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Optimizing Outdoor Illumination: Design and Performance Analysis of LED-based Lamp Posts controlled by a Photo switch with Programmable Timer

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Abstract**:** *The role of outdoor lighting in achieving sustainable development goals is a topic of growing importance. As lighting technology advances, there is a greater awareness of its environmental impacts, particularly in relation to light pollution. Light pollution refers to the adverse effects generated by artificial lighting and can have detrimental effects on both humans and other living beings. This research study focuses on optimizing outdoor illumination through the innovative design and performance analysis of LED-based lamp posts controlled by a photo switch with a programmable timer. The role of outdoor lighting in achieving sustainable development goals is highlighted, particularly in addressing light pollution and its adverse effects on humans and ecosystems. The study aims to enhance campus lighting efficiency and safety by strategically implementing LED-based lamp posts across the campus. Through a mixed-method approach, including surveys and thematic analysis, the study evaluates the perceived benefits, efficiency, adaptability, effectiveness, and reliability of the LED-based lamp posts among students and faculty members. Results show widespread agreement on the efficacy of the technology in enhancing outdoor illumination, with strong support for its potential benefits and transformative capabilities. The findings*

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underscore the importance of innovative lighting solutions in educational environments, with LED-based lamp posts demonstrating high levels of efficiency, adaptability, effectiveness, and reliability. Recommendations for optimizing outdoor illumination with LED-based lamp posts include ensuring compatibility, verifying voltage compatibility, and considering mesopic luminance for night-time illumination.

Key words: *Outdoor illumination, LED-based lamp posts, photo switch, programmable timer, sustainable development goals.*

1. Introduction

As educational institutions continue to extend their operational hours to accommodate evening classes and extracurricular activities, the demand for effective and energy-efficient lighting solutions becomes paramount (Creighton, 1998). The specific context of campus lighting necessitates addressing the goal of providing optimal illumination for students during evening classes throughout the week (Edwards & Torcellini, 2002). The implementation of LED-based lamp posts controlled by a photo switch with a programmable timer aims to enhance both the safety and efficiency of campus lighting (Chi, 2018).

Campus environments are dynamic spaces that require adaptable lighting solutions to meet diverse needs, including study sessions, recreational activities, and evening classes scheduled from Monday to Sunday (Ma et al., 2005). Conventional lighting systems frequently lack energy efficiency and adaptability, necessitating the development of creative methods for outdoor lighting (Cuttle, 2015). In conjunction with intelligent control systems, the application of LED technology, best known by its name Light Emitting Diode and renowned for its energy efficiency and durability, presents a possible solution to address these difficulties (Pode, 2020).

By strategically placing these intelligent lamp posts across the campus, we aim to create a well-lit environment that enhances safety and visibility during evening hours while minimizing energy consumption (Boyce, 2019). This research not only contributes to the field of outdoor lighting technology but also aligns with sustainability goals by promoting energy-efficient solutions in educational settings (Tavareset et al., 2021). As the study progresses, we anticipate gaining valuable insights into the real-world application of this smart lighting system, with the potential for broader implications in urban planning and environmentally conscious campus management. The following sections of this study will explore the techniques used for system creation, present the findings of performance analyses, and evaluate the significance of the results for optimizing campus lighting.

The primary objective of this study is to design, implement, and evaluate the performance of LED-based lamp posts equipped with a photo switch and programmable timer to optimize CTU Pinamungajan campus lighting.

2. Related Literature

Scholars have extensively studied the positive impact of smart lighting in educational environments on student well-being. However, the specific application of programmable timer-controlled LED lamp posts to extend campus hours remains an underexplored area, prompting a closer examination of the existing literature (Finch, 2020).

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Smart Lighting in Educational Environments: Existing literature highlights the increasing importance of smart lighting solutions in educational institutions (Badshah et al., 2023). Studies have emphasized the positive impact of well-designed lighting on student productivity, focus, and overall well-being. Researchers have explored the integration of LED technology and intelligent control systems to enhance the learning environment, but the specific application of programmable timer-controlled LED lamp posts for extended campus hours remains an underexplored area (Finch, 2020).

LED Technology in Outdoor Lighting: Literature in the field of outdoor lighting technology underscores the advantages of light-emitting diode (LED) technology (Medina, J. (2012). LED lights are considered for their high energy efficiency, extended durability, and low maintenance needs. The use of LEDs in urban and campus lighting projects has demonstrated significant energy savings compared to traditional lighting sources. However, limited studies delve into the integration of LEDs with advanced control systems like photoswitches and programmable timers for dynamic outdoor environments (Cambré & Aertsen, 2020).

