STATISTICS, OPTIMIZATION AND INFORMATION COMPUTING
Stat., Optim. Inf. Comput., Vol. **12**, May 2024, pp 737–751.
Published online in International Academic Press (www.IAPress.org)

Assessing public street lighting in Morocco: evaluating efficiency and the impact of geometrical parameters on luminance

Agrouaz Younes*, Mohamed Ouazzani Ibrahimi, Jamil Abdelmajid , Simou Zakariae, Hamdaoui Said

High School of Technology, Sidi Mohamed Ben Abdellah University(USMBA), Fez, Morocco

Abstract The main objective of this study is to present a bench marking of the public street lighting in typical road in Morocco. The study deals with a comparison between the conventional technology used in Moroccan road and the LED technology. The simulated system is based on road with two directions and a sidewalk, three arrangements type of pole layout are treated (Left, Middle and Two sides arrangement). Also, in this paper deals with a parametric analysis based on the variation of boom angle, light Center high and the pole distance in order to determine the luminance of each arrangement at each pole distance. The simulation is carried out using two luminaries, the first one represents a conventional technology and LED lamp. The founding of this paper shows that the LED lamp present a high luminance value of 20 cd/m² for a pole distance of 10m and boom angle of 0°, in comparison with the conventional lamp that present a luminance of 8 cd/m² at the same condition. The left arrangement type shows the best energy efficiency indicators such as DE and power per km, this means that this disposition is less consuming of energy and acceptable luminance values. Therefore, these two indicators play a crucial role in enhancing the efficiency of the lighting.

Keywords Public lighting, Energy consumption, Luminance, Efficiency

DOI: 10.19139/soic-2310-5070-1968

1. Introduction

The public lighting system in Morocco comprises approximately 1.6 million light points, resulting in a budgetary burden of approximately 1.5 billion Moroccan dirhams for local authorities. Electricity consumption related to public lighting accounts for between 10% and 15% of the municipality's operating budget, and in some municipalities, it can go as high as 20% . Hence, there is a pressing need to take drastic measures to alleviate this burden. There are various avenues to explore, and the potential for savings is substantial, potentially exceeding 60% , which can be financed through energy performance contracts [1]. Fabio et al. demonstrate in their study the effects of light on environmental deterioration, and they provide an effective strategy to reduce pollution, which includes shielding, avoiding over-lighting, and limiting illumination to the region. The study's originality is based on a novel approach that entails studying the spectra of common lamps, including LEDs, and comparing their emissions to human eye photoreceptors. The quantity of pollution produced by a light is largely influenced by its spectral proper-ties, with low pressure sodium lamps being more environmentally friendly. Switching from sodium to white bulbs may increase pollution and exacerbate current consequences on human health and the environment [2, 3]. Another study treats the street lighting systems in southern Italy are frequently inefficient due to obsolete bulbs and inadequate light management systems. Beccali et al illustrate in their paper that Improving energy efficiency is critical for the Public Administration's Sustainable Energy Action Plan. The FACTOR 20 project has provided planning choices for efficient street lighting systems. A careful study of Comiso's public lighting

*Correspondence to: Agrouaz Younes (Email: agrouazyounes@gmail.com). High School of Technology, Sidi Mohamed Ben Abdellah University, Fez, Morocco.

ISSN 2310-5070 (online) ISSN 2311-004X (print)

systems indicated considerable improvements in illumination quality as well as significant energy and economic savings. The methodology can be extended to cities in southern Italy that are similar [4]. By reviewing many papers, it found that Baglivo et al through their paper that provides a case study on sizing daylight devices for zenith light in sustain-able buildings, with a focus on energy savings and visual comfort. It tests 24 sun tunnel designs and 12 skylight scenarios in an Italian room [5].Another work of Beccali et al describes a strategy for designing street lighting based on user patterns and preferences in a test area. The technology is used on the outdoor lighting system of the University of Palermo campus. The findings reveal that the strategy optimizes lighting plant performance, energy savings, and light quality while taking into account local user feedback. According to survey results, 81% of people feel safe in test zones, 80% are satisfied, and the majority desire new lighting infrastructure elements. The estimated energy savings are over 70%, with a quick return on investment [6].Kostic et al write a paper where they treat a Metal halide lamp, which have greater color rendering and appearance, are frequently disregarded in road lighting for cost reasons. A detailed techno-economic investigation compared MH with HPS lamps, demonstrating that MH lamps are economically similar or even more advantageous for lower brightness levels [7, 8, 9].In other hand, we found that Leccese et al covers the difficulties in meeting global energy demand as well as the possible energy savings in road lighting systems. It analyzes and compares numerical indicators used to measure lighting and energy performance using a case study of Pisa's medieval town center. Geometric surveys, brightness and illumination measurements, and the development of national and international energy performance indicators are all part of the research. The findings of the authors aid in identifying the strengths and limitations of each indicator and give recommendations for acceptable indicators during the design stage of road lighting systems [10, 11].The introduction of LED technology in Rome's public lighting systems to enhance energy efficiency is discussed in this study present-ed by Campisi et al. Despite the higher initial price of LED light fixture , the study concludes that using LED technology is economically advantageous. The article presents strategic alternatives and flexibility, taking into account the possibility of dividing LED investment into five stages. Real choices are used to assess the project's economic cost-saving potential, taking into account the volatility of power prices and multi-stage investment. Real option analysis produces more realistic conclusions than net present value since it takes into account the causes of uncertainty [12, 13, 14].As covering many papers, there a lack of studies that treat a typical road in Morocco, therefore this paper came to cover this research gap. This study will present a bench-marking and tool for the deciders to have an idea about the energy efficiency of the LED lamp. That way the current study proposes a simulation of a public street lighting based on variation of geometrical parameters in order to give the designers a guideline to install an efficient street lighting system.

2. Methodology

2.1. Description of the study

The study treats a street lighting in a typical road in Morocco, the street used is compatible with the specification of Moroccan codes. The simulated road is composed of two roadways with two sidewalks. the specification of the roadways and the side-walks are depicted in the table below.

Table 1. Specification of the roadway and sidewalks in Morocco

	width(m)	Lighting Class
Roadway	3.5	M1
Sidewalk	0.8	P1

After the determination of the main characteristic of the roadway and the side-walk, these characteristics that depend on specific road and the traffic volumes. The current study presents a benchmarking between the conventional lighting that almost all the Moroccan road used as a technology of lighting, and the new technology which is LED lamp that represents a such more advantages than the conventional lamp. The simulation of this lighting system deals with three arrangements, each simulated arrangement type is analyzed by modifying a geometrical design of the Lamp technology. The arrangement type presented in this work are shown below, the first one is left arrangement where pole layout is positioned on the left of the roadway, the second one deals with a disposition in the both sides of the treated road and the last one shows the pole layouts in the middle of the roadway.

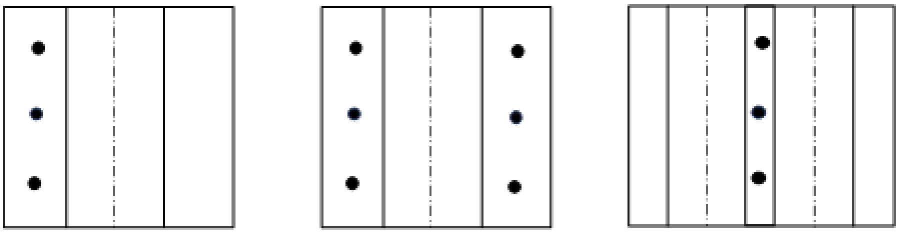


Figure 1. The arrangement type of the pole layout (A Left, B Two sides, C middle).

