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# Lighting Design Method of A Football Stadium Considering Visualization

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**ABSTRACT**

This research is about implementation of visualization to evaluate and correct lighting state and characteristics of lighting engineering on computers in lighting design of football pitch considering shelter and tower. The visualization of architectural lighting and ornament with lamplights designs has not been studied in detail until now in the world, and the method of visualization design for achieving FIFA standards in asymmetric four-tower football stadium lighting is described in the light mode and under the brief introduction by the lighting simulation programs DIALux and Relux..

**Keywords:** design, environment, lighting, temperature, visualization

## 1. Introduction

Architectural lighting design, made on computers, aims to meet the specific lighting demands of a project, with a modern focus on visual feeling, evaluating lighting indices to predetermine results. This approach ensures that labor and time are saved, achieving the most convenient outcome through specialized software [1] [2] [3]. Visualization plays a key role in this process, allowing for the valuation and correction of designs by displaying the lighting environment and engineering indices on screen before actual construction. It embodies the integration of architectural lighting and ornament design (Figure1), reflecting the plan's demand for both the interior and exterior of buildings and showcasing the lighting environment through the strategic placement and color of lights on computer screens [4] [5]. The process, which includes several design methods whose technical data and intensive methods are closely guarded secrets, culminates in a display that is both functional and aesthetically pleasing, as illustrated in the principle diagram of architectural lighting and ornament design.

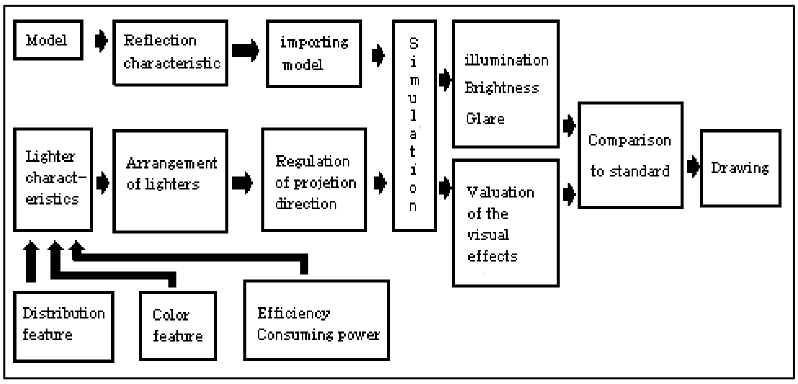


**Figure 1.** Diagram of the architectural lighting and ornament design for visualization

The summary of the architectural lighting design process, with a focus on visualization, encompasses a comprehensive and systematic approach. Initially, it involves creating the plane and section plans of the project, which serve as foundational blueprints. Subsequently, a vector model is developed using an architectural design program, such as Autodesk 3DS MAX, based on these plans. This model is crucial for modeling and should encapsulate all intricate details, including the arrangement of space, materials, and furniture, ensuring that the interior space can be viewed in perspective during the lighting simulation.

Modeling is a critical step where the model is crafted to have directivity, meaning it must be designed to allow the interior space to be perspectively seen during the simulation on computers [6] [7] [8]. The model, characterized by faces with directivity, is then prepared by ensuring it reflects comprehensive details and is arranged to showcase the space, material, and furniture effectively. The 3-D space is represented as a thin plane without thickness and is exported through plane turnover.

After creating the vector model, the next steps involve arranging the furniture and finishing materials within the model to reflect the intended design accurately. This model is then imported into a lighting simulation program, where the simulation calculus is carried out. The process includes selecting the appropriate light sources, placing the calculus plane within the simulator, and performing the simulation calculus. This simulation is essential for analyzing how light interacts with the space and materials within the model.

The results from the simulation are then meticulously analyzed, and the simulation is repeated as necessary until the outcomes align with the established "architectural lighting design standard." This iterative process ensures that the lighting design meets the desired criteria for both aesthetic appeal and functional requirements. Finally, a lighting target sketch is produced, along with calculations for the total power and lighting output power density, to ensure the design is both effective and energy-efficient. This methodical approach to architectural lighting design, through the use of sophisticated simulation and modeling tools, allows designers to visualize and refine their lighting plans to achieve optimal illumination that enhances both the functionality and ambiance of a space.

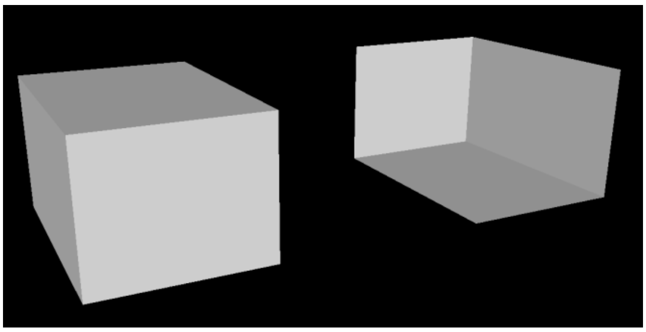

**Figure 2.** The vector model imported into the DIALux(on the right)

DIALux (Figure 2) is an advanced architectural lighting simulator renowned for its versatility in handling models for lighting design simulations. It has the capability to import models created by various design programs, or alternatively, users can create models directly within DIALux using its comprehensive suite of tools. Once a model is imported or created, DIALux facilitates the arrangement of lighting fixtures (referred to as "lighters") and the placement of the calculus plane, essential steps in preparing for the simulation calculus. Following these preparations, DIALux executes the simulation calculus, effectively displaying the results and illuminating the impact of lighting designs within the modeled space.

