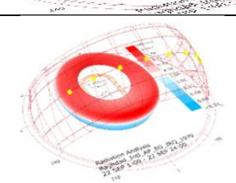
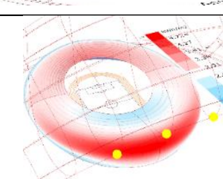


Figure 14. *Variation in the solar radiation values(kWh/m2) (1 Jan – 31 Dec, 2020)*

As shown in (Table 2), the prototype (02) cylindrical form presents better performance than the prototype (01) shell form in the radiation earning area. For radiation analysis of March, the radiation earning area of the prototype (02) increases by 22.5% than the prototype (01). For June, the radiation earning area of the prototype (02) increases by 25.5% than the prototype (01). For September, the radiation earning area of the prototype (02) increases by 12.3% than the prototype (01). For December, the radiation earning area of the prototype (02) increases by 9%, and only 6% increases for the prototype (01); These data are illustrated in (Figure 15).

Table 2 *- Analysis Results*

	March	June	September	December
Prototype (01) - shell Form.				
Prototype (02) - Cylindrical Form.				

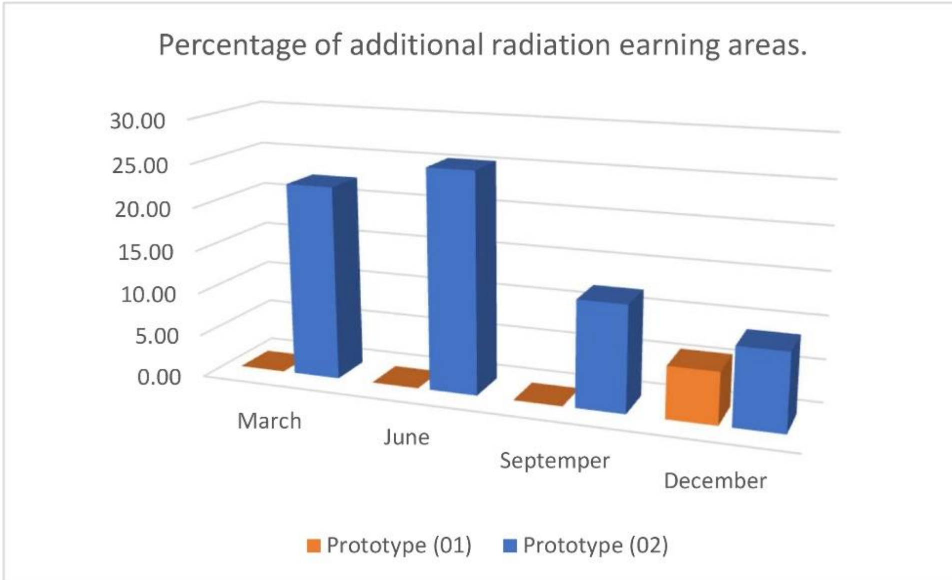
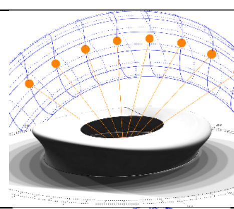
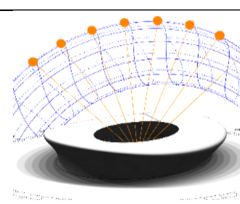
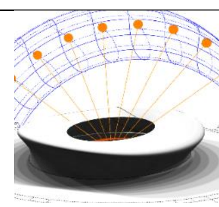
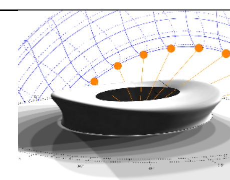
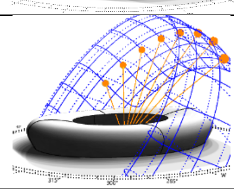
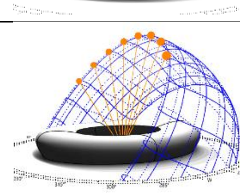
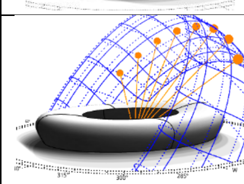
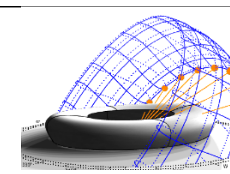


Figure 15. *Percentage of additional radiation earning area*

A.2. Shadow Analysis Results

As shown in (Table 3), For shadows analysis, the prototype (02) cylindrical form presents better performance than the prototype (01) shell form, with fewer shade areas. The shade areas of March of the prototype (02) are less by 15.75% than the prototype (01). For June, the shade areas of the prototype (02) are less by 11.75% than the prototype (01). For September, the shade areas of the prototype (02) are less by 16.3% than the prototype (01). For December, the shade areas of the prototype (02) are less by 37%, and only 29.3% decreasing the prototype (01); These data are illustrated in (Figure 16).

