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Proposed Electrical System Design of Streetlights at Megadike Access Road

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Abstract: Due to the absence of streetlights, it is unsafe for drivers to travel during the night in the current state of Mega Dike. The lack of streetlights causes low visibility for drivers, which is one of the major factors that causes road crashes. Thus, this study aims to propose an electrical system design of streetlights at the Mega Dike Access Road. In order to plan an electrical system design, the proponents would take in consideration the following parameters; Illumination formula for pole spacing; voltage drop calculation; economic analysis; and simulation of the system. The results will be presented in tabulated form for the respective parameters. The study examines five (5) different cases, taking into account different lamp wattages, voltage drop considerations, and cost analysis. The study would abide with the standards set by the Philippine Electrical Code (PEC) and Department of Energy (DOE). The goal of the proposed streetlights is to provide additional security for drivers on the Mega Dike Access Road by improving visibility and reducing the risk of road crashes caused by low visibility. Generally, the significance of streetlights is needed in Mega Dike Access Road in order to address the issue of low visibility for drivers and improve overall road safety in the area.

Keywords: Cost analysis, illumination, luminaires, pole spacing, voltage drop

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1. INTRODUCTION

Nowadays, streetlights play a vital role in our community especially at night in dark areas, they are also beneficial in today's transportation by illuminating areas that would be dark at night to ensure safety and to avoid any accidents [1]. Mega Dike serves as Pampanga's last defense against lahar during Mt. Pinatubo's eruption. In the current situation of Mega Dike, it becomes more dangerous for the drivers to travel at night due to its lack of streetlights and because of that the road becomes very dark during night time that leads to different accidents occurring in the said road. During night time street lighting is an efficient road safety intervention, driving at this time is considered to be much more dangerous, having up to three times higher fatality rates than daytime driving [2].

According to Section 2 of House Bill No. 9822 of the Eighteenth Congress, all national, provincial, municipal, city, and barangay roads and streets shall use streetlights to illuminate the night that its citizens cross [3]. It is commonly thought that improved street lighting reduces crashes that occur at night and it saves energy. In recent times, it has been more common for people to work at night which subsequently increases the crime rate during night time [4]. There is a rapidly increasing number of road accidents in the Philippines. Road accidents in the Philippines typically happen due to these certain factors; reckless driving over the speed limit; driving with the influence of alcohol; usage of the phone while driving. Among all of these factors. Moreover, another major cause of these road accidents is the lack of streetlights that causes streets to get very dark at night. A huge percentage of road accidents at night time occur due to low visibility, poor design of streetlights or the lack of streetlights. As recorded by statistics which focuses on records of global road crashes per year, an estimate of over 3000 deaths is recorded each day, totaling up to an annual record of 1.3 million casualties die in car accidents [5].

The occurrence of traffic accidents when visibility is impaired at night has been a significant issue because, despite a significantly lower volume of vehicles at night, there are comparatively more traffic accidents. According to a recent study, it is highlighted that almost 39% of roadway accidents happens at places where surroundings are not properly illuminated. The proportion of fatalities during that time was around 54%, although the proportion of traffic—the indicator of risk exposure—was roughly 29%. Despite their possibly modest percentage in traffic during the night, pedestrians were involved in more than 40% of accidents on roads in built-up areas during inadequate lighting, indicating a considerable rise in the proportion of fatalities. Winter, which includes a time change, is a particularly bad season since the length of the poor lighting conditions is prolonged [6].

Mega Dike Road is an accident-prone area especially at night due to its lack of streetlights. As reported by SunStar (2014), a motorbike and a sports utility vehicle crashed along the Eastern Mega Dike route in Barangay San Isidro, Bacolor, Pampanga, resulting in the deaths of two drivers and injuries to one passenger [7]. In 2017, another car accident happened at Mega Dike Road that injured three passengers of the vehicle and claimed the life of a Central Luzon police officer [8].