Urban Planning and Sustainable Campus Lighting: The intersection of smart lighting solutions and urban planning has gained attention in recent literature (Valkenburg & den Ouden, 2021). Environmentally conscious urban planning recognizes sustainable and energy-efficient campus lighting as an integral aspect. The deployment of intelligent lighting systems, particularly those utilizing photo switches and programmable timers, aligns with the broader goals of creating eco-friendly and user-centric urban spaces (Arcadio et al., 2023). The literature review will explore examples of successful implementations, challenges faced, and the overall impact on urban sustainability (Bibri & Krogstie, 2017).

User Satisfaction and Safety in Campus Lighting: Understanding user perceptions and preferences regarding campus lighting is crucial for the success of any lighting intervention (Galasiu & Veitch, 2006). Studies in this area have investigated the relationship between lighting design, user satisfaction, and safety. We expect the integration of programmable timer-controlled LED lamp posts to influence both the perceived safety of campus environments during evening hours and the overall satisfaction of students, faculty, and staff (Samancioglu, 2022).

Challenges and Opportunities in Implementing Smart Lighting Systems: The literature exploring challenges and opportunities in implementing smart lighting systems provides valuable insights for this research (Zarindast et al., 2021). We will explore potential barriers like technological limitations, cost considerations, and user acceptance (Kim, 2015). We will also look at successful case studies and innovative solutions to overcome these challenges, which will inform the implementation strategy of LED-based lamp posts with photo switches and programmable timers in a campus setting.

3. Statement of the Problem

In response to the increasing demand for efficient and sustainable lighting solutions in educational environments, this study embarks on a journey to optimize outdoor illumination through the innovative design and performance evaluation of LED-based lamp posts controlled by a photo switch with a programmable timer. Specifically, it sought to answer the following:

1. What are potential benefits of LED-based lamp post controlled by a photo switch with a programmable timer to optimize outdoor illumination as perceived by the students and faculty members?
2. How can the integration of LED technology and intelligent control systems improve in terms of the following:

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2.1 Efficiency

2.2 Adaptability?

3. What factors will be evaluated during the performance analysis of LED-based lamp posts equipped with a photo switch and programmable timer in terms of the following:

3.1 Effectiveness

3.2 Reliability?

4. Research Methodology

This study employs a mixed-method approach to thoroughly examine the efficacy of LED-based lamp posts controlled by a photo switch with a programmable timer in optimizing outdoor illumination at the CTU Pinamungajan campus. As respondents, we use a census approach to include the entire target population of 150 individuals, including both students and faculty members. We select participants with relevant knowledge and experience through purposeful sampling. We gather data through a semi-structured survey questionnaire, designed to capture both quantitative insights into participants' perceptions and qualitative feedback through open-ended questions. We administer the survey electronically, providing clear instructions that emphasize confidentiality and voluntary participation. Participants will rate their agreement with statements regarding LED-based lamp posts controlled by a photo switch with a programmable timer on a scale from 1 to 5 in the survey questionnaire. A rating of 1 corresponds to the response "strongly disagree," while a value of 5 represents the response "strongly agree." This scale allows respondents to express their level of agreement or disagreement with each statement clearly. By utilizing this scale, the study aims to capture the diverse range of perceptions and attitudes towards the effectiveness of the LED-based lamp posts, providing valuable insights into their overall reception among participants.

The analysis involves descriptive statistics for quantitative data and thematic analysis for qualitative data, aiming to identify patterns and themes. Ethical considerations prioritize informed consent, confidentiality, and voluntary participation. Despite potential limitations such as response biases and limited generalizability, the study's detailed timeline ensures the timely completion of phases, including survey design, data collection, analysis, and report writing. In the long run, the research seeks to provide significant insights and recommendations for sustainable lighting methods in educational environments, specifically targeting outdoor illumination optimization with LED-based lamp posts controlled by a photo switch with a programmable timer.