2.2. *The lamp designs*

the currently Moroccan road used a conventional lamp, this lamp consumes a lot amount of energy and their luminance decreases through time. Therefore, this paper will present an energy comparison between the current system and the proposed system, which is based on LED technology. The below figure presents the specification of the conventional lamp and the LED Lamp.

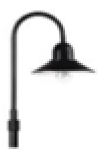
Lamp Type	Name	Specification
Conventionnel 	ALP530-HPS400	Luminance flux of the source: 9500 lm CCT 2000K CRI 22 LOR 58% Nominal power 500W
LED 	ALT3-168L	Luminance flux of the source: 5465 lm CCT 3000K CRI 70 LOR 100% Nominal power 307W

Figure 2. The Lamps used in this simulation

2.3. *Conception of the roadway*

The installation of road lighting serves a dual purpose: enhancing road safety while also minimizing both initial investment and ongoing operational costs. An efficiently designed road lighting system not only ensures adequate illumination for safe driving but also promotes energy efficiency. The process of designing such an installation commences with the classification of the road's lighting requirements, in accordance with the guidelines in EN 13201-1 (2014). This standard, denoted as EN-13201-1 (2014), introduces various lighting classes, each tailored to specific road types and traffic volumes. The detailed criteria for individual lighting parameters are outlined in EN-13201-2 (2015). For roads accommodating medium and high-speed motor vehicle traffic, it is recommended to adhere to class M lighting standards. Class M entails specific lighting parameters, including mean road surface luminance, over-all luminance uniformity, longitudinal luminance uniformity, threshold increment, and edge lighting coefficient. The designer's task encompasses a comprehensive understanding of several crucial factors, including the anticipated or existing road con-figuration, lane types (road, pedestrian, or mixed), traffic volume, vehicle speeds, the presence of crossroads, the existence of parked vehicles or separate lanes, ambient luminance levels, and visual guidance requirements. This information serves as the foundation for determining the appropriate lighting class for the road, as outlined in (EN 13201-2, 2015)[15, 16].

2.4. Energy indicators

Energy performance indicators for road lighting have recently been introduced at European level to quantitatively assess the potential energy savings achievable through improvements in road lighting systems. In the European standard, two key indicators have been defined: the Annual Energy Consumption Indicator (DE) (see equation 1) And Power per km.

$$DE = \sum_{j}^{M} (P_j \times t_j) \times A \tag{1}$$

the Annual Energy Consumption Indicator (DE) represents the electrical energy consumption of a road lighting system over the course of a year. This indicator also considers variations in energy consumption related to specific nighttime or seasonal lighting performance, accounting for potential changes in grid power usage during different nighttime or seasonal operation profiles. These indicators serve as valuable tools for comparing the energy performance of various lighting systems using different technologies and solutions for a single road. However, it's important to exercise caution when comparing lighting systems installed on roads with different characteristics, as these indicators depend on both the area to be illuminated and the specific lighting requirements [17, 18, 19, 20].

3. Results and Discussions

3.1. Effect of pole distance on the luminance of conventional Lamp

In a lighting arrangement with fixtures arranged on the left side, the position of the light source's center height plays a crucial role in determining the overall luminance. Luminance refers to the brightness or intensity of the light emitted by these fixtures. When the light center height is increased, there is a notable decrease in luminance across all boom angles, as it is mentioned in the fig 3. The luminance varies from 5 cd/m² to 3 cd/m² for the pole distance of 10m. This decrease in luminance with an increase in the light center height is primarily due to the change in the angle at which the light is projected. When the light source is positioned higher, the light rays have a steeper downward trajectory, resulting in a more spread-out and diffuse distribution of light. This often leads to a reduction in the perceived brightness in the illuminated area. Furthermore, the distance between two light fixtures also plays a significant role in determining luminance. As the distance between light fixtures increases, the overall luminance in the area between them decreases. This is a fundamental principle in lighting design. When fixtures are spaced farther apart, the overlap of their individual illumination areas decreases, which leads to lower overall brightness in the overlap-ping zone. Therefore, in a left-side lighting arrangement, increasing the light center height and widening the distance between light fixtures both contribute to a decrease in luminance. It is essential to carefully consider these factors when designing lighting layouts to achieve the desired lighting levels and uniformity in a given space.

luminance in the area between them decreases. This is a fundamental principle in lighting design. When fixtures are spaced farther apart, the overlap of their individual illumination areas decreases, which leads to lower overall brightness in the overlap-ping zone. Therefore, in a left-side lighting arrangement, increasing the light center

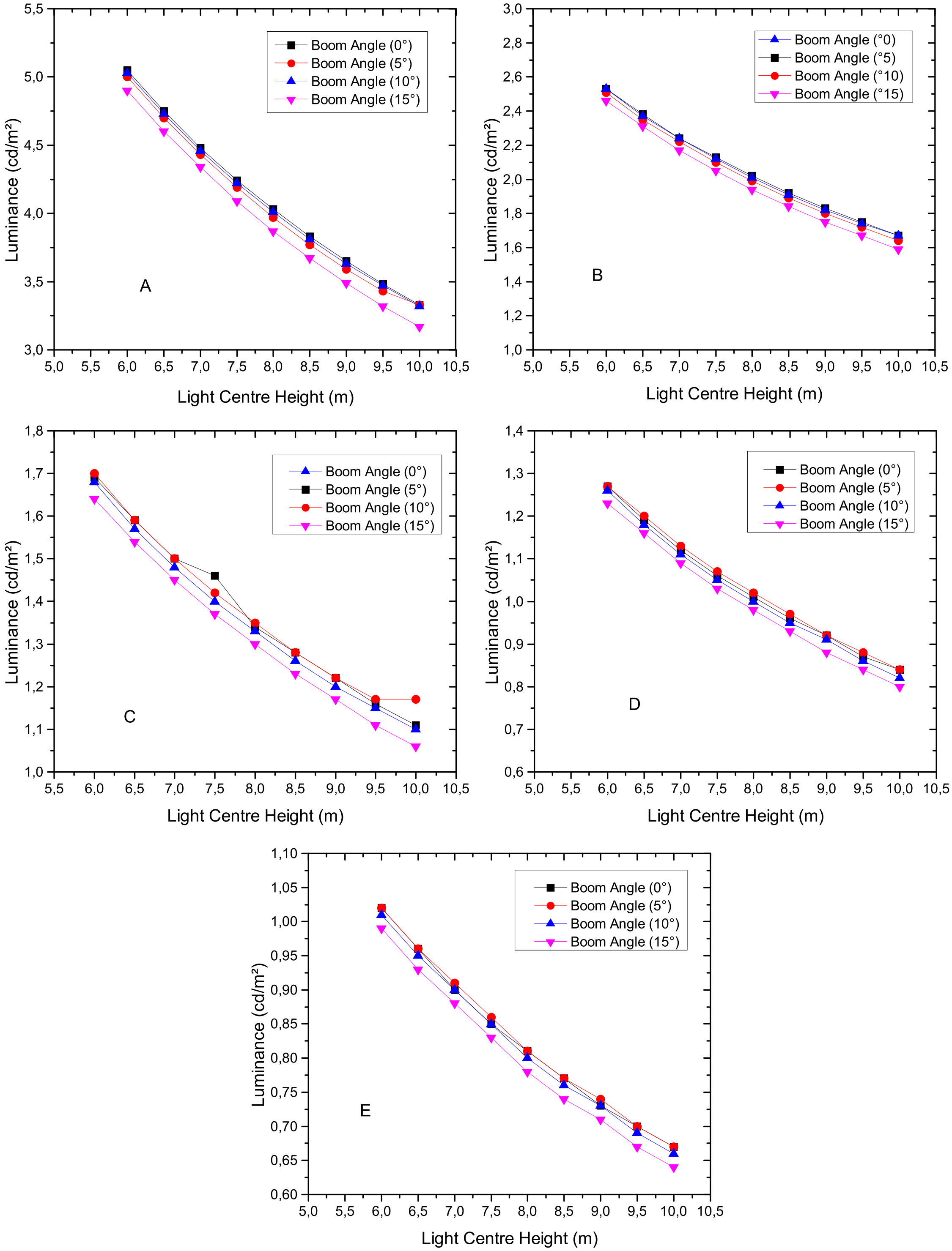


Figure 3. luminance for different pole distance (Left Arrangement) A=10m, B=20m, C=30m, D=40m, E=50m