One of the notable features of DIALux is its flexibility with model formats. Should there be any inaccuracies in the imported model, it allows for the model to be corrected back in the original design program and reimported into DIALux as many times as necessary to achieve the desired accuracy. This iterative process ensures that the lighting simulation reflects the intended design with precision. Additionally, DIALux supports the importation of models lacking material definitions. These models can be mapped within DIALux, providing users the ability to define material properties and effects on lighting within the simulation. Pre-mapped models, where materials have already been defined, can also be imported seamlessly. This level of adaptability in handling models, whether they are pre-mapped or require mapping within the software, underscores DIALux's comprehensive approach to architectural lighting simulation, making it a powerful tool for designers aiming to optimize their lighting designs [9].

## 2. Method

A modern stadium is envisioned to not only be aesthetically beautiful but also to be well-equipped with sports facilities and a neatly organized lighting environment. This entails providing proper illumination that includes adequate brightness, an ideal color temperature, and a cubic effect, all while ensuring that glare is meticulously avoided. It is essential for spectators to experience good visual effects, enhancing their overall viewing experience. Similarly, coaches and players should have access to the necessary lighting to meet their specific requirements for performance and safety.The strategic placement of lighting towers plays a crucial role in achieving these lighting standards. Asymmetrical placement of lighting towers or situating lighting towers toward the tribute of honor in areas of the stadium that are traditionally not well-lit can present unique challenges. To address these, lighting engineering demands careful consideration, including the selection of lighting fixtures ("lighters"), and the setting of targets and indices. These indices encompass horizontal illumination, vertical illumination, illumination uniformity, glare index, color temperature, and brightness levels. Each of these factors must be scientifically and technically reviewed with precision.Such a detailed and scientific approach ensures that all areas of the stadium are adequately lit, promoting not only the functionality of the space but also contributing to the safety and enjoyment of all its users. Through careful planning and technical review, the lighting design of a stadium can significantly enhance the ambiance, ensuring that both the aesthetic and practical needs are met to the highest standards [10] [11].

## 3. Result and Discussion

The "Results and Discussion" section of the study delves into the comprehensive analysis and findings derived from the application of advanced technological tools in the field of architectural lighting design, specifically within the context of football pitch illumination. This exploration is grounded in the objective to adhere to the stringent standards set forth by FIFA, aiming to not only meet but exceed expectations in terms of functionality, safety, and aesthetics. Through the utilization of sophisticated modeling software such as AutoCAD, 3DS MAX, and Sketch Up, our study presents a detailed account of the design process, highlighting the accuracy and efficiency these tools bring to the table.

The results showcased herein are the product of an iterative design and evaluation process, where lighting simulations play a pivotal role in visualizing the impacts of various lighting schemes on the football pitch. This section not only presents the outcomes of these simulations but also engages in a critical discussion about the implications of these results. We explore how the integration of lighting engineering evaluations alongside visualization techniques allows for a nuanced analysis of potential design flaws, enabling us to refine our approach and align more closely with FIFA's standards.

Moreover, the discussion extends to the practical benefits observed through the adoption of these advanced technologies, focusing on the notable improvements in design accuracy and speed. This analysis is complemented by a consideration of the challenges faced during the design process, including the technical hurdles and the strategies employed to overcome them.

By synthesizing the findings and insights garnered from this study, we aim to contribute to the ongoing discourse on enhancing architectural lighting design practices, particularly in the realm of sports facilities. The lessons learned and methodologies developed through this research hold significant potential for informing future projects, driving innovation, and setting new benchmarks in the field

1) International demand on football stadium lighting

Internationally recognized dimensions for a football pitch vary, typically measuring either 105×68 meters or 110×75 meters. To ensure the safety of players, lighting equipment must be strategically placed, adhering to specific guidelines. Notably, these fixtures are not to be installed within 5 meters of the sideline or the goal area's front line. Additionally, to prevent any interference with the spectator's experience, lighting equipment is positioned at an appropriate height behind the guest seating areas.

The placement of corner towers is carefully considered to avoid obstructing the players' view of the pitch and the goal line. These towers are positioned from 5 degrees outward from the sideline to 10 degrees behind the goal line, ensuring they remain outside the players' direct line of sight. The height of these towers is calculated based on the formula $hm=d\times\tan(\alpha)hm=d\times\tan(\alpha)$, where the angle ($\alpha\alpha$) between the center of the pitch and the projection line of the lowest lighting fixture is maintained at over 25 degrees. This is to ensure optimal lighting without causing visual discomfort or inconvenience. Towers shorter than 15 meters are avoided due to the potential for increased visual disturbance caused by the lighting fixtures.

Furthermore, lighting towers are installed at least 10 degrees away from the goal line to ensure that goalkeepers have an unobstructed view of the corner flag from the goalpost. The projecting angle of the light fixtures is restricted to below 70 degrees to minimize glare and prevent light from spilling outside the facility. It is also essential that two adjacent projectors (Figure 3) are spaced sufficiently apart to reduce light interference. In scenarios where one is observing a header in a vertical section, the distance between rows of lighting must be increased to eliminate light interruption.