Studies have shown the effect of good lighting can adequately improve the safety of an area when compared to places with not sufficient lighting. It shows that around 30%-35% of accidents are reduced in places where there is good lighting [9]. In addition, it is now also clear from reading the scientific evidence that street lighting can help in reducing crime. Whether lighting is important for reducing crime is no longer a reasonable question, and how illumination should be used to improve its outcome by combining with other measurements, which, in terms of impact, is both the most beneficial and economical. Things such as a multi-purpose crime prevention measure does not exist and by administering this study, crime suspects may be identified more quickly. In the case of serious crime, this may keep them out of the area temporarily. They may be discouraged from committing less serious crimes in an area that is now identified as dangerous [10].

Road accidents, which are frequently unintentional and avoidable, are a regular risk in daily life and can occur to practically anyone, anywhere. In many emerging nations, the issue of traffic accidents is becoming a greater danger to national development and public health [11]. In addition, driving at night without streetlights has a substantial impact on severe casualties and traffic accidents caused by weariness and lack of visibility [12]. Consequently, the installation of streetlights would significantly help with the improvement of the delineation of road geometrics, presenting safer passing possibilities, and making it easier to observe traffic management at night. All road users' safety depended critically on their ability to see and be seen [13].

Street light design in the Philippines is aided by the Department of Energy (DOE), which they developed in order to provide information with the streetlight design in order to maximize the safety and technical efficiency of the system design. Moreover, the standard also gives out certain standards in order to attain an efficient use of energy with streetlighting. Furthermore, the system design of streetlights in the DOE's guideline differs from each type of roadway. On top of that, Mega Dike Access Road falls under the category of a rural highway under the DOE's Road Lighting Guideline, as it serves as an access road to certain residential areas of Pampanga, such as Bacolor, San Fernando, and Porac. With this in mind, the DOE set minimum standards of road lighting for the category of rural highway. Such as, lamp wattages, pole spacing, mounting height, and the mast arm length of each streetlight [14].

Solar street lights have the potential to enhance energy resilience in rural communities. However, it is important to note that without proper maintenance for this system, lighting could fail relatively quickly. On the other hand, grid-connected street lighting systems prioritize reliability by eliminating the need for energy generation and storage components, ensuring increased long-term dependability. Despite incurring monthly bills, these systems are more likely to bring sustained benefits to the communities they serve. Therefore, while solar street lights offer potential advantages, the superior choice for reliable street lighting remains with grid-connected systems [15]. On the other hand, solar road studs are widely used in many countries, are small devices embedded in the road surface that serve the primary purpose of enhancing driver visibility and guiding them by highlighting important road features and providing visual cues [16].

1.1 Objectives

The objective of this study is to propose an electrical system of design of streetlights at Mega Dike Access Road. Firstly, this study aims to calculate the spacing between each pole in order to achieve the illuminance required. Secondly, the voltage drop of each design would need to abide with the standard set by the Philippine Electrical Code (PEC) of less than 3%. Thirdly, the proponents would simulate each of the system designs in order to visualize the design in an actual setup and provide values for the uniformity ratio. Lastly, the study would present the economic analysis of each design, specifically the life-cycle cost analysis in order to determine the cost-efficient design.