Table 3 *- Shadow analysis*

	March	June	September	December
Prototype (01) - shell Form.				
Prototype (02) - Cylindrical Form.				

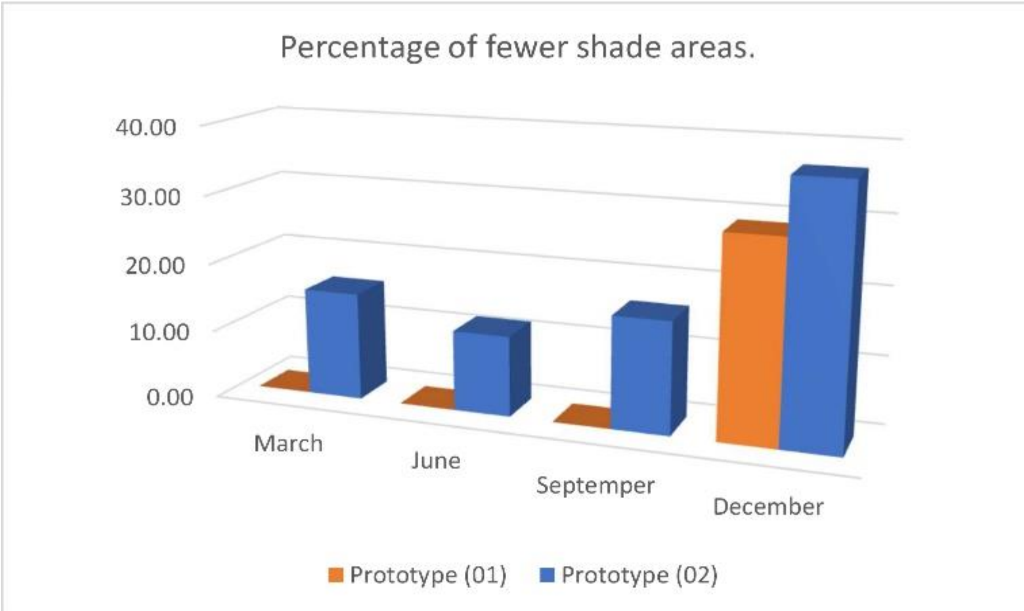
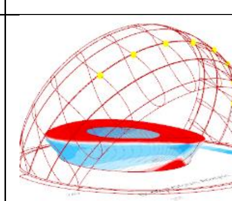
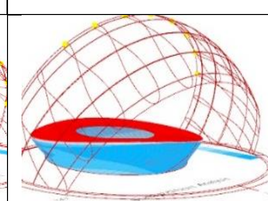
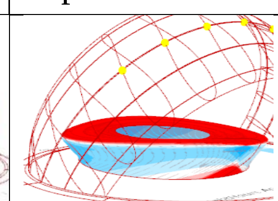
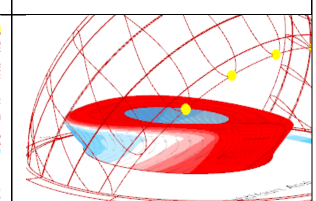
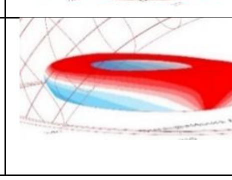
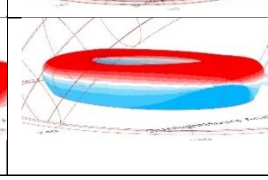
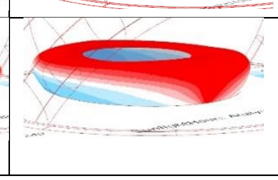
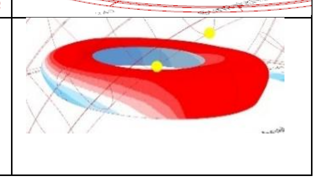


Figure 16.*Percentage of fewer shade areas*

A.3. Sunlight Hours Analysis Results

As shown in (Table 4), For sunlight hours analysis, the prototype (02) cylindrical form presents better performance than the prototype (01) shell forming the sunlight hours earning area. Where the sunlight hours earning area of March, the prototype (02) increases by 45.5% than the prototype (01). For June, the sunlight hours earning area in the prototype (02) increases by 29.5% than the prototype (01). For September, the sunlight hours earning area in the prototype (02) increases by 40% than the prototype (01). For December, the sunlight hours earning area in the prototype (02) increases by 46%, and only 29% increases for the prototype (01); These data are illustrated in (Figure 17).