In terms of vertical alignment, the header of the tower (Figure 4) is set at a 15-degree gradient. This configuration ensures that the light projection from the top fixtures is not obstructed by those mounted below, thereby optimizing the lighting distribution across the pitch. These meticulously designed guidelines ensure that both the players' safety and the spectators' viewing experience are prioritized, contributing to the overall enjoyment and functionality of the football facility.

Lighters are not to be placed (Figure 5) in 15 degrees from the goal line to supply players offending from the corners and the goalkeeper with the better visual conditions [12] [13] [14] [15].

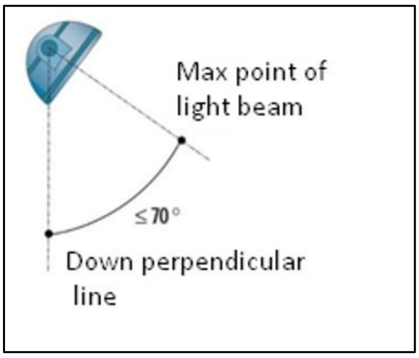


**Figure 3.** Maximum gradient of the projector

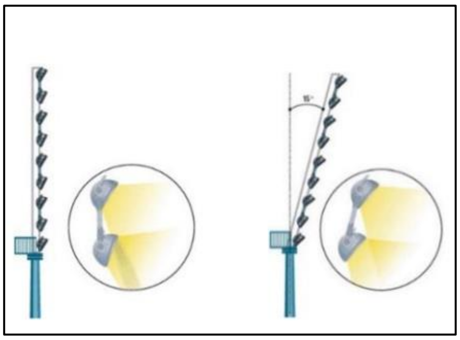

**Figure 4.** Gradient of the header of the tower

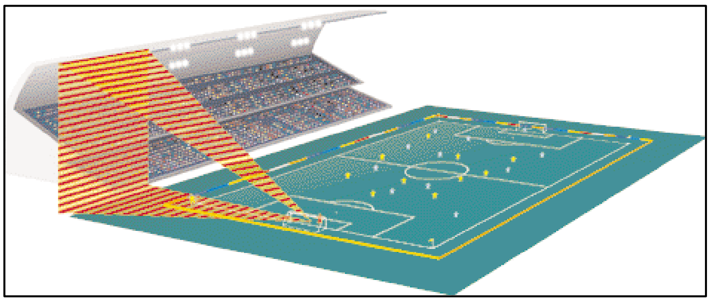

**Figure 5.** Non-lighting area.

2) FIFA standard [2,5,11]

The table articulates the 2015 FIFA standards for football pitch illumination, categorized into three distinct classes: Home (Class 3), Club (Class 2), and Training (Class 1). These standards are meticulously defined across several parameters, including average illumination (Eh.ave) in lux, minimum uniformity (U2), color temperature (Tk) in Kelvin, and color rendering index (Ra). For the Home class, an average illumination of 750 lux and a uniformity of 0.7 are mandated. The Club class standards require 500 lux with 0.6 uniformity, whereas the Training class is set at a lower threshold of 200 lux with 0.5 uniformity. Importantly, all classes must adhere to a color temperature exceeding 4000 Kelvin and a color rendering index minimum of 65, ensuring both visual clarity and fidelity across different levels of play (Table 1). This structured specification underscores FIFA's commitment to enhancing the quality of play and viewer experience by standardizing optimal lighting conditions across various football environments.

**Table1.** 2015 illumination standard of football pitch set by FIFA

| Illumination (not for broadcasting) | | | | |
|---|---|---|---|---|
| level | h. illumination $E_{h.ave}$(lx) | uniformity$U_2$ | Colour temperature $T_k$(K) | Colour rendering index $R_a$ |
| Home(class3) | 750 | 0.7 | >4 000 | ≥65 |
| Club(class2) | 500 | 0.6 | >4 000 | ≥65 |
| Training(class1) | 200 | 0.5 | >4 000 | ≥65 |

*vertical illumination is the one in the direction of the fixed or moving camera. All illuminations are stay values. Stay index is 0.7 and first value is 1.4 times. Glare rating GR is below 50.

The table delineates the illumination standards for broadcasting environments, distinguishing between international (class 5) and domestic (class 4) settings. It specifies average illumination levels (Ev.ave and Eh.ave) in lux, uniformity ratios (U1, U2), color temperature in Kelvin (Tk), and color rendering index (Ra) for both fixed and moving positions at floor level. International standards necessitate higher illumination levels, reflecting the demand for superior broadcast quality on global platforms (Table 2). The document underscores the importance of adhering to these standards, particularly emphasizing the need to maintain a specific illumination gradient to ensure optimal visual quality for broadcast audiences.

**Table 2.** Standards for Broadcasting Illumination: International and Domestic Specifications

| Illumination (for broadcasting) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| level | direction | vertical | | | horizontal | | | Properties of emitter | |
| | | $E_{v.ave}$ (lx) | uniformity | | $E_{h.ave}$ (lx) | uniformity | | Colour temperature $T_k$(K) | Colour rendering index $R_a$ |
| | | | $U_1$ | $U_2$ | | $U_1$ | $U_2$ | | |
| International (class5) | fixed | 2 400 | 0.5 | 0.7 | 3 500 | 0.6 | 0.8 | >4 000 | ≥65 |
| | Moving (floor level) | 1 800 | 0.4 | 0.65 | | | | | |
| Domestic (class4) | fixed | 2 000 | 0.5 | 0.65 | 2 500 | 0.6 | 0.8 | >4 000 | ≥65 |
| | Moving (floor level) | 1 400 | 0.35 | 0.6 | | | | | |

*these values should be maintained and the factor is 0.7 so first value is about 1.4 times. Gradient of the illumination should be below 30%/10m.