2. CONCEPTUAL FRAMEWORK

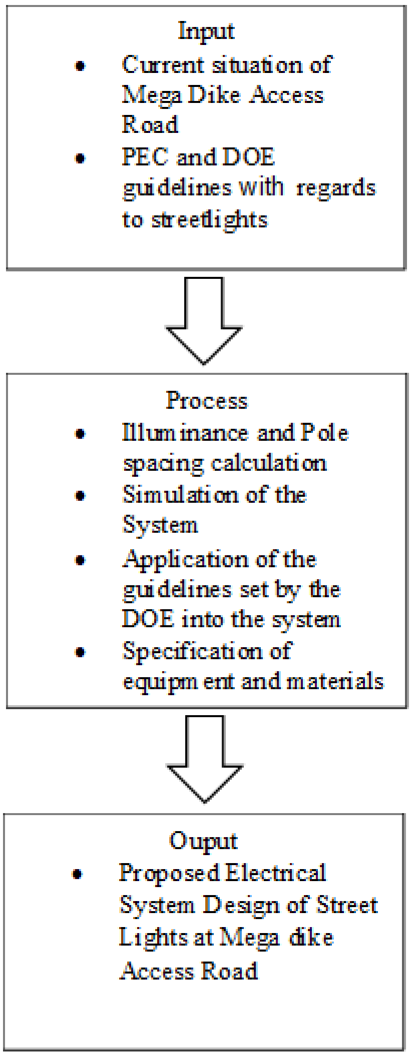

Figure 1. Conceptual Framework of the Proposed Study

Figure 1 illustrates the input-process-output (IPO) model of the study. The input indicates all the necessary standards that are set by the Department of Energy (DOE), and the Philippine Electrical Code (PEC) with regards to streetlight. For the process, calculations of the required lux level and pole spacing would be conducted, and the simulation would take in place. An expected output will be an electrical system design of streetlight at Mega Dike Access Road.

3. METHODS

3.1 Pole Spacing

The calculation of roadway luminaire pole spacing is a crucial aspect of roadway lighting design. The formula for calculating the spacing is determined by the following parameters [18]:

$$Pole\ Spacing = \frac{[(LO)(CU)(LLF)]}{Eh(w)} \quad (1)$$

In this equation, LO represents Lamp Lumens, which are the initial lumens emitted by the lamp or LED luminaire upon installation. CU stands for the Coefficient of Utilization, and LLF represents the Light Loss Factor, which takes into lamp lumen depreciation and luminaire dirt depreciation. Eh refers to the average maintained design horizontal illuminance, while w pertains to the width of the lighted roadway in meter (m) that the luminaire is intended to light. In a scenario where the roadway consists of multiple lanes but the luminaire is only expected to light a portion of it, only the width of the targeted lanes should be used in the equation

Table 1 presents the pole spacing calculated for each case, taking into consideration similar values for the LLD, LDD, LLF, Eh, and w. Cases 1 and 3 both incorporates the use of 50W LED Streetlight, the calculated appropriate spacing for the pole should be at 22m. On the other hand, for cases 2, 4 and 5, the use of 100W LED streetlight were taken into consideration and the required, higher wattage for LED streetlights produces a higher amount of lumen output. Hence, the pole spacing for a 100W LED streetlight is significantly higher.

$$No.of\ Streetlights = No.of\ Poles = \frac{Road\ Length}{Pole\ Spacing} \quad (2)$$

Moreover, the number of poles needed for a desired road length would be divided with the appropriate pole spacing calculated.

Table 1. Pole Spacing

Case	Lamp Wattage	Pole Spacing
1	50 Watts	22 meters
2	100 Watts	40 meters
3	50 Watts	22 meters
4	100 Watts	40 meters
5	100 Watts	40 meters

3.1.1 Coefficient of Utilization

The Coefficient of utilization (CU) would be based upon the coefficient of utilization curve that indicates the proportion of the luminaire’s lumens that will fall on the roadway surface, which takes upon the ratio of the road width and mounting height of the luminaires [17]. The measured road width of the Mega dike access road is 6 meters and the appropriate mounting height of the luminaires in consideration with the rural highway is 8 meters, referring to Table 6.5.3, which provides guidelines for specifying roadway lighting parameters as per the Department of Energy (DOE) [19].

3.1.2 Illuminance

Illuminance can be used to measure actual gradual degradation of luminaires or reflective surfaces throughout time. The value of the illuminance would depend upon the class of road which is being lit. In this case, the Mega Dike Access Road falls under the rural highway class road, which requires a minimum lighting level of 5 lux is necessary for this road class [20].

3.1.3 Light Loss Factor

Light Loss Factor would depend upon the product of the Lamp Lumen Depreciation (LLD), and Luminaries Dirt Depreciation Factor (LDD). This is a critical parameter in order to efficiently design a streetlight system design, as this takes into consideration various factors affecting the luminaires. Such as, decay of the luminaires over time, as well as how dirt accumulates in time on lighting fixtures.