5. Results and Discussions

In examining the data and conducting analysis, it becomes apparent that there is widespread agreement among night students regarding the efficacy of LED-based lamp posts controlled by a photo switch for optimizing outdoor illumination. Outdoor lighting plays a pivotal role in modern educational environments, especially with the extension of operational hours to accommodate evening activities. In this context, the demand for effective and energy-efficient lighting solutions is paramount. This research focuses on optimizing campus lighting through the design and performance analysis of LED-based lamp posts controlled by a photoswitch with a programmable timer. By addressing the dynamic lighting needs of educational spaces, this study aims to enhance safety, efficiency, and sustainability while minimizing energy consumption.

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Graph 1. Potential benefits of LED-based lamp post as perceived by the students and faculty members

The graph 1 above presents a thorough analysis of responses that reveals a strong agreement from 75% of participants, indicating widespread recognition of the potential benefits of optimizing outdoor illumination through LED-based lamp posts controlled by a photo switch. This strong consensus underscores the perceived value of such technology in bolstering safety, security, and visibility in outdoor settings. However, 15% of respondents only agree, suggesting a need for additional clarification or information to solidify their stance. Addressing uncertainties among this group is crucial to garner broader support. Furthermore, 10% of participants are uncertain or unaware of the research, presenting an opportunity to increase awareness and provide supplementary details to potentially sway their opinion in favor of the proposed approach.

In interpretation, outdoor illumination emerges as a pivotal factor in ensuring safety, security, and visibility in outdoor environments. The optimization of outdoor lighting not only yields energy savings but also enhances lighting performance. LED-based lamp posts controlled by a photo switch represent a promising solution for achieving this optimization. This technology facilitates automatic adjustments in lighting levels based on ambient conditions, ensuring appropriate illumination levels at all times.

Design considerations for LED-based lamp posts encompass critical factors such as LED selection, photo switch control, and proper mounting and orientation. LED-based lamp posts offer numerous advantages over traditional lighting sources, including energy efficiency, longevity, and improved lighting quality. By selecting LEDs with suitable color temperature and spectral distribution, enhancing visibility and color perception is achievable. Additionally, photo switch control ensures optimal illumination without being excessively bright or dim, while proper mounting and orientation ensure uniform lighting distribution across outdoor spaces.

Performance analysis involves evaluating various parameters, including energy efficiency, lighting uniformity, light levels, and maintenance and lifespan. By comprehensively analyzing these performance parameters, the effectiveness and suitability of LED-based lamp posts controlled by a photo switch can be robustly demonstrated, further reinforcing their potential as a valuable outdoor lighting solution.

Legends (Category)

5 –Strongly Agree 4 –Agree 3 – Neutral 2 – Disagree 1 – Strongly Disagree

How can the integration of LED technology and intelligent control systems improve in terms of the following:				
Variable	**Thematic Statement**	**Category**	**Frequency**	**Percentage**
	Theme 1. LED technology and intelligent control	5	149	99%
		4	1	1%
		3	0	0%

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Efficiency	systems embodies the synergy between innovation and functionality, driving efficiency to new heights.	2	0	0%
		1	0	0%
	Total: 150 100%			
	Theme 2. The integration of LED technology and intelligent control systems illuminates a path towards heightened efficiency.	**Category**	**Frequency**	**Percentage**
		5	147	98%
		4	3	2%
		3	0	0%
		2	0	0%
		1	0	0%
	Total: 150 100%			
		Category	**Frequency**	**Percentage**
	Theme 3. LED technology with intelligent controls redefines efficiency, revolutionize energy management and conservation practices	5	148	98%
		4	2	2%
		3	0	0%
		2	0	0%
		1	0	0%
	Total: 150 100%			

Table 1. Efficiency of the device

When looking to assess or evaluate a device, there are several important factors to consider such as determining its effectiveness. As what is shown in the table the respondents are able to evaluate and answer the questions pertaining to the efficiency gains achievable through the integration of LED technology and intelligent control systems. Across three distinct thematic statements, the vast majority of participants expressed a resounding endorsement, with almost all responses falling into the highest rating category of "Strongly Agree." Specifically, for the thematic statement emphasizing the synergy between innovation and functionality, 99% of respondents strongly agreed, with only 1% expressing agreement.

Similarly, for the thematic statements highlighting the path towards heightened efficiency and the redefinition of energy management practices, 98% of respondents strongly agreed, with a marginal 2% expressing agreement. These data points illustrate a remarkable degree of consensus among respondents, indicating a widespread belief in the transformative potential of LED technology and intelligent control systems to revolutionize energy efficiency. Even the few respondents who didn't strongly agree still leaned towards affirmation, underscoring the prevailing confidence in these technologies' ability to drive innovation and promote sustainable energy practices.

