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Lighting Installation System Design in the Parking Area of Prof. Dr. Soekandar Mojokerto Regional Hospital Based on Dialux Software

Desain Sistem Instalasi Penerangan pada Area Parkir RSUD Prof Dr Soekandar Mojokerto berbasis Dialux Software

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Abstract _ This study proposes a DIALux Evo-based redesign of the outdoor parking lighting installation at RSUD Prof. Dr. Soekandar Mojokerto to address insufficient illuminance, poor light uniformity, glare, and the trade-off between lighting quality and energy consumption. The technical contribution of this work is an evidence-based luminaire layout optimization using field-based geometry and existing lamp data, followed by evaluation against SNI 7391:2008 and normalized energy-performance indicators. The existing system, consisting of three 150 W High Pressure Sodium (HPS) lamps, produced an average illuminance of 35.3 lux, an average luminance of 3.37 cd/m², a uniformity ratio of 0.005, a Unified Glare Rating (UGR) of 25, and energy consumption of 5.400 kWh/day for 12 h operation. The proposed lighting redesign employs 17 LED luminaires, each rated at 57 W with a luminous efficacy of 132 lm/W. Simulation results indicate that this configuration substantially improves the lighting performance of the hospital parking area, as reflected by an average illuminance of 96.5 lux, minimum illuminance of 35.9 lux, average luminance of 9.21 cd/m², a uniformity ratio of 0.37, which may be approximated to 0.40, and a Unified Glare Rating of 19. These results demonstrate that the proposed LED arrangement provides a more balanced distribution of light, improves nighttime visibility, and enhances visual comfort compared with the existing system. Although the daily energy consumption increases to 11.628 kWh/day due to the additional number of luminaires required to reduce dark zones, the normalized illuminance-to-energy performance improves from 6.54 to 8.30 lux/(kWh/day). This represents an improvement of approximately 27%, indicating that the proposed system delivers higher lighting quality per unit of electrical energy consumed. These results show that the LED-based design provides safer, more uniform, and more visually comfortable lighting while offering a practical reference for hospital parking areas and similar public facilities. This study is limited to simulation-based validation; therefore, field measurement after installation is recommended to confirm actual performance under operating conditions.

Keywords: parking area, DIALux Evo, illuminance, LED lamp, energy efficiency, lighting system.

Penelitian ini mengembangkan rancangan ulang sistem instalasi penerangan pada area parkir RSUD Prof. Dr. Soekandar Mojokerto dengan memanfaatkan perangkat lunak DIALux Evo sebagai alat bantu simulasi dan evaluasi teknis. Perancangan ulang ini dilakukan untuk menjawab permasalahan utama pada sistem eksisting, yaitu tingkat iluminansi yang belum memenuhi kebutuhan visual, distribusi cahaya yang tidak merata, potensi silau yang mengganggu kenyamanan pengguna, serta hubungan kompromistis antara peningkatan kualitas pencahayaan dan konsumsi energi listrik. Kontribusi teknis penelitian ini terletak pada optimasi tata letak luminer berbasis data geometri aktual lapangan dan spesifikasi lampu eksisting, kemudian dievaluasi menggunakan acuan SNI 7391:2008 serta indikator kinerja energi ternormalisasi. Dengan pendekatan tersebut, penelitian ini tidak hanya menilai besarnya konsumsi energi secara absolut, tetapi juga menilai seberapa efektif energi listrik dikonversi menjadi kualitas pencahayaan yang lebih layak, aman, dan nyaman bagi pengguna area parkir rumah sakit. Sistem eksisting yang menggunakan tiga unit lampu High Pressure Sodium (HPS) 150 W menghasilkan iluminansi rata-rata 35,3 lux, luminansi rata-rata 3,37 cd/m², uniformitas 0,005, Unified Glare Rating (UGR) 25, dan konsumsi energi 5,400 kWh/hari untuk operasi 12 jam. Rancangan usulan menggunakan 17 unit luminer LED 57 W dengan efikasi 132 lm/W dan menghasilkan iluminansi rata-rata 96,5 lux, iluminansi minimum 35,9 lux, luminansi rata-rata 9,21 cd/m², uniformitas 0,37 (dibulatkan menjadi 0,40), dan UGR 19. Meskipun konsumsi energi harian meningkat menjadi 11,628 kWh/hari karena diperlukan penambahan luminer untuk menghilangkan area gelap, rasio iluminansi terhadap energi meningkat dari 6,54 menjadi 8,30 lux/(kWh/hari) atau sekitar 27%. Hasil penelitian menunjukkan bahwa rancangan berbasis LED mampu memberikan pencahayaan yang lebih aman, lebih merata, dan lebih nyaman secara visual, sekaligus menjadi acuan praktis untuk area parkir rumah sakit dan fasilitas publik sejenis. Validasi penelitian ini masih berbasis simulasi, sehingga pengukuran lapangan setelah instalasi direkomendasikan untuk memastikan kinerja aktual pada kondisi operasi.