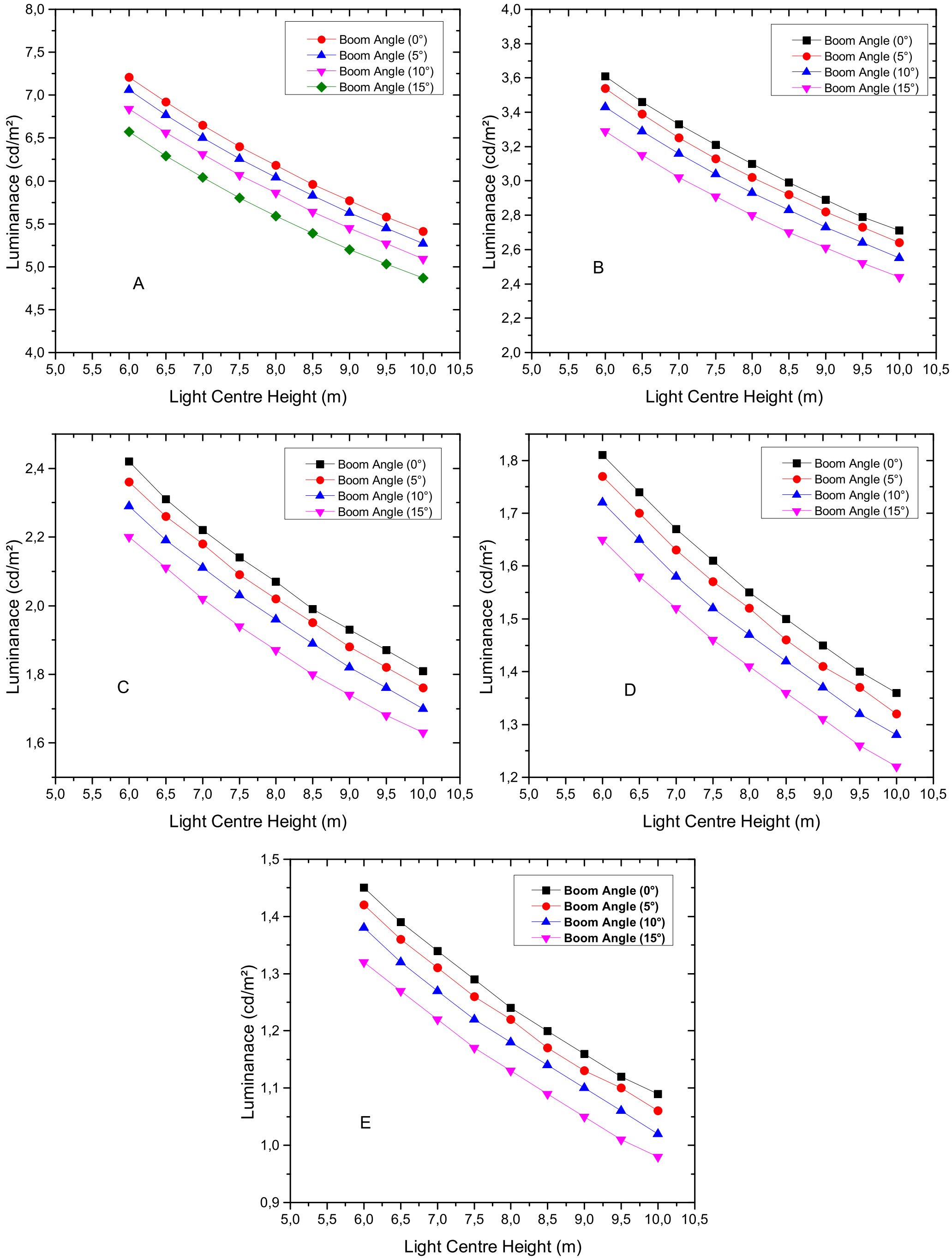


Figure 4. luminance for different pole distance (Middle Arrangement) A=10m, B=20m, C=30m, D=40m, E=50m

Fig 4 illustrates a lighting arrangement with light fixtures positioned in the middle, and it reveals a significant contrast with the left-side arrangement in terms of luminance intensity. The luminance for the pole distance of 10m shows a high luminance value which is about 7.5 cd/m² and the lower luminance presented by the pole distance of 50m which equal to 1cd/m². In this arrangement, luminance is notably more pronounced compared