In the design of the football pitch lighting, design methods considering visualization should be introduced to display the lighting environment after construction on screen and valuate and correct.

3) design method considering visualization

In this method illumination, brightness and glare of the project after construction is valuated and shown as real so that correction stage can be scientific.

-modeling

Draw the plane and section plan in AutoCAD (Figure 6-9).

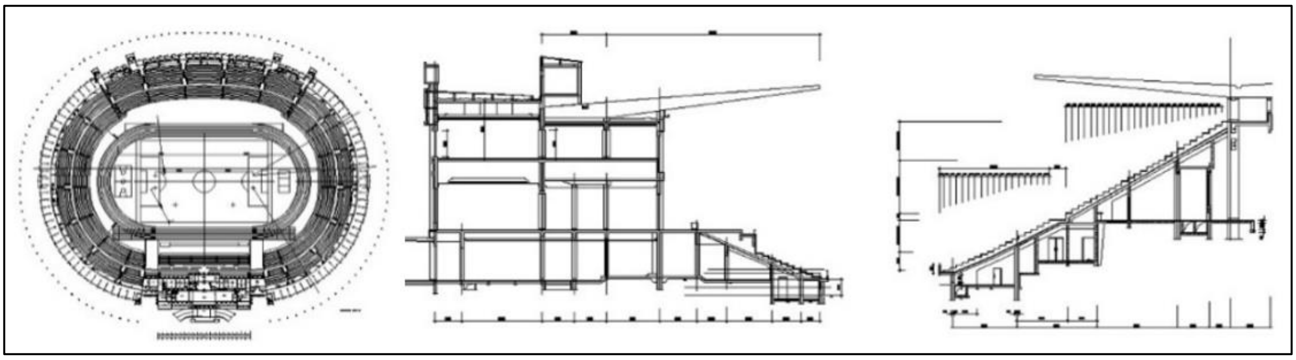

**Figure 6.** Plane and section plan by AutoCAD

Create the vector model by 3DS MAX.

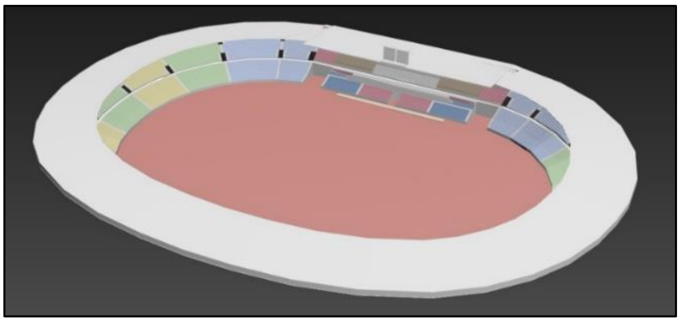

**Figure 7.** Model created by 3DS MAX.

-confirmation of characteristics of the lighters by light arrangement curves.

Import the model file into DIALux.

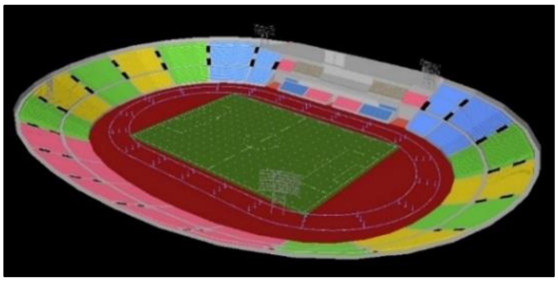

**Figure 8**. Model imported to DIALux.

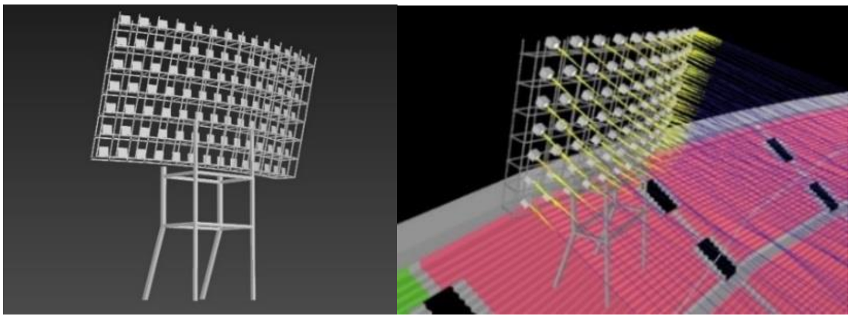

**Figure 9.** Arrangement of lighting lamp.

Lighters are arranged on the lighting towers and simulated on computer as real products.

A method of control of light arrangement curves is applied to the simulation and change of the lighting indices depending on the change of the curves is analysed and proper lighters and targets are selected.

The curves are simulated on Cat B1, Cat B2, Cat B3 and lighters are selected for control of glare and illumination.