Kata kunci: area parkir, DIALux Evo, iluminansi, lampu LED, efisiensi energi, sistem penerangan.

I. INTRODUCTION

The development of public infrastructure in Indonesia, particularly in the healthcare sector, requires continuous improvement in the quality of supporting facilities and infrastructure. Hospitals, as public service institutions, are not only expected to provide optimal medical services, but also to ensure a safe, comfortable, and efficient environment for patients, visitors, and healthcare personnel. One of the supporting aspects that plays an important role, yet often receives insufficient attention, is the lighting system, especially in outdoor areas such as parking lots[1].

Hospital parking areas have a strategic function as transition spaces between the external environment and healthcare service facilities. These areas are used intensively by vehicles, patients, patients' families, healthcare workers, and visitors, both during the day and at night. Therefore, lighting quality in parking areas should not be regarded merely as a supplementary aspect, but rather as an integral part of the safety and comfort system of public facilities. Inadequate lighting can reduce users' ability to recognize objects, vehicle lanes, markings, pedestrians, and potential obstacles within the parking area. Such conditions may increase the risk of accidents, create greater opportunities for criminal activity, and reduce users' visual comfort. Conversely, a properly designed lighting system can support safety, security, visual orientation, and environmental comfort, while also strengthening the image of the hospital as a professional public service institution that is responsive to user needs. Therefore, the quality of lighting in parking areas needs to be planned technically and measured in accordance with applicable standards.

In addition to safety and comfort aspects, energy efficiency has also become an important consideration in lighting system planning. Inefficient use of electrical energy will increase hospital operational costs and affect the sustainability of facility management[3]. In this study, energy performance is not assessed only from absolute kWh consumption, but also from normalized indicators, including installed power, daily operating energy, and average illuminance per unit of energy used. This normalization is important because a redesign may increase total energy consumption when additional luminaires are needed to eliminate dark zones, but it can still provide better energy performance if the improvement in delivered illuminance, uniformity, and visual comfort is proportionally higher[4].

In electrical engineering, optimal lighting system planning can be carried out through a simulation-based approach using specialized software. DIALux Evo is one of the lighting simulation software packages widely applied in lighting design and evaluation. The software enables designers to construct a digital model of the analyzed area, select appropriate luminaire types, determine the required number and placement of luminaires, evaluate light distribution, assess glare potential, and estimate electrical energy consumption. Its application is particularly valuable because the proposed lighting design can be examined virtually before physical implementation. Through this

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simulation-based approach, possible design weaknesses such as insufficient illuminance, excessive contrast, non-uniform light distribution, and glare can be identified at the planning stage. Consequently, the use of DIALux Evo improves the accuracy, efficiency, and technical reliability of the lighting design process, while also helping ensure that the resulting design is aligned with applicable lighting standards and operational requirements[5-8].

Based on the initial condition of the parking area at RSUD Prof. Dr. Soekandar Mojokerto, the existing lighting system still uses 150 W HPS lamps installed only at a limited number of points[9]. Previous studies have discussed DIALux-based lighting design for classrooms, buildings, campuses, and road lighting[3]-[8], as well as the use of LED technology for energy improvement[9],[12]. However, most of these studies emphasize either illuminance achievement or energy saving separately. There is still limited analysis that evaluates a hospital parking area by simultaneously comparing an existing HPS system and an LED redesign based on SNI 7391:2008, glare, uniformity, and normalized energy performance. This research gap is important because hospital parking areas require lighting that is safe, visually comfortable, standards-compliant, and energy-aware in a continuous public-service environment.