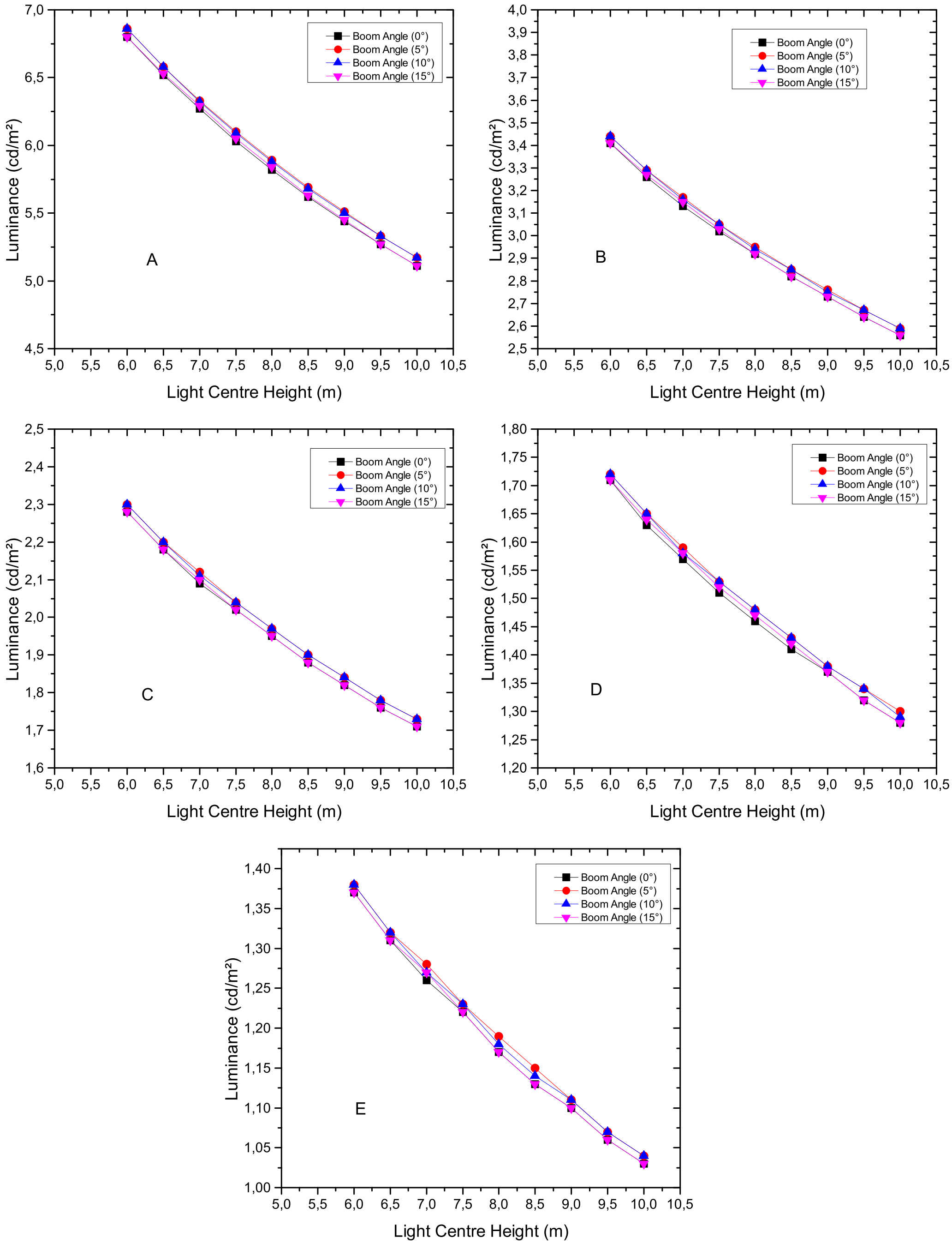


Figure 5. luminance for different (Two sides Arrangement) pole distance A=10m, B=20m, C=30m, D=40m, E=50m

to the left arrangement. The standout observation from Fig.4 is the pronounced effect of the boom angle of the light fixtures on luminance intensity. As the boom angle varies, there is a discernible shift in the brightness levels within the illuminated area. Moreover, the graphs in Fig.4 demonstrate a consistent trend with the previous observations, even when adjusting the pole distance. This suggests that the relationship between the boom angle and luminance intensity remains consistent across different pole distances. The tendency observed in the graphs, presumably showing how changes in boom angle influence luminance, is in alignment with the findings of the previous arrangement. The effect of boom angle on luminance when the light source's center height is increased is found to be largely insignificant. In various studies and practical applications, it has been observed that altering the boom angle while keeping the light source at an elevated position does not result in substantial changes in luminance levels. This can be attributed to the relatively small changes in the angle of incidence of the light rays as they interact with the target surface. Furthermore, the luminance of the middle arrangement exhibits a similar trend to that of the two side arrangements. When adjusting the boom angle, whether it is an increase or decrease in the angle, the luminance levels tend to change consistently across all three arrangements. This consistency in luminance behavior suggests that the relationship between boom angle and luminance is fairly uniform, regardless of the specific arrangement of the lights. Consequently, this knowledge can be valuable for lighting designers and engineers, as it allows for more predictable and controllable lighting outcomes when adjusting boom angles in different lighting configurations.

3.2. Effect of pole distance on energy efficiency indicators

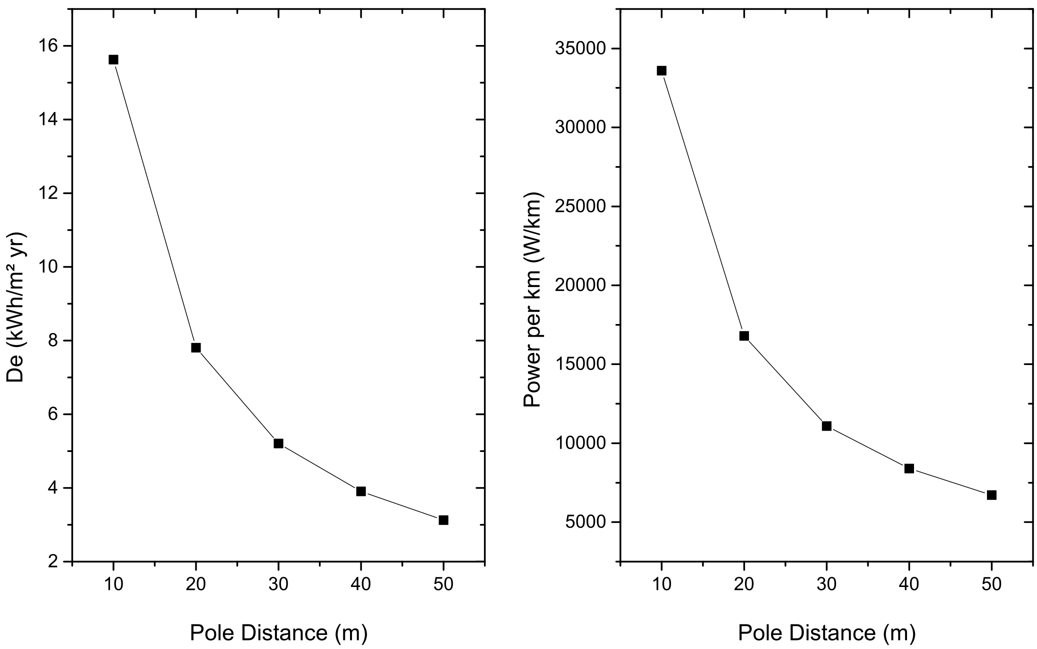


Figure 6. Effect of pole distance on DE and Power per km (Left Arrangement)

The Annual Energy Consumption Indicator (DE) serves as a crucial metric for assessing and comparing the energy efficiency of different arrangements within a given system. In the context of our analysis, we are focusing on two specific arrangements: the middle arrangement and the left arrangement. Upon examination, it becomes evident that the middle arrangement exhibits a notably lower DE in comparison to the left arrangement. This disparity underscores a significant difference in energy efficiency between the two configurations. One key contributing factor to this disparity lies in the power per kilometer metric. The power per kilometer represents the energy consumed or required to travel a distance of one kilometer. In our evaluation, it is apparent that the left arrangement demonstrates substantially higher values for power per kilometer when compared to the middle arrangement. This observation is of paramount importance as it highlights the middle arrangement as a more energy-efficient option, suggesting that it consumes less energy to cover the same distance when compared to the left arrangement. Such

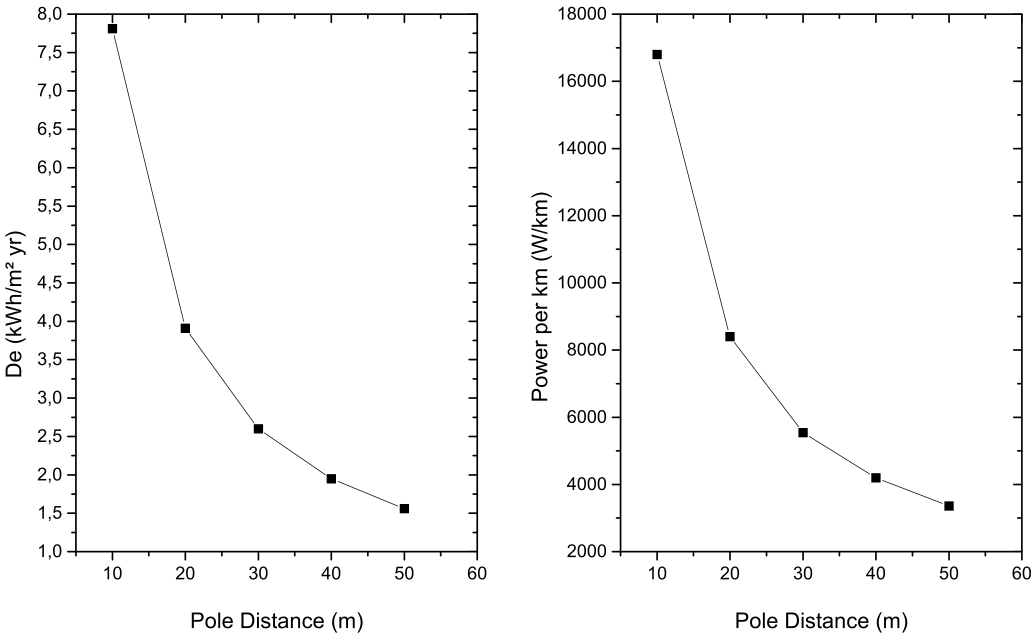


Figure 7. Effect of pole distance on De and Power per km (Middle Arrangement)