MVF404 serial lighters have types of Cat B1~ Cat B8 and here curves are created and simulated on Cat B1~ Cat B3 [16].

Result tables created by DIALux are shown below for certainty (Figure 10-11, Table 3-5).

-result of simulation on Cat B1

**Figure 10.** Result scene.

**Table 3.** Results overview on Cat B1

| No. | Type | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 | $E_{min}$ / $E_{max}$ |
|---|---|---|---|---|---|---|
| 1 | perpendicular | 4 929 | 3 779 | 8 055 | 0.77 | 0.47 |
| 2 | horizontal | 4 929 | 3 779 | 8 055 | 0.77 | 0.47 |
| 3 | vertical, 0.0° | 4 409 | 2 706 | 6 449 | 0.61 | 0.42 |
| 4 | vertical, perpendicular to sideline 1 | 5 254 | 3 527 | 7 461 | 0.67 | 0.47 |
| 5 | vertical, perpendicular to sideline 2 | 4 409 | 2 706 | 6 449 | 0.61 | 0.42 |
| 6 | vertical, perpendicular to sideline 3 | 5 013 | 3 758 | 7 397 | 0.75 | 0.52 |
| 7 | vertical, perpendicular to sideline 4 | 4 409 | 2 706 | 6 449 | 0.61 | 0.42 |

**GR Observerlist**

| No. | Designation | Position [m] X | Y | Z | Viewing sector [°] Start | End | Increment | Slope angle | Max |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.000 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 46 2) |
| 2 | 2 | -25.000 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 2) |
| 3 | 3 | -25.000 | 17.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 50 2) |
| 4 | 4 | -25.000 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 50 2) |
| 5 | 5 | 0.000 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 46 2) |
| 6 | 6 | -52.500 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 46 2) |
| 7 | 7 | -52.500 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 2) |
| 8 | 8 | -25.000 | -17.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 48 2) |
| 9 | 9 | -25.000 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 46 2) |
| 10 | 10 | 0.000 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 44 2) |
| 11 | 11 | -52.500 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 45 2) |

-result of simulation on Cat B2

**Figure 11.** Result scene.

**Table 4.** Results overview on Cat B2

| No. | Type | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 | $E_{min}$ / $E_{max}$ |
|---|---|---|---|---|---|---|
| 1 | perpendicular | 4 163 | 3 672 | 5 428 | 0.88 | 0.68 |
| 2 | horizontal | 4 163 | 3 672 | 5 428 | 0.88 | 0.68 |
| 3 | vertical, 0.0° | 3 742 | 2 902 | 4 478 | 0.78 | 0.65 |
| 4 | vertical, perpendicular to sideline 1 | 4 552 | 3 641 | 5 514 | 0.80 | 0.66 |
| 5 | vertical, perpendicular to sideline 2 | 3 742 | 2 902 | 4 478 | 0.78 | 0.65 |
| 6 | vertical, perpendicular to sideline 3 | 4 252 | 3 184 | 5 436 | 0.75 | 0.59 |
| 7 | vertical, perpendicular to sideline 4 | 3 742 | 2 902 | 4 478 | 0.78 | 0.65 |

**GR Observerlist**

| No. | Designation | Position [m] | | | Viewing sector [°] | | | | Max |
|---|---|---|---|---|---|---|---|---|---|
| | | X | Y | Z | Start | End | Increment | Slope angle | |
| 1 | 1 | 0.000 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 [2)] |
| 2 | 2 | -25.000 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 [2)] |
| 3 | 3 | -25.000 | 17.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 [2)] |
| 4 | 4 | -25.000 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 [2)] |
| 5 | 5 | 0.000 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 45 [2)] |
| 6 | 6 | -52.500 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 46 [2)] |
| 7 | 7 | -52.500 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 [2)] |
| 8 | 8 | -25.000 | -17.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 48 [2)] |
| 9 | 9 | -25.000 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 49 [2)] |
| 10 | 10 | 0.000 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 45 [2)] |
| 11 | 11 | -52.500 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 45 [2)] |

-result of simulation on Cat B3

**Figure 12.** Result scene.

**Table 5.** Results overview on Cat B3

| No. | Type | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 | $E_{min}$ / $E_{max}$ |
|---|---|---|---|---|---|---|
| 1 | perpendicular | 3 818 | 3 436 | 4 482 | 0.90 | 0.77 |
| 2 | horizontal | 3 818 | 3 436 | 4 482 | 0.90 | 0.77 |
| 3 | vertical, 0.0° | 3 360 | 2 543 | 3 959 | 0.76 | 0.64 |
| 4 | vertical, perpendicular to sideline 1 | 4 076 | 3 040 | 4 668 | 0.75 | 0.65 |
| 5 | vertical, perpendicular to sideline 2 | 3 360 | 2 543 | 3 959 | 0.76 | 0.64 |
| 6 | vertical, perpendicular to sideline 3 | 3 801 | 2 926 | 4 548 | 0.77 | 0.64 |
| 7 | vertical, perpendicular to sideline 4 | 3 360 | 2 543 | 3 959 | 0.76 | 0.64 |

**GR Observerlist**

| No. | Designation | Position [m] X | Y | Z | Viewing sector [°] Start | End | Increment | Slope angle | Max |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.000 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 44 2) |
| 2 | 2 | -25.000 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 46 2) |
| 3 | 3 | -25.000 | 17.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 2) |
| 4 | 4 | -25.000 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 2) |
| 5 | 5 | 0.000 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 44 2) |
| 6 | 6 | -52.500 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 43 2) |
| 7 | 7 | -52.500 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 45 2) |
| 8 | 8 | -25.000 | -17.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 46 2) |
| 9 | 9 | -25.000 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 44 2) |
| 10 | 10 | 0.000 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 43 2) |
| 11 | 11 | -52.500 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 44 2) |

As shown in results, illumination of B1 is too high and there are points where GR is over 50.