Therefore, the novelty of this study lies in the integrated evaluation of lighting quality and normalized energy performance in an outdoor hospital parking case using field-based geometry and DIALux Evo simulation[12]. The technical contributions of this study can be classified into three main aspects. First, the study identifies and maps the non-compliance of the existing lighting system, which consists of only three 150 W HPS lamps and produces insufficient illuminance, very low uniformity, and excessive glare. Second, the study develops an optimized LED-based luminaire layout designed to improve average illuminance, minimum illuminance, average luminance, light uniformity, and glare control. Third, the study introduces a comparative energy-performance assessment by considering not only daily electrical energy consumption, but also the amount of average illuminance delivered per unit of energy consumed. This normalized evaluation is important because a lighting redesign may require higher installed power to eliminate dark zones, yet still provide better technical performance when the improvement in lighting quality is proportionally greater. Therefore, the findings of this study are expected to provide a practical and technical reference for designing outdoor lighting systems in hospital parking areas and similar public facilities

METHODS

This study employed a descriptive quantitative approach to evaluate the existing lighting conditions and to design a more optimal lighting system for the parking area of RSUD Prof. Dr. Soekandar Mojokerto. This approach was selected because the study focused on measuring lighting parameters, analyzing simulation results, and comparing the performance of the lighting system before and after redesign.

The research was conducted through two main stages, namely field data collection and lighting system design simulation using DIALux Evo 13.0 software. The standard used as the basis for evaluation was SNI 7391:2008 concerning lighting specifications for roads and outdoor areas. The main parameters analyzed included average illuminance, minimum illuminance, maximum illuminance, luminance, uniformity, glare level (UGR), and energy consumption[10].

1. *Research Location and Object*

The object of this study was the lighting system in the parking area of RSUD Prof. Dr. Soekandar Mojokerto. The parking area analyzed has dimensions of 43 m in length and 29 m in width. Under the existing condition, the site still used three units of 150 W HPS floodlights installed at several points, resulting in uneven light distribution and inadequate lighting performance for nighttime parking activities.

2. *Data Collection*

The research data were obtained through direct observation at the study site and documentation review. The data collected included:

a) the dimensions of the parking area;
b) the type, number, power rating, and layout of the existing lamps;
c) the initial lighting condition of the study area; and
d) lighting standard references and technical specifications of the luminaires used in the simulation.

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In addition, a literature review was conducted to obtain the theoretical foundation regarding outdoor lighting systems, the characteristics of HPS and LED lamps, the use of DIALux Evo software, and lighting requirements based on SNI 7391:2008.

Validity of Input Data and Simulation Assumptions

To strengthen data validity, all input parameters in DIALux Evo were checked against direct observation, site documentation, technical luminaire specifications, and the requirements of SNI 7391:2008. The same parking geometry (43 m × 29 m), calculation area, observation plane, and operating duration assumption (12 h/day) were applied to both the existing and optimized scenarios so that the comparison was made under identical conditions. Energy consumption was calculated from total installed power multiplied by daily operating hours, while lighting quality was evaluated using average illuminance (Eavg), minimum illuminance (Emin), maximum illuminance (Emax), average luminance (Lavg), uniformity ratio, and UGR. This procedure reduces inconsistencies between site data, manufacturer data, and simulation outputs and improves the reproducibility of the analysis.