To calculate LLD (Light Loss Depreciation), the duration of streetlight operation needs to be determined. The streetlights operate for 11 hours each day, resulting in a value of 78% LLD referring to the manufacturer's graph [21]. To calculate LDD (Luminaire Dirt Depreciation), use the graph and consider the maintenance time in 5 years and moderate road cleanliness that gives a value of 88% LDD [22].

3.2 Pole Arrangement

The pole arrangement of the system would abide upon the guidelines set by the DOE. Specifically, under section 6.1 which is entitled Lighting Arrangements. The Mega Dike Access Road has a width of 6m and all of the designs would include poles with a height of 8m. Consequently, a single side pole arrangement is employed in the road design due to the road width being equal to or less than the pole height. However, it is crucial to note that certain sections of the Mega Dike Access Road are adorned with numerous trees along the roadside, allowing for the possibility of alternate pole arrangements if necessary.

3.3 Voltage Drop Calculation

According to PEC [23] section 2.15.1.2 FPN No. 2 and 2.10.2.2 FPN No. 4 defined in article 1.1, in order for feeders and branch circuits to provide a reasonable efficiency of operation the sized to prevent a voltage drop exceeding 3% at the farthest outlet of power where the maximum voltage drop on both feeders and branch circuits to the farthest outlet shall not exceed 5%.

Voltage drop calculation would be used in order to get the power dissipated or the voltage loss coming from the streetlight from one pole to another. By considering the voltage drop in design and installation of the streetlights can ensure that the streetlights are operating properly and efficiently. By considering the current, length, number of sets, and impedance the voltage drop can be calculated by using equation (3).

$$VD = 2IZ\left(\frac{L}{305}\right)\left(\frac{1}{N}\right) \qquad (3)$$

3.3.1 Length of Furthest Load (L)

The length of the furthest load of the first branch circuit would be calculated using the formula:

$$VL = Pole\ Spacing * Quantity\ of\ Streetlights \qquad (4)$$

On the other hand, succeeding branch circuits' length would be determined by using the formula:

$$L_n = Pole\ Spacing * (Quantity_n) + L_{n-1} \qquad (5)$$

where: n= branch circuit; n-1= distance from branch circuit 1 up to the succeeding term.

3.3.2 Current (I)

In order to find the value of the current, both the Ohm's Law and Power Triangle would be taken into consideration.

Streetlights available nowadays have a power factor less than 1. Thus, solving for the apparent power is necessary. Impedance is a part of the conductor wires which opposes the flow of current and is needed in streetlighting. Which also affects the overall voltage received by each streetlight**.**

Specifically:

$$S = \frac{P}{pf} \quad Streetlights \qquad (6)$$

$$I = \frac{S}{230} * Quantity\ of\ Streetlights \qquad (7)$$

where: S = apparent power; pf = power factor; and I = current

3.3.3 Impedance (Z)

The Impedance of the circuit would be calculated by the formula:

$$Z = \sqrt{X^2 + R^2} \qquad (8)$$

In reference with PEC 2017 [22], the size of wire would depend on the value calculated using equation 9 and with reference to table 3.10.2.6(B) (16) Allowable ampacities of insulated conductors that would be used as reference for table 9.1.1.9 Alternating-Current Resistance and Reactance, in order to find the values of X and R.

3.4 Identification of the System Components

This study incorporates essential standards in order to determine the electrical components of each system design. These components includes wire size; grounding conductor; circuit breaker; and panel box.

3.4.1 Conductor / Wire size

The required sizes of wires would be calculated with the formula:

$$Wire\ Size\ (I_W) = I_T * DF \qquad (9)$$

Where: I_T = Total Current of the Circuit; DF = Demand Factor of the System.

In reference with PEC 2017 article 3, the computed value using equation 9 would be used as reference in table 3.10.2.6(B) (16) Cable Ampacity [23].

3.4.2 Circuit Breaker

The formula for calculating the appropriate circuit breaker sizes would depend upon the formula:

$$Circuit\ Breaker\ Size\ (I_{CB}) = I_T * DF \qquad (10)$$

Where: I_T = Total Current of the Circuit; DF = Demand Factor of the System.