And in terms of B3, equality and GR fits the standard but the first illumination is lower than the standard.

However all indices of B2 fits the standard and it seems to be a lighter appropriate the aesthetical characteristics of lighting towers.

According to the international standard only horizontal illumination is calculated for 1~3 classes but both vertical and horizontal ones are calculated for filming in 4,5 class. Result of the simulation of the illumination is following (Table 6-10, Figure 13).

**Table 6.** First class

**Results overview**

| No. | Type | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 | $E_{min}$ / $E_{max}$ |
|---|---|---|---|---|---|---|
| 1 | perpendicular | 345 | 225 | 838 | 0.65 | 0.27 |

**Table 7.** Second class

| No. | Type | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 | $E_{min}$ / $E_{max}$ |
|---|---|---|---|---|---|---|
| 1 | perpendicular | 784 | 550 | 1 155 | 0.70 | 0.48 |

**Table 8.** Third class

| No. | Type | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 | $E_{min}$ / $E_{max}$ |
|---|---|---|---|---|---|---|
| 1 | perpendicular | 1224 | 892 | 2 006 | 0.73 | 0.44 |

**Table 9.** Fourth class

| No. | Type | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 | $E_{min}$ / $E_{max}$ |
|---|---|---|---|---|---|---|
| 1 | perpendicular | 3 063 | 2 465 | 4 342 | 0.80 | 0.57 |
| 2 | horizontal | 3 063 | 2 465 | 4 342 | 0.80 | 0.57 |
| 3 | vertical, 0.0° | 2 721 | 2 019 | 3 517 | 0.74 | 0.57 |
| 4 | vertical, perpendicular to sideline 1 | 3 192 | 2 491 | 4 258 | 0.78 | 0.58 |
| 5 | vertical, perpendicular to sideline 2 | 2 721 | 2 019 | 3 517 | 0.74 | 0.57 |
| 6 | vertical, perpendicular to sideline 3 | 3 042 | 2 072 | 3 858 | 0.68 | 0.54 |
| 7 | vertical, perpendicular to sideline 4 | 2 721 | 2 020 | 3 516 | 0.74 | 0.57 |

**Figure 13.** Result scene of fifth class.

**Table 10.** Fifth class

| No. | Type | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 | $E_{min}$ / $E_{max}$ |
|---|---|---|---|---|---|---|
| 1 | perpendicular | 4 163 | 3 672 | 5 428 | 0.88 | 0.68 |
| 2 | horizontal | 4 163 | 3 672 | 5 428 | 0.88 | 0.68 |
| 3 | vertical, 0.0° | 3 742 | 2 902 | 4 478 | 0.78 | 0.65 |
| 4 | vertical, perpendicular to sideline 1 | 4 552 | 3 641 | 5 514 | 0.80 | 0.66 |
| 5 | vertical, perpendicular to sideline 2 | 3 742 | 2 902 | 4 478 | 0.78 | 0.65 |
| 6 | vertical, perpendicular to sideline 3 | 4 252 | 3 184 | 5 436 | 0.75 | 0.59 |
| 7 | vertical, perpendicular to sideline 4 | 3 742 | 2 902 | 4 478 | 0.78 | 0.65 |

As shown in the table horizontal and directional vertical illumination are beyond the international standard and the equality is good.

The vertical illumination in the camera direction is over the standard and especially GR Figure 14, Table 11 of the main camera should be below 50 and calculated on internationally-determined GR points [13] [15] [17].

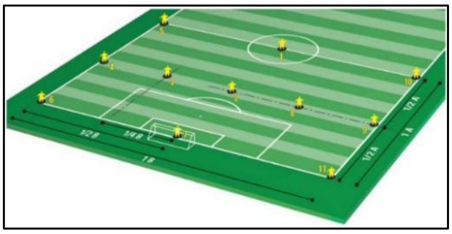

**Figure 14.** Locations of the GR points.

**Table 11.** GR observer list

**GR Observerlist**

| No. | Designation | Position [m] X | Y | Z | Viewing sector [°] Start | End | Increment | Slope angle | Max |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.000 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 2) |
| 2 | 2 | -25.000 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 2) |
| 3 | 3 | -25.000 | 17.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 2) |
| 4 | 4 | -25.000 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 2) |
| 5 | 5 | 0.000 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 45 2) |
| 6 | 6 | -52.500 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 46 2) |
| 7 | 7 | -52.500 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 2) |
| 8 | 8 | -25.000 | -17.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 48 2) |
| 9 | 9 | -25.000 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 49 2) |
| 10 | 10 | 0.000 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 45 2) |
| 11 | 11 | -52.500 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 45 2) |

Targets selected to lighting are not directed to the player's eyes and maximize the projection angle since the height of the tower is low. As shown in the results of the table illumination fulfills the standard. It is important to fix the lighters.