3. *Research Procedure*

The research procedure was carried out in several stages as follows.

a. Identification of Existing Conditions

At this stage, observations were conducted on the lighting system installed in the parking area, including the number of lamps, lamp power, installation positions, and the coverage of light distribution.

b. Collection of Geometric Data of the Area

This stage involved measuring the dimensions of the parking area and constructing the geometric model of the site as the basis for simulation in DIALux Evo.

c. Modeling of the Existing Lighting System

The observation data were entered into DIALux Evo 13.0 to create a parking area model in accordance with actual site conditions. At this stage, the luminaire positions, mounting height, and specifications of the existing light sources were defined.

d. Simulation of Existing Conditions

The existing lighting system model was then simulated to obtain values of illuminance, luminance, uniformity, glare level, and energy requirements. These simulation results were used as the basis for evaluating the compliance of the existing lighting system with SNI 7391:2008.

e. Proposed Lighting System Design

After identifying the weaknesses of the existing system, a redesign was carried out using 57 W LED lamps. The design focused on determining the number of lamps, luminaire arrangement, and light distribution in order to achieve more uniform, visually comfortable, and standards-compliant lighting performance.

f. Simulation of the Proposed Design

The new design was then re-simulated using DIALux Evo to obtain the lighting parameters of the proposed system.

g. Comparative Analysis

The final stage involved comparing the simulation results of the existing condition with those of the proposed design based on technical lighting parameters and energy consumption. From this comparison, the most feasible lighting system design was determined.

4. *Data Analysis Technique*

The data were analyzed using a descriptive-comparative method by comparing the lighting parameters under the existing condition and the optimized condition. The feasibility of the lighting system was determined based on the level of conformity of the simulation results with SNI 7391:2008. This analysis was used to assess whether the proposed design was capable of improving the lighting quality of the parking area in terms of light intensity, distribution uniformity, visual comfort, and energy efficiency.

5. *Success Indicators*

The proposed lighting system was considered better if it met the following criteria:

a) the average illuminance value met or exceeded the minimum standard;
b) the light distribution became more uniform, as indicated by an increase in the uniformity value;
c) the glare level remained within the range of visual comfort; and
d) the energy consumption remained proportional to the improvement in lighting quality achieved.

II. RESULTS AND DISCUSSION

The parking area that became the focus of this study is located within the hospital grounds of RSUD Prof. Dr. Soekandar. The analyzed area measures 43 m × 29 m, or approximately 1,247 m². The currently inadequate lighting condition may increase the risk of accidents and heighten the potential for criminal activity. This condition emphasizes the need for a lighting design that is not only safe and visually comfortable, but also evaluated using consistent technical and energy-performance indicators.

A. Existing Condition of the Parking Area

The parking area still used conventional lighting with 150 W HPS floodlights. The lamps were installed at three points (two on the southern side and one on the northern side). The following figure shows the sketch of the existing lamp positions:

Figure 1 Existing Lamp Layout

The following figure presents the false-color simulation result of the existing condition using DIALux to observe its light distribution:

Figure 2 False-Color Result of the Existing Condition Simulation

The spacing between the lamps was too wide, resulting in poor uniformity of light distribution. Conventional lamps such as HPS emit light from a point source, which often causes very high intensity directly beneath the lamp and dark areas between lamps.

The simulation of the existing condition conducted using DIALux Evo software produced the following results:

- Average illuminance = 35.3 lux
- Minimum illuminance = 0.181 lux
- Maximum illuminance = 276 lux
- Average luminance = 3.37 cd/m²
- Uniformity ratio = 0.005
- Glare level = 25
- Energy consumption = 5.400 kWh/day (12 h operation)

B. Optimization Using 57 W LED Lamps and 132 lm/W Efficacy

This study used 17 units of 57 W LED lamps. The following figure shows the optimized lamp placement in DIALux:

Figure 3 Optimized Lamp Placement in DIALux Software

The following false-color result was obtained from the simulation of 17 units of 57 W lamps using the DIALux Evo application:

Figure 4 3D False-Color View of the Optimized Lighting

The optimization simulation using 17 units of 57 W LED lamps in DIALux produced the following results:

- Average illuminance = 96.5 lux
- Minimum illuminance = 35.9 lux
- Maximum illuminance = 147 lux
- Average luminance = 9.21 cd/m²
- Uniformity ratio = 0.37
- Unified Glare Rating (UGR) = 19
- Energy consumption = 11.628 kWh/day (12 h operation)

C. Analysis of Results

This study was conducted to evaluate and design an optimal lighting installation system for the parking area of RSUD Prof. Dr. Soekandar by comparing the existing condition and the simulated design using DIALux Evo software. The main parameters analyzed included average illuminance (Eavg), minimum illuminance (Emin), maximum illuminance (Emax), average luminance (Lavg), light uniformity, UGR, installed power, daily energy consumption, and normalized lighting performance.