findings are critical for decision-makers and stakeholders involved in optimizing energy usage and promoting sustainable practices within the system.

3.3. Effect of pole distance on the luminance of LED Lamp

Furthermore, the luminance of LED lamps can be significantly influenced by the angle at which the light is emitted, known as the ”boom angle.” When adjusting the boom angle, it becomes evident that there is a substantial impact on luminance levels,

as shown in fig.8 the value of luminance at pole distance of 10m is about 10 cd/m² and at 50 m of pole distance layout is about 2 cd/m². Specifically, when the light source is elevated to a greater height, the luminance tends to decrease. This effect can be attributed to the distribution of light over a larger area as the light source moves higher, resulting in a reduction in perceived brightness at any given point. Additionally, the distance between the light source (pole) and the area being illuminated plays a pivotal role in determining luminance levels. As the pole distance increases, there is a noticeable decrease in luminance. In practical terms, for a left arrangement of lighting fixtures, it has been observed that the optimal pole distance to achieve the highest luminance is approximately 10 meters. This distance strikes a balance between the distribution of light, the height of the light source, and the efficiency of LED technology, resulting in an optimal luminance level for the intended application. Figures 9 and 10 provide a comprehensive analysis of how the elevation of the light center height impacts luminance while considering varying boom angles and simulated pole distances. These visual representations unveil an intriguing relationship between these factors and luminance levels, offering valuable insights for lighting design optimization. In both Figure 8 and Figure 9, the x-axis represents the light center high, with the boom angle, which is the light source is inclined above the horizontal plane. This parameter plays a crucial role in determining how light is distributed and perceived within the illuminated area. The results clearly demonstrate that as the boom angle increases, meaning the light source is positioned at a steeper angle, there is a consistent and notable decrease in luminance. Figure 9 and Figure 10 also examine the influence of varying pole distances on luminance. The y-axis represents the luminance values in cd/m². Notably, as the simulated pole distance increases, the luminance levels consistently decrease.

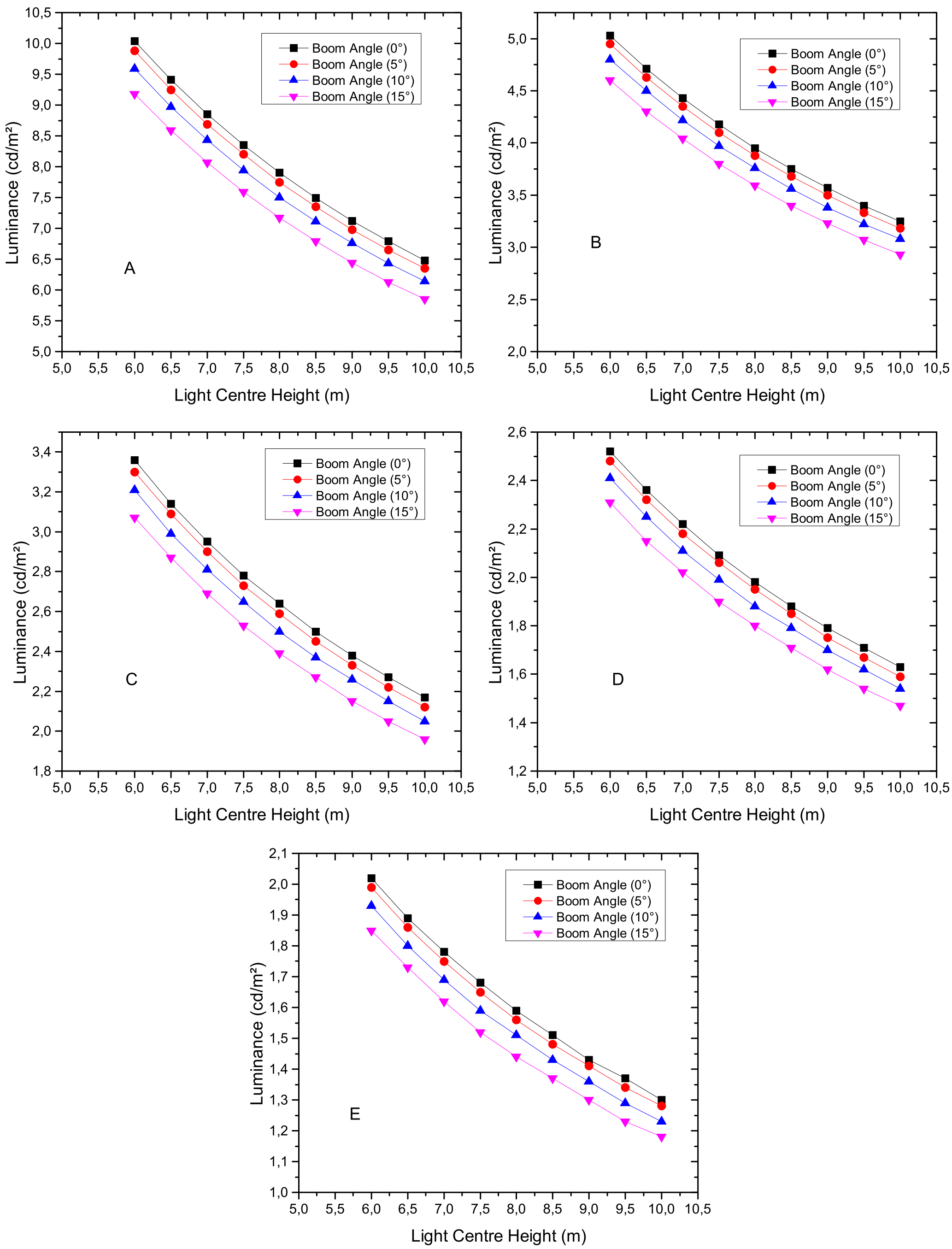


Figure 8. luminance for different (Left Arrangement) pole distance A=10m, B=20m, C=30m, D=40m, E=50m-LED Lamp

This phenomenon is in accordance with the inverse square law, which dictates that light intensity diminishes with the square of the distance from the source. A key finding derived from the analysis of Figures 9 and 10 is that both middle and two-side lighting arrangements exhibit significant increases in luminance as the light center height is decreased and the boom angle minimized. However, the two-side lighting arrangement consistently outperforms