4) comparison to symmetric arrangement

The comparison of vertical and horizontal illuminations between non-symmetric and symmetric configurations in a four-tower lighting setup reveals that lighting conforming to international standards can be achieved. This assessment is conducted for the highest class of lighting. Simulators prefer the symmetric arrangement, opting for a configuration that involves arranging lights in a manner that is either four-directional or two-directional, depending on the symmetry. Specifically, a two-directional approach is used for non-symmetric arrangements, while a four-directional method is employed for symmetric ones. Consequently, the arrangement speed for simulations using symmetric configurations is significantly faster.

Lighter numbers and targets are coincidence between symmetric and non-symmetric arrangement. The result of the simulation is following: (Figure 15, Table12).

**Figure 15.** Result scene

**Table 12.** Comparison of illumination and GR between symmetric and non-symmetric method

| No. | Type | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 | $E_{min}$ / $E_{max}$ |
|---|---|---|---|---|---|---|
| 1 | perpendicular | 3 536 | 3 085 | 4 635 | 0.87 | 0.67 |
| 2 | horizontal | 3 536 | 3 085 | 4 635 | 0.87 | 0.67 |
| 3 | vertical, 0.0° | 4 194 | 3 077 | 5 036 | 0.73 | 0.61 |
| 4 | vertical, perpendicular to sideline 1 | 3 114 | 2 465 | 4 247 | 0.79 | 0.58 |
| 5 | vertical, perpendicular to sideline 2 | 4 194 | 3 077 | 5 036 | 0.73 | 0.61 |
| 6 | vertical, perpendicular to sideline 3 | 3 114 | 2 465 | 4 247 | 0.79 | 0.58 |
| 7 | vertical, perpendicular to sideline 4 | 4 194 | 3 077 | 5 036 | 0.73 | 0.61 |

**GR Observerlist**

| No. | Designation | Position [m] X | Y | Z | Viewing sector [°] Start | End | Increment | Slope angle | Max |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.000 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 46 [2)] |
| 2 | 2 | -25.000 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 50 [2)] |
| 3 | 3 | -25.000 | 17.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 49 [2)] |
| 4 | 4 | -25.000 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 52 [2)] |
| 5 | 5 | 0.000 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 48 [2)] |
| 6 | 6 | -52.500 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 48 [2)] |
| 7 | 7 | -52.500 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 [2)] |
| 8 | 8 | -25.000 | -17.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 49 [2)] |
| 9 | 9 | -25.000 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 52 [2)] |
| 10 | 10 | 0.000 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 48 [2)] |
| 11 | 11 | -52.500 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 48 [2)] |

**Table 13.** Illumination and GR in symmetric method

| No. | Type | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 | $E_{min}$ / $E_{max}$ |
|---|---|---|---|---|---|---|
| 1 | perpendicular | 4 163 | 3 672 | 5 428 | 0.88 | 0.68 |
| 2 | horizontal | 4 163 | 3 672 | 5 428 | 0.88 | 0.68 |
| 3 | vertical, 0.0° | 3 742 | 2 902 | 4 478 | 0.78 | 0.65 |
| 4 | vertical, perpendicular to sideline 1 | 4 552 | 3 641 | 5 514 | 0.80 | 0.66 |
| 5 | vertical, perpendicular to sideline 2 | 3 742 | 2 902 | 4 478 | 0.78 | 0.65 |
| 6 | vertical, perpendicular to sideline 3 | 4 252 | 3 184 | 5 436 | 0.75 | 0.59 |
| 7 | vertical, perpendicular to sideline 4 | 3 742 | 2 902 | 4 478 | 0.78 | 0.65 |

**GR Observerlist**

| No. | Designation | Position [m] X | Y | Z | Viewing sector [°] Start | End | Increment | Slope angle | Max |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.000 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 [2)] |
| 2 | 2 | -25.000 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 [2)] |
| 3 | 3 | -25.000 | 17.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 [2)] |
| 4 | 4 | -25.000 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 [2)] |
| 5 | 5 | 0.000 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 45 [2)] |
| 6 | 6 | -52.500 | 34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 46 [2)] |
| 7 | 7 | -52.500 | 0.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 47 [2)] |
| 8 | 8 | -25.000 | -17.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 48 [2)] |
| 9 | 9 | -25.000 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 49 [2)] |
| 10 | 10 | 0.000 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 45 [2)] |
| 11 | 11 | -52.500 | -34.000 | 1.500 | 0.0 | 360.0 | 15.0 | -2.0 | 45 [2)] |

As shown in the table 13, horizontal illumination decreases and GR of some points are over 50 in symmetric method. However in the non-symmetric method projection direction control for control of glare is accurate and proportion between vertical and horizontal illumination and directional vertical illuminations.

5) Drawing sketch of lighting targets and lighting construction

In this design, the construction method depends on a foundation that incorporates newly introduced building apparatus. When positioning lighters, a sketch is drawn to ensure that floor targets (Figure 16) are accurately marked and constructed at every specified point. This approach has accelerated the construction speed while saving on labor and materials.