Variable	Thematic Statement	Category	Frequency	Percentage
	Theme 1. Adaptability becomes the cornerstone for it enables lighting solutions to dynamically respond to diverse	5	148	98%
		4	1	1%
		3	1	1%
		2	0	0%
		1	0	0%

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Adaptability	environmental and user needs.			
	Total: 150 100%			
	Theme 2. LED technology and intelligent control systems facilitates tailored brilliance	Category	Frequency	Percentage
		5	149	99%
		4	1	1%
		3	0	0%
		2	0	0%
		1	0	0%
	Total: 150 100%			
		Category	Frequency	Percentage
	Theme 3. LED technology with intelligent controls fosters adaptability by design, offering lighting solutions	5	147	98%
		4	3	2%
		3	0	0%
		2	0	0%
		1	0	0%
	Total: 150 100%			

Table 2. Adaptability of the device

The data presented in the table highlights a strong consensus among respondents regarding the adaptability of lighting solutions enabled by the integration of LED technology and intelligent control systems. Across three thematic statements emphasizing adaptability, the majority of respondents expressed high levels of agreement.

In Theme 1, 98% of respondents strongly agreed that adaptability serves as a cornerstone, allowing lighting solutions to dynamically respond to diverse environmental and user needs. Similarly, in Themes 2 and 3, 99% and 98% of respondents respectively strongly agreed that LED technology and intelligent control systems facilitate tailored brilliance and foster adaptability by design.

These findings underscore a widespread acknowledgment of the crucial role adaptability plays in optimizing lighting solutions to meet the evolving demands of various environments and users. With minimal disagreement among respondents, the data suggests a strong belief in the capacity of LED technology and intelligent control systems to provide adaptable lighting solutions tailored to specific needs.

Table 3: The performance analysis of an LED-based lamp posts in terms of effectiveness as perceived by the students and faculty

Indicators	VHE	HE	E	LE	NE	M	SD	VD
	5	4	3	2	1			
It is important to maximize light output while minimizing energy consumption	4.65	4.55	4.60	4.65	4.70	4.63	0.06	VHE
LED lamp posts emphasizes the commitment to sustainability	4.65	4.65	4.70	4.55	4.55	4.62	0.07	VHE

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LED lamp posts underscores the value of longevity and durability	4.75	4.65	4.60	4.60	4.55	4.63	0.08	VHE
Total:	4.69	4.62	4.63	4.60	4.60	4.63	0.07	VHE
Interpretation:	***VERY HIGHLY EFFECTIVE***							

Legend:

		M	MEAN	1.50	2.49	LE	Less Effective
		%	Percentage	1.00	1.49	NE	Not Effective
		VD	Verbal Description				
4.50	5.00	VHE	Very Highly Effective				
3.50	4.49	HE	Highly Effective				
2.50	3.49	E	Effective				

The data from Table 3 presents a comprehensive analysis of the effectiveness of LED-based lamp posts, as perceived by both students and faculty. Across various indicators, including the importance of maximizing light output while minimizing energy consumption, emphasizing sustainability, and highlighting longevity and durability, the LED lamp posts consistently received high ratings. The mean scores range from 4.60 to 4.75, with an overall mean score of 4.69, indicating a very high level of effectiveness. Particularly noteworthy is the emphasis on sustainability and durability, with mean scores consistently above 4.60. This data suggests that LED lamp posts are viewed as highly effective in meeting the criteria of energy efficiency, sustainability, and longevity. Therefore, based on the ratings provided by both students and faculty, it can be concluded that LED-based lamp posts are very highly effective in their performance, aligning well with the goals of maximizing light output while minimizing energy consumption and emphasizing sustainability and durability.

Table 4: The performance analysis of an LED-based lamp posts in terms of reliability as perceived by the students and faculty

Indicators	VHA	HA	A	LA	NA	M	SD	VD
	5	4	3	2	1			
LED-based lamp posts is evident in their consistent performance	4.75	4.65	4.65	4.55	4.60	4.64	0.07	VHS
LED lamp posts highlights their reliability in withstanding various weather conditions	4.85	4.75	4.55	4.65	4.65	4.69	0.11	VHS
Stability in performance, maintaining consistent light output and quality throughout their lifespan	4.85	4.85	4.70	4.70	4.75	4.77	0.06	VHS
Total:	4.77	4.75	4.63	4.63	4.67	4.70	0.08	VHS
Interpretation:	***VERY HIGHLY ACCEPTABLE***							