Table 4 **-** Sunlight hours

	March	June	September	December
Prototype (01) - shell Form.				
Prototype (02) - Cylindrical Form.				

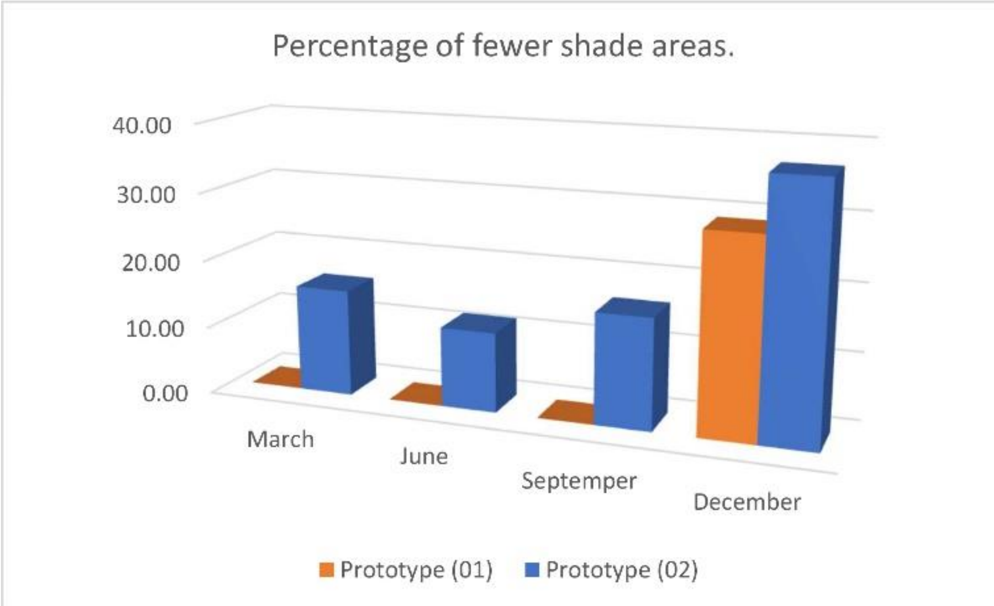


Figure 17.*Percentage of fewer shade areas*

As clearly shown in the tables above, the cylindrical form presents better performance than the shell form. The concept of increasing the stadium's surface to earn more roof area for solar plates, as in the case of shell form, may not be perfect. The increasing of surfaces as cantilevers may increase the cost of the construction. Furthermore, it could complicate the structural design and the construction methods. So, simulate the effect of climate on a building is very essential, it helps to understand the pros and cons of a design for a function not only form.

B. TOPOLOGY OPTIMIZATION TOOLS REVIEW

The parametric tools show a huge development in the way of programming of these tools but this for the architectural side. For the structure side, it still needs more development to be conceded as a design reference. To understand the level of development of these tools, Table 5below shows the difference between the architectural simulation tools, and topology optimization tools; and shows the pros and cons for each other.

Table 5.*Parametric tools comparison*

Comparison factor	Structure tools (Topology optimization tools: TOPOS)	Architectural tools (Simulation tools: Ladybug, DIVA 4.0)
Hardware requirements	High	Medium, Low
Processing time	Long time	Short time
Interactive view	Slow	Fast
Easy to use	Normal	Normal
Accuracy	Low	High
Range of functions	Limited	Multi-functional
Programming level	Beginner	Advanced

VI. CONCLUSION

In this study, the integration of architectural design and civil engineering and how solar energy from energy sources can be activated by building envelope design was investigated. solar energy panels have increasingly developed technology and application areas today. However, in cases where the building does not cooperate with the shell design or is not integrated into use, both the installation-maintenance-repair cost increases and its efficiency decreases.

The studies were carried out using a computer program (Grasshopper) supported simulation technique using the BIM (Building Information Modelling) system. The ability to respond to changes in data entry in algorithms gives architects the opportunity to optimize structures and form at the same time. Replacing the inputs with the parametric technique saves time in the design process, any changes that are made regularly in the design need to be redesigned from the beginning. However, building a structure for energy efficiency must use maximum surfaces to put solar plans. The algorithmic design simulates the effect and optimizes the geometry to achieve maximum energy efficiency for the building form.

Designers sometimes make decisions based on the eye in which the simulation analysis shows differences in values with different colours. Depending on the designer's opinion, the colours can be changed algorithmically. Colour preview helps to better understand the behaviour of the analysis.