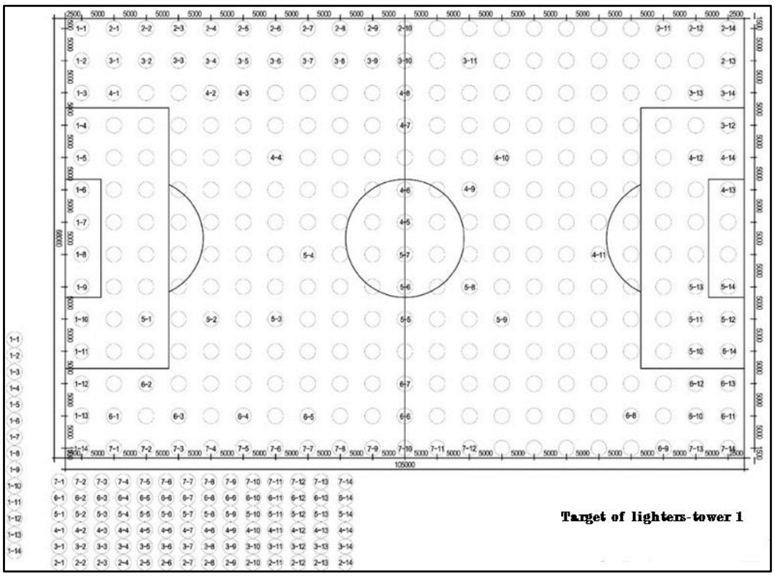


**Figure 16.** Sketch of lighting targets

So when placing lighters sketch is drawn so that floor targets are pointed and built on every number.

This fastened the construction speed and save labour and materials.

## 4. Conclusion

The integration of architectural and lighting standards set by organizations like FIFA with advanced modeling and visualization technologies underscores a comprehensive approach to the design of football pitches. The use of sophisticated software tools such as AutoCAD, 3DS MAX, and SketchUp is pivotal in creating high-quality models that allow for detailed and precise visualization of architectural designs, including nuanced lighting schemes. This technological integration facilitates a seamless process where lighting design is not only visualized but also evaluated from an engineering perspective. This critical step enables the identification and correction of any design flaws, ensuring that the final outcome meets the rigorous standards required. Moreover, this methodology significantly enhances both the speed and accuracy of the design process. By merging the capabilities of advanced software with thorough engineering evaluations, designers are equipped to efficiently pinpoint and address potential issues, leading to the development of optimized and compliant lighting solutions. This holistic approach highlights the importance of leveraging technological advancements in architectural lighting design, especially in sports facilities, where adherence to precise standards and specifications is crucial.

## 5. Acknowledgment

This research represents our dedicated effort to advance architectural science, with a particular emphasis on innovating lighting design within football stadiums. It is our sincere hope that this work will serve as a valuable foundation for future investigations and developments in this field

## References

[1] D. Li dan E. Tsang, "An analysis of measured and simulated daylight illuminance and lighting savings in a daylit corridor," *Building and Environment,* vol. 40, no. 8, pp. 973-982, 2005.

[2] W. Osterhaus, "Discomfort glare assessment and prevention for daylight applications in office environments," *Solar Energy,* vol. 79, no. 2, pp. 140-158, 2005.

[3] D. Bouchlaghem, H. Shang, J. Whyte dan A. Ganah, "Visualisation in architecture, engineering and construction (AEC)," *Automation in Construction,* vol. 14, no. 3, pp. 287-295, 2005.

[4] A. Gallardo, 3D LIGHTING, Rockland: Massachusetts, 2001.

[5] L. Nong dan L. Xuanye, “The prospects of applying BIM technology to architectural lighting design,” *Illumination technology journal,* 2013.

[6] W. Breugem dan B. Boersma, “irect numerical simulations of turbulent flow over a permeable wall using a direct and a continuum approach,” *Physics of Fluids,* vol. 17, no. 2, 2005.

[7] K.-c. Lee, J. Ho dan D. Kriegman, “Acquiring linear subspaces for face,” *IEEE Transactions on Pattern Analysis and Machine,* vol. 27, no. 5, pp. 684-698, 2005.

[8] S. Patwardhan, A. Dhawan dan P. Relue, “Monte Carlo simulation of light-tissue interaction: three-dimensional simulation for trans-illumination-based imaging of skin lesions,” *IEEE Transactions on Biomedical Engineering,* vol. 52, no. 7, pp. 1227-1236, 2005.

[9] Y. Liang, Application of DIALux in road illumination design, Application Technology, 2013.

[10] O. Bullough, M. Figueiro dan a. M. R. P. Morgan, The IESNA LIGHTING HANDBOOK, Illuminating Engineering Society of North America, 2000.

[11] R. Ganslandt dan H. Hofmann, Handbook of Lighting Design, Druckhaus Maack: Lüdenscheid, 1999.

[12] Artificial sports lighting design guide, Sport England, November, 2012.

[13] FIFA stadium tech rec guide to lighting, Lighting and power supply, 2015.

[14] Guide to the artificial lighting of football pitches, Philips Lighting, 2012.

[15] UEFA guide to quality stadiums, Switzerland, 2011.

[16] Arena Vision MVF404–exceptional optical efficiency, Koninklijke Philips, October 21, 2015.

[17] N. S. o. P. G. 50034-2013, Standard for lighting design of buildings, Chinese construction industry publishing house, 2014.