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Legend:

		M	MEAN	1.50	2.49	LA	Less Acceptable
		%	Percentage	1.00	1.49	NA	Not Acceptable
		VD	Verbal Description				
4.50	5.00	VHA	Very Highly Acceptable				
3.50	4.49	HA	Highly Acceptable				
2.50	3.49	A	Acceptable				

The data from Table 4 provides a comprehensive evaluation of the reliability of LED-based lamp posts, as perceived by both students and faculty. Across various indicators, such as consistent performance, reliability in withstanding various weather conditions, and stability in maintaining consistent light output and quality throughout their lifespan, the LED lamp posts consistently received high ratings. The mean scores range from 4.63 to 4.85, with an overall mean score of 4.77, indicating a very high level of acceptability in terms of reliability. Particularly noteworthy is the emphasis on the ability of LED lamp posts to withstand different weather conditions and maintain stable performance over time, with mean scores consistently above 4.65. This data suggests that LED lamp posts are perceived as highly reliable in their performance, demonstrating consistency and stability even under challenging environmental circumstances. Therefore, based on the ratings provided by both students and faculty, it can be concluded that LED-based lamp posts are very highly acceptable in terms of reliability, highlighting their ability to consistently deliver dependable performance in various situations.

6. Summary of Findings

The research study delved into the efficacy of LED-based lamp posts controlled by a photo switch in enhancing outdoor illumination within educational environments. The results revealed a unanimous consensus among night students regarding the technology's potential benefits, with a significant majority acknowledging its role in bolstering safety, security, and visibility. This agreement, with 75% strongly supporting and 15% in agreement, underscores the widespread recognition of the advantages offered by these innovative lighting solutions. Our findings confirm the study done by Bhusal et al. (2007), who found that the application of efficient lighting technology and renewable energy sources has been a sustainable solution to the basic lighting needs of many people.

Furthermore, participants overwhelmingly endorsed the integration of LED technology and intelligent control systems to enhance efficiency. A staggering 98–99% of respondents strongly agreed across thematic statements emphasizing innovation, functionality, and energy management. This overwhelming support signals a strong consensus on the transformative capabilities of these technologies in optimizing outdoor lighting systems. Nevertheless, our findings confirm the research done by Gonzaga and Akdidach (2022), who found that smart lighting systems result in energy savings and, thus, can be an environmentally and economically beneficial technology to implement.

The study also highlighted the adaptability of LED technology and intelligent control systems to cater to diverse lighting needs. With 98–99% of respondents strongly agreeing across various thematic statements, there was a robust belief in these technologies' capacity to deliver tailored lighting solutions. This adaptability ensures that lighting environments can be finely tuned to meet specific environmental and user requirements. Similarly, these recent findings were corroborated by

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the previous findings conducted by Frascarolo et al. (2014), who argued that the smart lighting system was designed with the goals of sustainability, visual comfort, flexibility, and user requirements; basically, the logic of light where and when it is needed.

Furthermore, both students and faculty believed LED-based lamp posts to be highly effective and reliable. The devices garnered praise for their ability to maximize light output while minimizing energy consumption, thereby promoting sustainability. Our findings align with the findings of Oladiran et al. (2024), who discovered that energy-efficient lighting technologies such as LEDs, CFLs, and advanced lighting controls offer numerous benefits such as reduced energy consumption, lower maintenance costs, and enhanced illumination quality. Consistently high ratings were recorded for the devices' performance and quality throughout their operational lifespan, indicating very high levels of effectiveness and acceptability.

To sum up, the findings present a compelling case for LED-based lamp posts controlled by a photo switch as a viable solution for optimizing outdoor illumination in educational settings. The technology's efficiency, adaptability, effectiveness, and reliability align closely with the overarching goals of enhancing safety, efficiency, and sustainability while minimizing energy consumption. This research underscores the potential of innovative lighting solutions to positively impact educational environments.

7. Conclusion and Recommendations

Optimizing outdoor illumination through the design and performance analysis of LED-based lamp posts controlled by a photo switch with a programmable timer offers significant benefits in terms of energy efficiency, lighting quality, and customization. We can tune outdoor lighting systems to achieve the right lighting levels while reducing energy waste by applying these technologies and strategies.