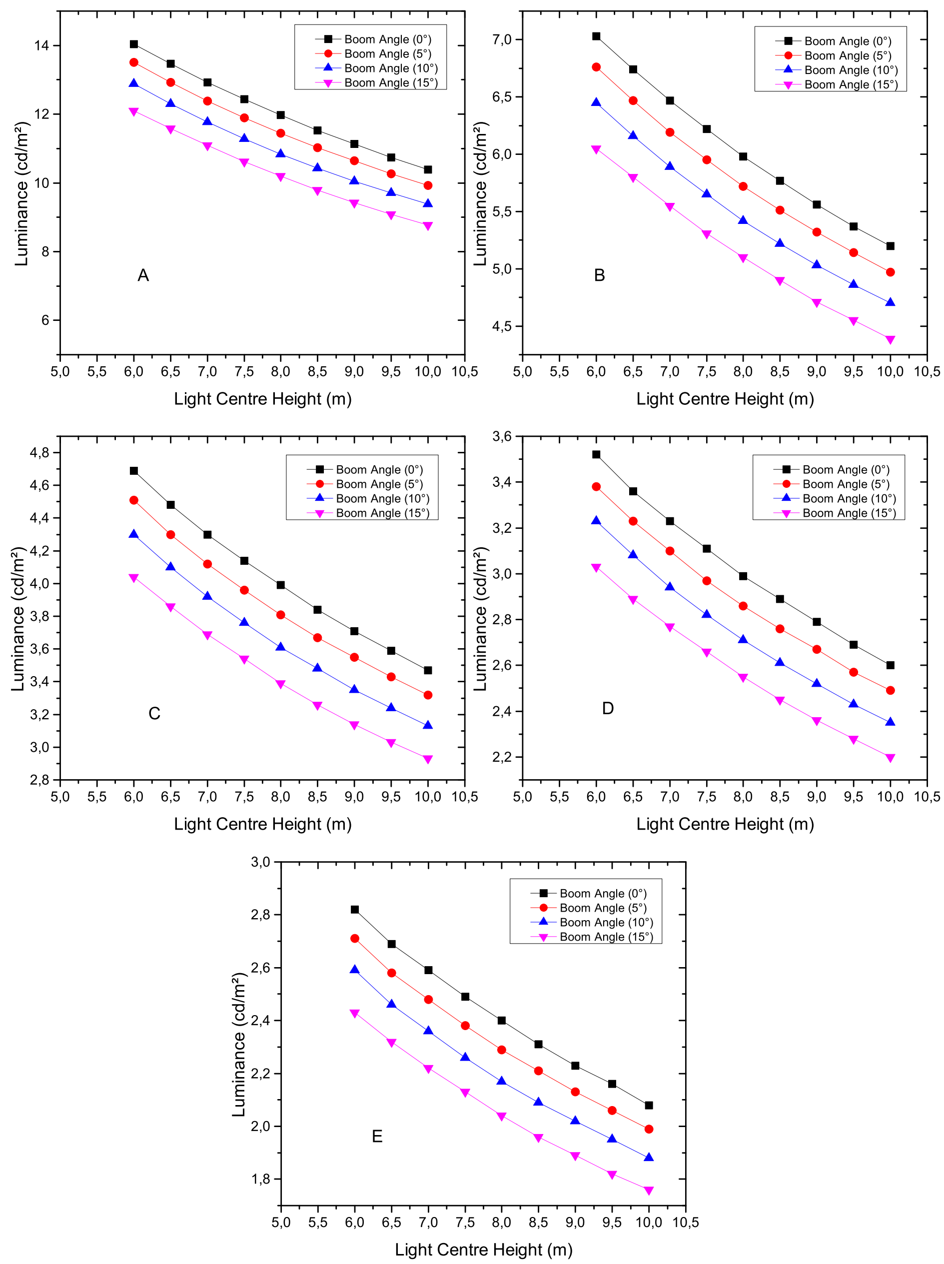


Figure 9. luminance for different (Middle Arrangement) pole distance A=10m, B=20m, C=30m, D=40m, E=50m-LED Lamp

the middle arrangement in terms of luminance enhancement. Across all simulated pole distances, ranging from 10 meters to 50 meters, the two-side arrangement consistently delivers the highest luminance values. This suggests that positioning lighting fixtures on both sides of the target area is the most effective strategy for achieving superior luminance levels. This configuration maximizes the coverage and brightness of the illuminated space, ensuring optimal visibility and illumination for various applications. In summary, the results depicted in Figures 9 and 10 highlight the significant impact of light center height, boom angle, and pole distance on luminance. These findings underscore the importance of thoughtful lighting design and emphasize the advantages of two-side lighting arrangements for achieving the best luminance outcomes across a range of simulated pole distances.

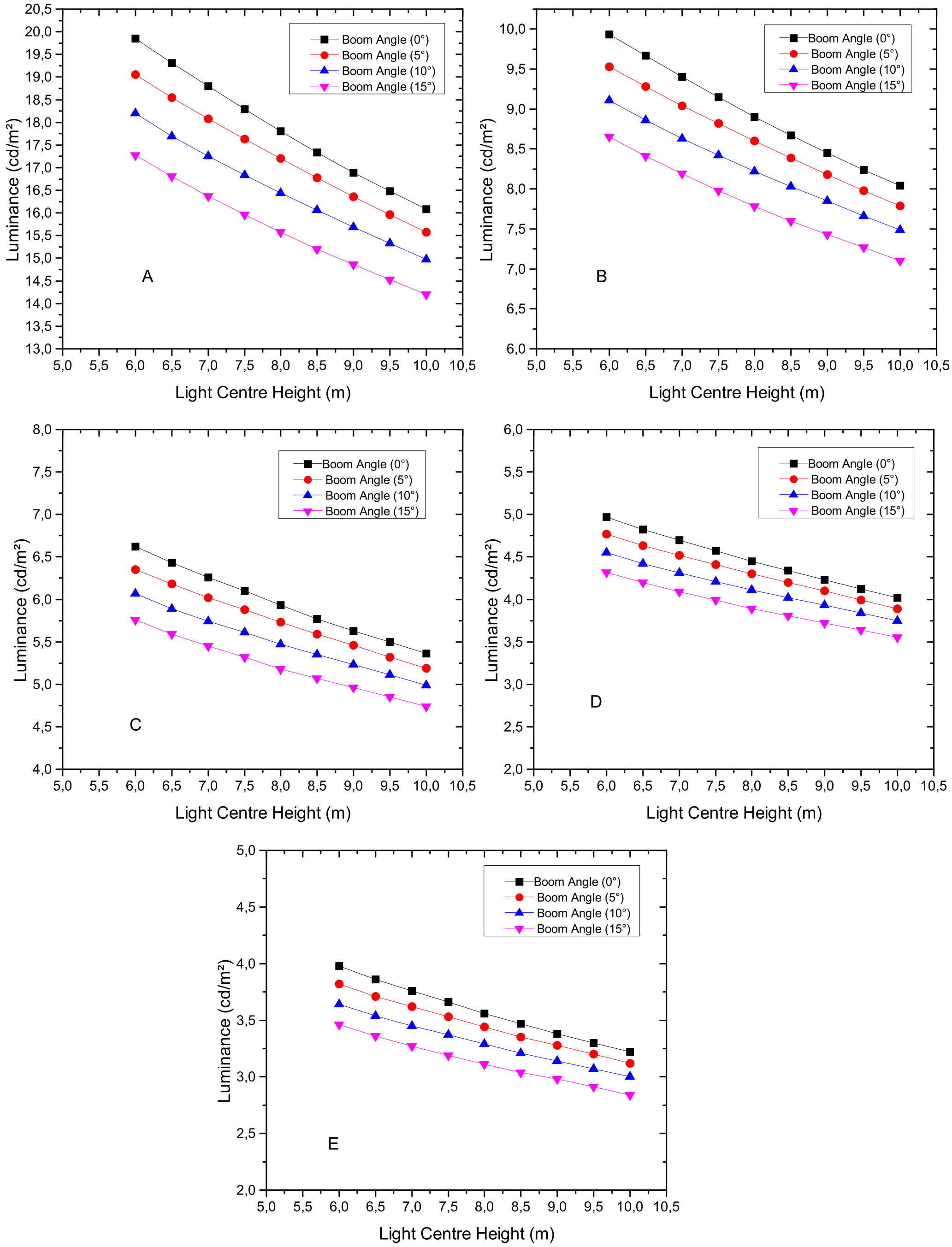


Figure 10. luminance for different (Two sides Arrangement) pole distance A=10m, B=20m, C=30m, D=40m, E=50m-LED Lamp