Table I Comparison of Existing and Optimized Lighting

1. Average Illuminance

The average illuminance (Eavg) of the existing system with three 150 W HPS lamps was 35.3 lux. This value is below the SNI 7391:2008 requirement of at least 50 lux for parking areas, indicating that the existing system does not provide adequate visibility and visual comfort at night. After redesign using 17 units of 57 W LED luminaires, Eavg increased to 96.5 lux. This result exceeds the minimum standard and shows that the optimized luminaire layout can provide brighter and more usable illumination across the parking area.

2. Minimum Illuminance

The minimum illuminance (Emin) of the existing HPS system was only 0.181 lux, whereas the LED redesign increased this value to 35.9 lux. Based on SNI 7391:2008, Emin should not be less than 40% of Eavg. In the existing system, the ratio of Emin/Eavg was only 0.005, showing the presence of very dark zones. In the optimized design, the ratio increased to 0.37, which is very close to the 0.40 threshold and is commonly rounded to 0.40 in the comparative table. This result indicates a substantial improvement in light distribution, although minor field adjustment of luminaire angles or spacing is recommended during implementation to ensure full compliance with the uniformity threshold.

3. Maximum Illuminance

The maximum illuminance (Emax) parameter indicates the highest lighting level at a specific point in the simulated area. In the existing HPS system, Emax reached 276 lux while Emin was only 0.181 lux, producing an extreme contrast ratio and indicating non-uniform lighting. In the LED redesign, Emax decreased to 147 lux while Emin increased to 35.9 lux, resulting in a much more balanced light distribution. The optimized design therefore reduces excessive bright spots and dark zones, which are important factors for driver visibility, pedestrian safety, and visual comfort.

4. Average Luminance

The existing system with three HPS lamps produced an average luminance (Lavg) of 3.37 cd/m², whereas the redesigned LED system produced 9.21 cd/m². This increase indicates that the LED system improves the perceived brightness of the parking area and supports better object recognition for both drivers and pedestrians. The luminance result also confirms that the proposed system exceeds the minimum luminance criterion used in the evaluation.

5. Light Uniformity

The uniformity ratio in the existing system was 0.005, indicating highly uneven light distribution and the potential creation of dark and overly bright areas. This condition can reduce safety, particularly for pedestrians and vehicles moving at night. In the LED system, the uniformity ratio increased to 0.37, or approximately 0.40 when rounded. This improvement shows that the new design distributes light more evenly, although final commissioning should include luminaire aiming adjustment to achieve a uniformity value equal to or greater than 0.40 in the field.

6. Glare Level

The HPS system produced a UGR of 25, which exceeds the recommended maximum value for outdoor visual comfort and may cause discomfort for drivers and pedestrians. The LED redesign reduced the UGR to 19, which is below the recommended limit of 22. This result indicates that the proposed system improves visual comfort by reducing glare while maintaining adequate illuminance.

7. Energy Consumption

The existing system had an installed power of 450 W and consumed 5.400 kWh/day for 12 h operation, while the LED redesign had an installed power of 969 W and consumed 11.628 kWh/day. The increase in daily energy consumption was 115.3%, but the average illuminance increased by 173.4%. The normalized lighting performance of the proposed system increased from 6.54 to 8.30 lux/(kWh/day), equivalent to an improvement of approximately 27%. This result indicates that the proposed LED design should not be evaluated solely based on its higher absolute energy consumption. Although the total daily energy use increases, the system provides a greater amount of useful illumination, significantly reduces dark zones, improves the uniformity of light distribution, and lowers the glare level to a more visually comfortable range. In this context, the additional energy consumption can be technically justified because it is accompanied by a substantial improvement in lighting quality and user safety. Nevertheless, to maintain operational efficiency, the implementation of the proposed design should be supported by energy management strategies such as scheduled switching, photocell-based control, motion sensors, or dimming systems during periods of low activity. These control strategies would help reduce unnecessary energy use without compromising the minimum lighting performance required for safety and comfort.