Another advantage of simulation analysis is related to the reduction of construction costs by neglecting unnecessary surfaces that do not reach sunlight. The question is, this technique is easier to use than it is before, and how could it become widespread in the future for use in apartments, homes, and other structures.

Optimization in the TOPOS tool is the link between architectural and structural engineering in parametric technique. This tool, like other software, is based on structural analysis, but this tool tries to optimize the structure by neglecting unnecessary parts of the geometry. It mainly focuses on reducing the cost of construction. As shown in (Table 5) TOPOS is in the early stages of tool development and needs more work to compete with others optimizing software such as "Autodesk Fusion 360".The parametric tools served the field of architecture in terms of forms and functions very well, more than structural tools.

VII. REFERENCES

[1] A. Al-Mashhadani (2015). “Story of Al-Shaab stadium. An Iraqi facility was never built like it before.,” *Ishtar Channel*, [Online]. Available: https://www.ishtartv.com/viewarticle,64637.html.

[2] FIFA (2007). “Football Stadiums - Technical recommendations and requirements,” *FIFA Fédération Int. Footb. Assoc.*, [Online].Available:http://www.fifa.com/mm/document/tournament/competition/football_stadiums_technical_recmmendations_and_requirements_en_8211.pdf%5Cnhttp://scholar.google.com/scholar?hl=en&btnG=Searh&q=intitle:Football+Stadiums.+Technical+recommendations+and+requirements.

[3] S. G. Attia, “Early design simulation tools for net zero energy buildings : a comparison of ten tools design process &tools of nzeb,” *Buildings*, pp. 14–16, 2011.

[4] P. Caponi, F. Cutroni, and L. Rhode-Barbarigos, “Revisiting the ‘M Stadium’ project by luigi moretti: A forgotten model of parametric architecture,” *IASS Symp. 2019 - 60th Anniv. Symp. Int. Assoc.*

Shell Spat. Struct. Struct. Membr. 2019 - 9th Int. Conf. Text. Compos. Inflatable Struct. FORM FORCE, no. September, pp. 2247–2256, 2019.

[5] M. S. Roudsari and M. Pak, “Ladybug: A parametric environmental plugin for grasshopper to help designers create an environmentally-conscious design,” *Proc. BS 2013 13th Conf. Int. Build. Perform. Simul. Assoc.*, pp. 3128–3135, 2013.

[6] A. Shiota, A. Tada, S. Yamada, K. Yokozawa, T. Kerdphol, and Y. Mitani, “Construction of Solar Radiation Simulation Database and Solar Radiation Simulation System using GIS and Application to the Agriculture Field,” *Acta Sci. Agric.*, vol. 3, no. 10, pp. 02–09, 2019.

[7] P. Shepherd, R. Hudson, and D. Hines, “Aviva Stadium: A parametric success,” *Int. J. Archit. Comput.*, vol. 9, no. 2, pp. 167–185, 2011.

[8] W. Khider, (2019). “The story of the design and construction of Al-Shaab International Stadium,” *kooora*, [Online]: Available: https://bit.ly/3sJIbGV.(1-5-2021)

[9] Ali Ismaeel. (2019). “*Al-Shuhada Stadium in Iraq. the first environmentally friendly sports project that adopts solar energy*.,” [Online]: Available:https://bit.ly/3d9eB7S.(2-5-2021).

[10] M. Ramadhan.(2021). *“Habibiya stadium in Baghdad,” Rudaw.net*, 2021.[Online]: Available: https://bit.ly/3e63wGl.

[11] *Nidanews*, (2020). *Al-Shuhada Stadium waiting for the green light to announce the opening.,* [Online]: Available:https://cutt.ly/2vMMG6e.

[12] J. de S. Freitas, J. Cronemberger, and R. M. Soares, “Using rhinoceros plugins grasshopper and ladybug to assess BiPV Façades in Brasília.,” *Proc. Build. Simul. 2019 16th Conf. IBPSA*, vol. 16, no. July 2020, pp. 4467–4472, 2020.

[13] E. Touloupaki and T. Theodosiou, “Optimization of building form to minimize energy consumption through parametric modelling,” *Procedia Environ. Sci.*, vol. 38, pp. 509–514, 2017.

[14] C. Sun, H. Giles, and Z. Lian, “Parametric regression model for lighting calibration,” *Indoor Built Environ.*, vol. 25, no. 2, pp. 407–423, 2016.

[15] S. Bialkowski, “Topos GPGPU accelerated structural optimisation utility for architects,” vol. 1, pp. 679–688, 2004.