3.4. Effect of pole distance on energy efficiency indicators

The choice of lighting arrangement type has a significant impact on various performance indicators, notably including the (DE) and power consumption per kilometer (power per km). In the context of our study, Figure 11, 12, and 13 provide crucial insights into these effects for different pole distances across the left, middle, and two-side lighting arrangements.

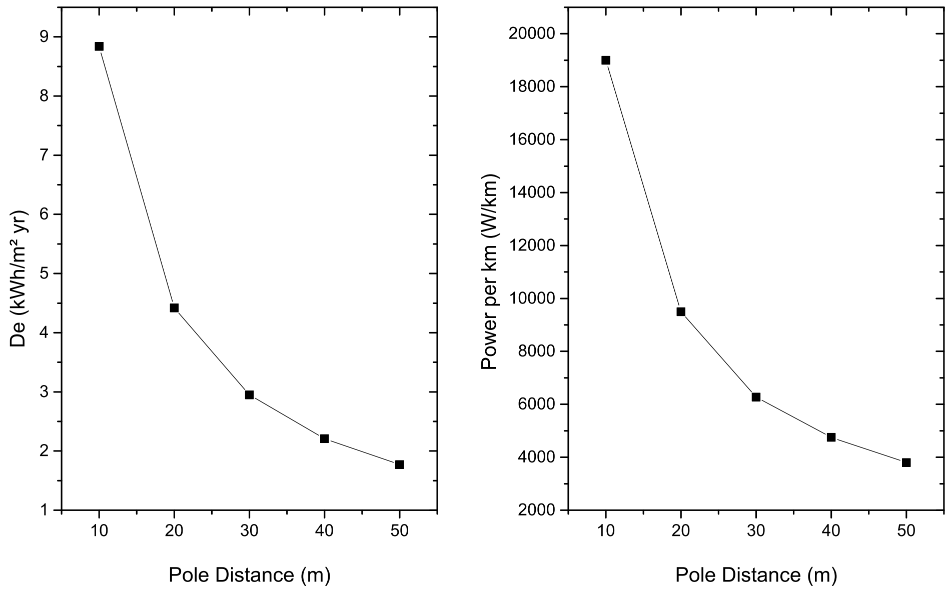


Figure 11. Effect of pole distance on DE and Power per km (Left Arrangement)

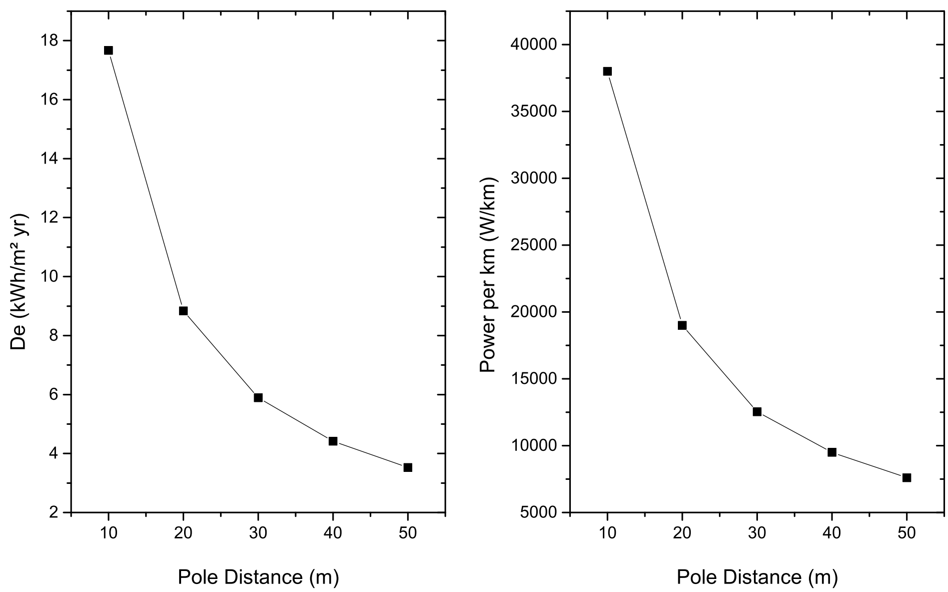


Figure 12. Effect of pole distance on DE and Power per km (Middle Arrangement)

Notably, it is evident from the data that the left arrangement consistently yields lower DE indicators (at 10m it shows a DE equal to 9 kWh/m². year) and lower power consumption per kilometer (Almost 200kW per meter at 10 m pole distance) when compared to the middle and two-side arrangements. This signifies that the left arrangement is the most efficient in terms of minimizing DE and optimizing energy usage. Therefore, if the objective is to optimize your lighting system for both superior luminance and reduced DE indicators, the left arrangement emerges as preferred choice. By implementing this configuration and referencing Figures 11, 12, and 13, we can effectively design a lighting system that not only maximizes visibility but also minimizes DE, contributing to safer and more energy-efficient lighting solutions.

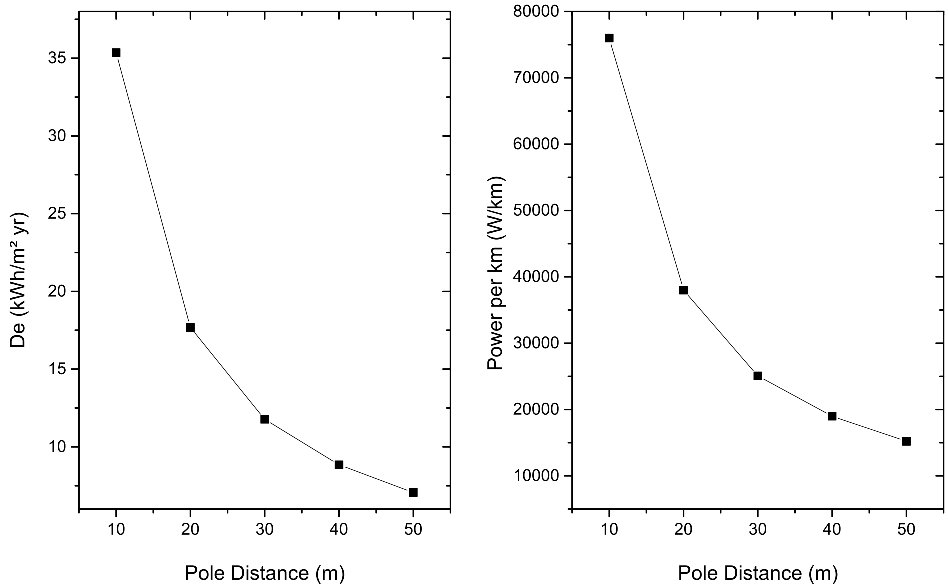


Figure 13. Effect of pole distance on DE and Power per km (Two sides Arrangement)