Moreover, branch circuit breakers and main distribution breakers would be based upon Article 2.40, specifically at 2.40.1.6(A) of the Philippine Electrical Code which deals with ampere rating for circuit breakers [23].

3.4.3 Grounding Conductor

In reference to PEC 2017, the grounding conductor that would be used in the system will follow the standard set by the PEC and specified in article 2.50 Grounding and Bonding [23].

3.4.4 Panel Box

For cases 1 and 2, a panel box that is placed within the vicinity of a police station. A distribution board type of panel box would be employed. On the other hand, for cases 3, 4, and 5, a freestanding type of panel box would be integrated. In line with this, the type of freestanding panel box should be within the standard of National Electrical Manufacturers Association (NEMA).

3.5 Dialux Evo 11

Dialux Evo 11 would be used in order to provide a simulation of the system design in an actual setup. This software would provide calculations of illuminance, specifically the uniformity ratio of lux levels from one pole to another. The uniformity ratio set by the DOE should not be below 0.40 [24]. In order to simulate the system design, the values that would be deployed on the software would be in accordance with the type of road, pole spacing, road width, luminous flux, and the wattage of the lamp to be used shall be specified accordingly with the design. By following the certain parameters set by the researchers, Dialux Evo 11 would provide calculation results regarding the design's illuminance level and uniformity ratio.

3.6 Economic Analysis

In order to determine the most economical design among the five cases, life cycle cost analysis of each design would be calculated and would depend on the following parameters; Initial Investment Cost; Residual Cost; and Residual Value. These conditions would serve as parameters in determining the appropriate economical design of streetlights at the Mega Dike Access Road. The lowest value for the life cycle cost analysis would be deemed the appropriate economical design.

$$Life\ Cycle\ Cost = IV + PV_{RC} - PV_{RV} \tag{11}$$

$$PV_{RC} = RC * \left(\frac{1-(1+r)^{-t}}{r}\right) \tag{12}$$

$$PV_{RV} = \frac{RV}{(1+r)^t} \tag{13}$$

Where: r = discount rate; n = number of years

3.6.1 Initial Investment Cost (IV)

The initial investment cost is the sum of all material, equipment, and labor costs. The data required for the initial investment cost are gathered by prices listed on online markets.

3.6.2 Present Value of Recurring Cost (PV_{RC})

In order to get the recurring cost of the designs, it is important to consider the sum of operating cost and maintenance cost of the system. The present value of the recurring cost would be implemented in order to adjust the future cost of the recurring costs in today's value. For the design, the consideration for the discount rate is at 3% [25]

3.6.3 Present Residual Value (PV_{RV})

The value of the residual value is often determined by getting the 25% of the project's initial investment cost [26]. Consequently, the calculation for the present residual value would be considered in order to account the conversion of future residual value into its present worth.

3.6.4 Operating Cost

The operating cost would include the total power consumption of the design annually.

$$Operating\ Cost = \frac{W * no\ of\ hours\ used\ per\ day * n * 365}{1000} * Rate\ of\ the\ Electric\ Cooperative \tag{14}$$

Where: W = Wattage of the streetlight; n = no. of streetlights

3.6.5 Maintenance Cost

Maintenance cost would involve the replacement of a luminaire once its lumen output does not satisfy the minimum requirements of lux level. In line with this, the life expectancy of each streetlight would be taken into consideration in identifying the maintenance period of the design. Moreover, life expectancy of each streetlight would be the main component in determining the maintenance cost of the system.

3.7 Five Distinct Cases

The researchers will present five different cases of electrical system design of streetlights at Mega Dike Access Road. All of these cases would abide with the standards set by the DOE and the PEC. The standards with regards to; The minimum lux level of 5 lux; uniformity ratio of ≥0.40; and voltage drop of <3% [20, 23, 24]. Moreover, the economic analysis of each design would also be in consideration in choosing the appropriate design out of all the cases.

Case 1

In case 1, there is a plan to implement a lighting system that involves three main panel boxes located at the police stations. These panel boxes serve as central control points for the lighting infrastructure in the area. The lighting system will utilize 50W LED streetlights, which would produce 5000 lumens and the pole spacing for case 1 would be 22 meters.