D. Technical Recommendations and Equipment Specifications

Based on the simulation results using DIALux Evo software and the performance comparison between the existing system (three 150 W HPS lamps) and the new design system (17 units of 57 W LED lamps), the following technical recommendations can be formulated:

1. Lamp Type

Use outdoor LED luminaires with high luminous efficacy, in this case approximately 132 lm/W. LED luminaires offer advantages in

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energy performance, longer service life, instant illumination without warm-up time, and better glare control compared with HPS lamps. LEDs are also more environmentally friendly because they do not contain mercury like some conventional discharge lamps.

2. Number and Placement of Lamps

Number of luminaires: 17 units. Power per luminaire: 57 W. The luminaires should be installed evenly across the 43 m × 29 m area with a pole height of approximately 6 m. Installation spacing and aiming angles should be adjusted during commissioning so that the light distribution remains uniform and dark zones are avoided.

3. Lighting Performance Produced

Average illuminance: 96.5 lux. Minimum illuminance: 35.9 lux. Average luminance: 9.21 cd/m². Uniformity ratio: 0.37 (≈0.40). UGR: 19. The reference standard used is SNI 7391:2008 for outdoor parking areas, with particular attention to average illuminance, uniformity, glare limitation, and visual comfort.

4. Energy Efficiency and Power Consumption

Existing system power: 3 × 150 W = 450 W (0.450 kW); energy consumption = 0.450 kW × 12 h = 5.400 kWh/day.

The proposed LED lighting system consists of 17 luminaires, each with a power rating of 57 W, resulting in a total installed power of 969 W or 0.969 kW. Assuming an operating duration of 12 hours per day, the daily energy consumption of the proposed system is calculated as 0.969 kW × 12 h, or 11.628 kWh/day. Although this value is higher than the energy consumption of the existing system, the proposed design achieves better normalized lighting performance, increasing from 6.54 to 8.30 lux/(kWh/day). This demonstrates that the LED system is more effective in delivering lighting quality per unit of energy used. Therefore, the proposed design should be understood as a quality-oriented and performance-based improvement rather than merely an energy-reduction strategy. For practical implementation, the lighting system should be integrated with operational control mechanisms such as time scheduling, photocell-based switching, adaptive dimming, or motion-based control to minimize unnecessary energy consumption during low-traffic periods while maintaining adequate safety and visibility.

5. Implementation Validation

After installation, field validation should be carried out by measuring illuminance at representative grid points and comparing the results with DIALux output and SNI criteria. This step is necessary to confirm the effects of pole height, luminaire aiming, surface reflectance, lumen depreciation, and environmental conditions on actual lighting performance.

III. CONCLUSION

Based on DIALux Evo simulation, the existing lighting system in the parking area of RSUD Based on the DIALux Evo simulation results, the existing lighting system in the parking area of RSUD Prof. Dr. Soekandar Mojokerto does not satisfy the required lighting performance criteria. The existing installation, which uses three 150 W HPS lamps, produces an average illuminance of only 35.3 lux, a uniformity ratio of 0.005, and a UGR value of 25. These results indicate insufficient lighting intensity, highly uneven light distribution, and potential visual discomfort due to glare. The proposed redesign using 17 units of 57 W LED luminaires significantly improves the lighting performance, increasing the average illuminance to 96.5 lux, minimum illuminance to 35.9 lux, average luminance to 9.21 cd/m², and uniformity ratio to 0.37, which is approximately 0.40, while reducing the UGR value to 19. These improvements indicate that the proposed system provides better visibility, more uniform illumination, and improved visual comfort for parking area users.

Although the daily energy consumption increases from 5.400 kWh/day to 11.628 kWh/day, the normalized lighting performance also increases from 6.54 to 8.30 lux/(kWh/day). Therefore, the proposed LED-based system is technically more effective because the increase in energy use is accompanied by a greater improvement in lighting quality, especially in terms of illuminance, uniformity, glare reduction, and elimination of dark zones. The main contribution of this study is the development of a standard-based and energy-normalized redesign framework for hospital parking lighting systems. Future research should include post-installation field measurements to validate the simulation results and evaluate the potential application of dimming systems, motion sensors, or automatic control strategies to reduce operational energy consumption while maintaining lighting performance.