4. Conclusion

When it comes to comparing LED lamps to conventional lamps, one of the notable distinctions lies in the luminance they produce. Luminance, often described as the amount of visible light emitted per unit area, is a critical factor when evaluating the performance of lighting systems. In this regard, this study shows that the best technology should be used in the Moroccan Road is LED lamps. LED lamps typically exhibit a significantly higher luminance when compared to their conventional Lamp. The key contributing factor to this disparity in luminance is the efficiency of LED technology. LED lamps are known for their exceptional energy efficiency and light output, which translates into a higher luminance for the same amount of energy consumed. This higher luminance is a result of the LED's ability to convert a larger portion of the electrical energy into visible light, minimizing wasted energy in the form of heat. Also, determining the suitable arrangement type for the road plays a crucial role in augmenting the efficiency of the luminance. Therefore, the results of this study shows that the left arrangement present a lower annual energy consumption and an acceptable luminance for a lower boom angle. In this phase of designing a road lighting system, the objective is to identify the optimal solution that balances lighting quality and energy efficiency. Also, there is a high potential to develop the street lighting based on renewable energy such as Photovoltaic energy, in order to have a sustainable street lightning[20] and the future work should make an optimization of street lighting based on artificial intelligent decision[22, 23].

REFERENCES

1. Kasseh Y, Touzani A, El Majaty S,(2023) *What public lighting governance model should be deployed in Moroccan cities for sustainable and efficient energy management?*, Mater Today Proc 72:3244–3252. https://doi.org/10.1016/j.matpr.2022.07.123
2. Leccese F, Salvadori G, Rocca M, (2017) , *Critical analysis of the energy per-formance indicators for road lighting systems in historical towns of central It-aly.*, Energy 138:616–628. https://doi.org/10.1016/j.energy.2017.07.093.
3. Falchi F, Cinzano P, Elvidge CD, et al (2011), *Limiting the impact of light pol-lution on human health, environment and stellar visibility.*, J Environ Manage 92:2714–2722. https://doi.org/10.1016/j.jenvman.2011.06.029.
4. Beccali M, Bonomolo M, Ciulla G, et al (2015) , *Improvement of energy effi-ciency and quality of street lighting in South Italy as an action of Sustainable Energy Action Plans. The case study of Comiso (RG).*, Energy 92:394–408. https://doi.org/10.1016/j.energy.2015.05.003.
5. Baglivo C, Bonomolo M, Beccali M, Congedo PM (2017), *Sizing analysis of interior lighting using tubular daylighting devices.*, Energy Procedia. Else-vier Ltd, pp 179–186.
6. Beccali M, Bonomolo M, Lo Brano V, et al (2019), *Energy saving and user satisfaction for a new advanced public lighting system.*, Energy Convers Manag 195:943–957. https://doi.org/10.1016/j.enconman.2019.05.070.
7. Pardo-Bosch F, Blanco A, Sesé E, et al (2022) *Sustainable strategy for the implementation of energy efficient smart public lighting in urban areas: case study in San Sebastian.*, Sustain Cities Soc 76:. https://doi.org/10.1016/j.scs.2021.103454.
8. Fathi M (2010), *Eclairage public solaire autonome à LEDs Blanches haute puissance SiN Passivation of Si wafer for PV View project Silicon Passivation by SiN Thin Films Using PECVD Technique View project*,
9. Kostic M, Djokic L, Pojatar D, Strbac-Hadzibegovic N (2009), *Technical and economic analysis of road lighting solutions based on mesopic vision.*, Build Environ 44:66–75. https://doi.org/10.1016/j.buildenv.2008.01.013.
10. Davidovic M, Kostic M (2022), *Comparison of energy efficiency and costs re-lated to conventional and LED road lighting installations.*, Energy 254:https://doi.org/10.1016/j.energy.2022.124299.
11. KLuo W (2014), *Outdoor lighting-Mesopic photometry, adaptation conditions and user preferences in pedestrian way lighting.*.
12. Ozadowicz A, Grela J (2014), *he street lighting integrated system case study, control scenarios, energy efficiency.*, 9th IEEE International Conference on Emerging Technologies and Factory Automation, ETFA 2014. Institute of Electrical and Electronics Engineers Inc.
13. Kostic M, Djokic L, Pojatar D, Strbac-Hadzibegovic N (2009), *Technical and economic analysis of road lighting solutions based on mesopic vision.*, Build Environ 44:66–75. https://doi.org/10.1016/j.buildenv.2008.01.013.
14. Akindipe D, Olawale OW, Bujko R (2022), *Techno-Economic and Social As-pects of Smart Street Lighting for Small Cities – A Case Study. Sustain Cities.*, Soc 84:. https://doi.org/10.1016/j.scs.2022.103989.
15. Dizon E, Pranggono B (2022) , *Smart streetlights in Smart City: a case study of Sheffield.*, J Ambient Intell Humaniz Comput 13:2045–2060. https://doi.org/10.1007/s12652-021-02970-y.
16. Lv Z, Guo H, Zhang L, et al (2024) *Urban public lighting classification method and analysis of energy and environmental effects based on SDGSAT-1 glimmer imager data.*, Appl Energy 355:122355. https://doi.org/10.1016/j.apenergy.2023.122355.
17. Shao Z, Li Y, Huang P, et al (2023) *Analysis of the opportunities and costs of energy saving in lightning system of library buildings with the aid of building information modelling and Internet of things.*, Fuel 352:. https://doi.org/10.1016/j.fuel.2023.128918.
18. Sikora R, Markiewicz P (2021) *A new approach to calculating energy per-formance indicators of road lighting. Sustain Cities .*, Soc 75:https://doi.org/10.1016/j.scs.2021.103232.
19. Benito B, Guillamón MD, Martínez-Córdoba PJ (2020) *Determinants of effi-ciency improvement in the Spanish public lighting sector.*, Util Policy 64:. https://doi.org/10.1016/j.jup.2020.101026.
20. Hashempour, M., Alizadeh, M. (2023) *A New Weighted Half-Logistic Dis-tribution:Properties, Applications and Different Method of Estimations.*, Sta-tistics, Optimization and Information Computing, 11(3), 554-569. https://doi.org/10.19139/soic-2310-5070-1314.
21. Boulmrharj S, Bakhouya M, Khaidar M (2023) *Green hydrogen for public transportation fueling and street lighting electrification: Towards more sus-tainable Moroccan cities.*, Sustain Prod Consum 36:217–232. https://doi.org/10.1016/j.spc.2022.12.018.
22. Carli R, Dotoli M, Pellegrino R (2018) *A decision-making tool for energy efficiency optimization of street lighting.*, Comput Oper Res 96:223–235. https://doi.org/10.1016/j.cor.2017.11.016.
23. uang, H., Peng, S., Yu, G., Huang, J., Hu, W. (2023) *Hyperspectral image restoration based on color superpixel segmentation.*, Statistics, Optimization and Information Computing, 12(1), 267-280. https://doi.org/10.19139/soic-2310-5070-1912.
24. Al-Bossly, A., Eliwa, M. S., Ahsan-Ul-Haq, M., El-morshedy, M. (2023) *Discrete Logistic Exponential Distribution with Application.*, Statistics, Optimization and Information Computing, 11(3), 629-639. https://doi.org/10.19139/soic-2310-5070-1396.