Case 2

For case 2, the three main panel boxes from case 1 would be retained. The difference of case 1 and 2 is the application of higher power of LED streetlights. For this case, a 100W LED streetlight is chosen to be the main luminaire. This streetlight would emit 12,500 lumens and each streetlight would have a spacing for their poles of 40 meters.

Case 3

In case 3, the utilization of freestanding panel box would be implemented. This would be done in order to accommodate the use of smaller sizes of wire in the system design. Multiple panel boxes would help in order to minimize the voltage drop encountered by the streetlights. In this case, a similar LED streetlight as case 1 would be implemented, which is a 50W LED Streetlight that omits 5000 lumens and the pole spacing is 40 meters.

Case 4

In case 4, the design in terms of the use of freestanding panel boxes would be implemented. The difference between case 4 and case 3 is the choice of luminaire. The LED streetlight in case 4 would be the same as case 2, 100W LED streetlight which has a lumen output of 12,500 lumen and the pole spacing would be at 40 meters.

Case 5

For Case 5, the design would feature the same freestanding panel boxes from case 3 and 4. The difference would be the implementation of solar road studs at the curve part of Mega Dike Access Road. In addition, 100W LED streetlight would also be integrated in the design, these streetlights would be spaced at 40m between and would have a 12,500-lumen output.

4. RESULTS AND DISCUSSION

4.1 Voltage Drop Calculation

4.1.1 Voltage Drop Calculation for Case 1

In order to meet the necessary voltage, drop levels prescribed by the PEC, the researchers divided the whole length of Mega Dike Access Road into three different Sections.

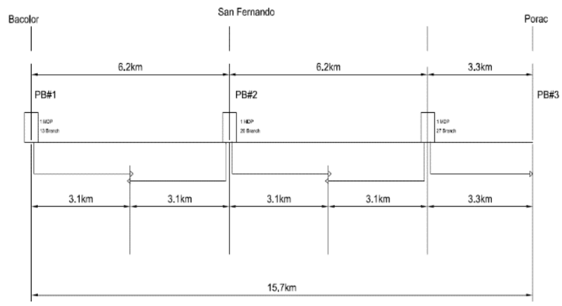

Figure 2. Strategic Location of Panel Box for Case 1

Figure 2 presents the three sections of the Mega Dike Access Road. Higher value for the length of wire translates into having higher voltage drop levels. In order to accommodate the high voltage, drop levels, it is necessary to partition the whole span of the road. Moreover, having multiple luminaires per branch circuit equates into having higher amount of current, which also raises the voltage drop level significantly. To allow for the voltage drop per branch circuit not to exceed 3%, it is vital to have multiple branch circuits inside the panel box.

4.1.2 Voltage Drop Calculation for Case 2

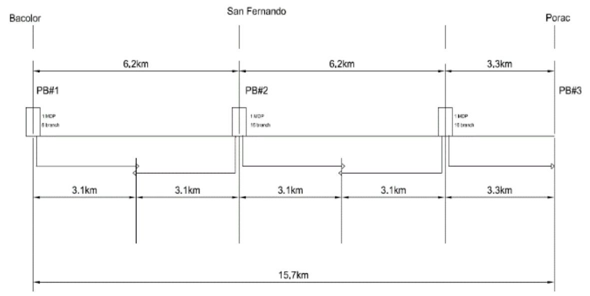

Figure 3. Strategic Location of Panel Box for Case 2

Figure 3 presents the partition of the Mega Dike Access Road into three different sections. The value of the length plays a significant role in having high voltage drop levels. Thus, the partition of the whole road was implemented. In line with this, Case 2 incorporates higher wattages of streetlights which denotes into having significantly higher current. In addition, fewer number of streetlights are required for Case 2, which leads to having fewer branch circuits.