LED-based lamp posts provide advantages over traditional lighting technologies by offering improved energy efficiency and longer lifespans. They also allow for better control and customization of lighting levels. Integrating a photo switch with a programmable timer enables the lighting system to automatically activate and deactivate based on ambient light levels and specific time schedules. This ensures that outdoor lighting is only active when necessary, resulting in energy savings.

Follow several key recommendations to optimize outdoor illumination with LED-based lamp posts controlled by a photo switch. Firstly, ensure compatibility between the LED fixtures and the photo switch by using photo controls specifically designed for LED applications, as traditional devices may not function properly. Secondly, verify voltage compatibility to prevent electrical issues. Thirdly, review the rated loads of the photo control device to ensure it can handle the LED fixtures' demand, considering the maximum load for LED lighting.

Additionally, consider mesopic luminance for night-time illumination, utilizing spectral optimization and mesopic luminous efficiency models like the X-model or MOVE-model to enhance visual performance. Lastly, factor in the spectral power distribution of LED sources to achieve optimal luminous efficiency for efficient mesopic lighting. The outdoor lighting system can operate effectively and efficiently if it adheres to these recommendations.

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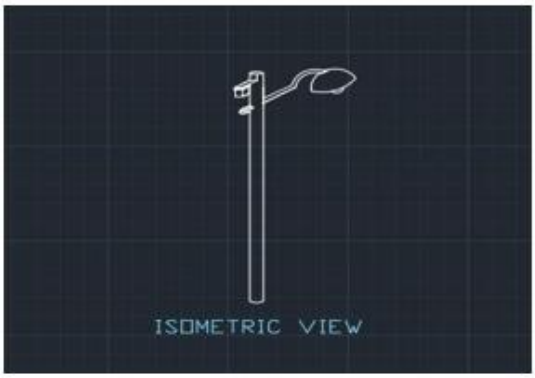
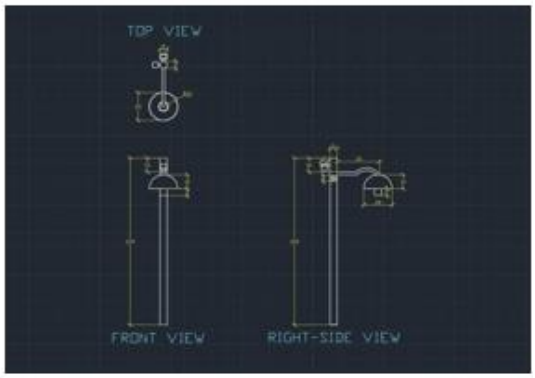
Documentation of LED-based Lamp Posts Controlled by a Photo switch with Programmable Timer

Documentation/Drawing of the Design Optimizing Outdoor Illumination Technology at Cebu Technological University (CTU) Pinamungajan Campus



Isometric Drawing



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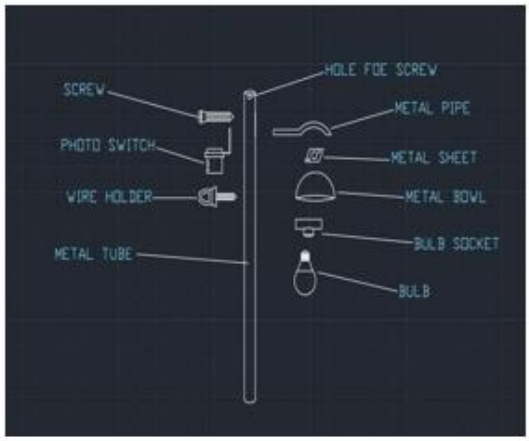
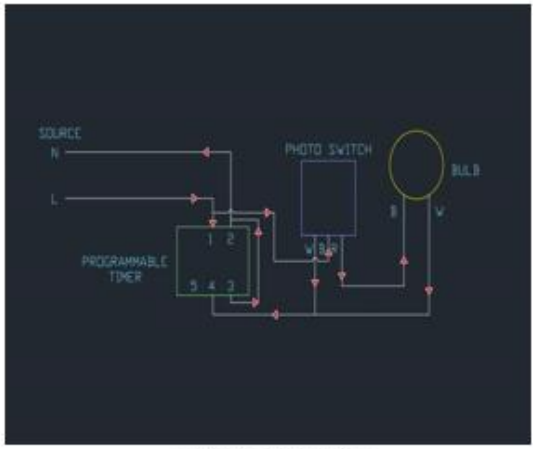


Exploded Drawing



Block Drawing

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