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Parameter	Existing	Optimized	SNI
Eavg	35.3 lux	96.5 lux	≥50 lux
Emin	0.181 lux	35.9 lux	≥0.4×Eavg
Emax	276 lux	147 lux	≤10×Emin
Lavg	3.37 cd/m²	9.21 cd/m²	≥1.0 cd/m²
Uniformity	0.005	0.37 (≈0.40)	≥0.40
UGR	25	19	≤22
Power	450 W	969 W	N/A
Energy (12 h)	5.400 kWh/day	11.628 kWh/day	N/A
Eavg/(kWh/day)	6.54	8.30	N/A

Table I Comparison of Existing and Optimized Lighting

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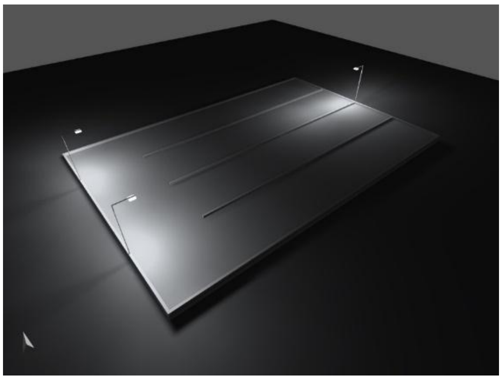

Figure 1 Existing Lamp Layout

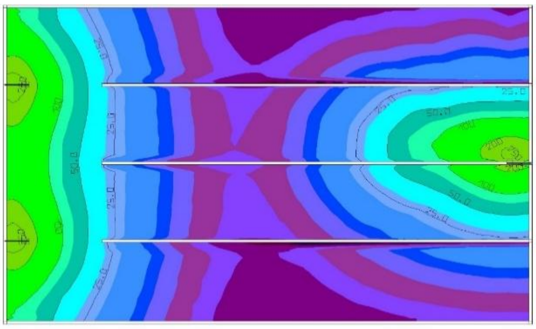

Figure 2 False-Color Result of the Existing Condition Simulation

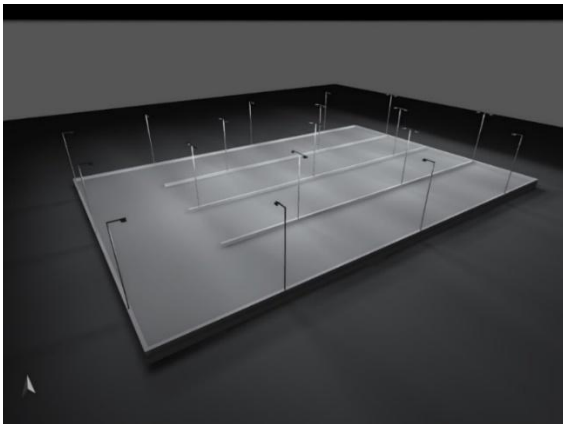

Figure 3 Optimized Lamp Placement in DIALux Software

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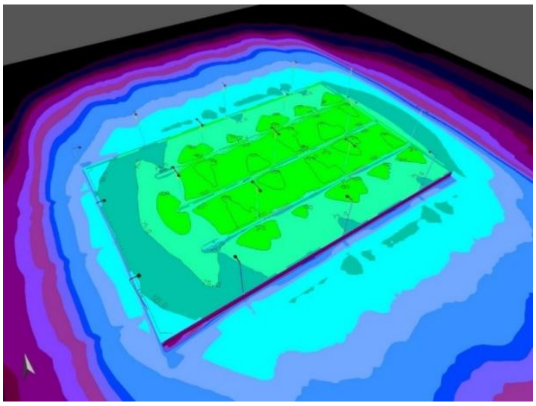

Figure 4 3D False-Color View of the Optimized Lighting