4.1.3 Voltage Drop Calculation for Case 3

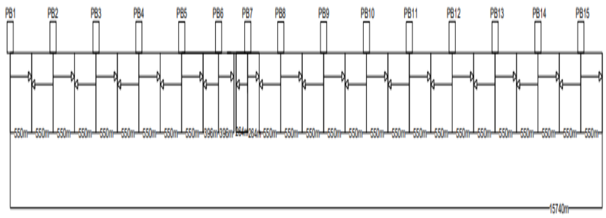

Figure 4. Strategic Location of Freestanding Panel Box for Case 3

Figure 4 presents the positioning of 15 freestanding panel box and the symmetrical distance of 550 meters. For this case, each panel box would only host 1-2 branch circuits in order to avoid having higher amount of current per panel box. By having 1-2 branch circuits per panel, the design could maximize the use of each wire implemented in the design.

4.1.4 Voltage Drop Calculation for Case 4

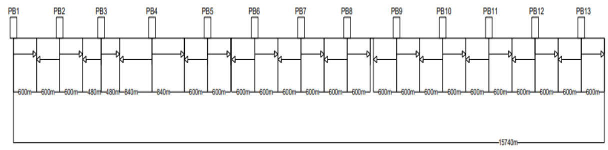

Figure 5. Strategic Location of Freestanding Panel Box for Case 4

Figure 5 presents the positioning of 14 freestanding panel box and the symmetrical distance of the furthest load per branch circuit is 600 meters. For this case, 100W LED streetlights were implemented in the design, which generates the least number of luminaires needed in the design. Taking the previous statement in consideration, the amount of needed freestanding panel box would also be reduced.

4.1.5 Voltage Drop Calculations for Case 5

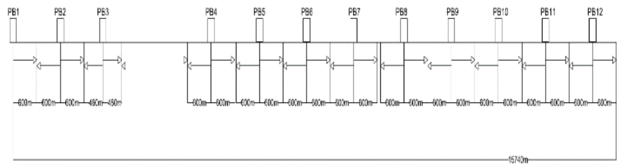

Figure 6. Solar Road Stud Location for Case 5

Figure 6 represents the location of the road studs needed in the design for case 5. This case would incorporate a similar setup with case 4 in regards with the pole spacing, pole arrangement, and type of LED streetlight used in the design. The only difference between case 4 and 5 is that for the curve road of Mega Dike Access Road, solar road studs would be employed. The gap between panel box 3 and 4 would be replaced with solar road studs that are spaced 3m within one another and would cover 1.6km of distance in total.

4.1.6 Summary of Voltage Drop Calculated

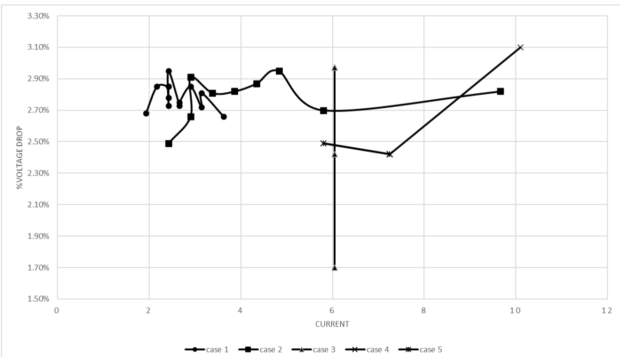

Figure 7 Summary of Voltage Drop Attained for each Cases

Figure 7 presents the summary of voltage drop calculated; the x-axis represents all of the current drawn in every case. Starting with Case 1, the total number of branch circuit voltage drop needed to be calculated is totaled up to 13 branch circuits. As seen by the figure of case 1, the voltage drops increases as the current increases. In order to have A total of 11 branch circuits are deemed critical in terms of voltage drop which has voltage drop of 2.7% and above.

For Case 2, the total number of branch circuit voltage drop needed to be calculated is totaled up to 9 branch circuits. The least amount of quantity needed is recorded at 8 street lights which has a current rating of 2.42A and the last branch circuit which has the longest value for the furthest load. The highest quantity is 20 streetlights which has 9.66A. A total of 7 branch circuits are close into achieving 3% voltage drop.

For Case 3's voltage drops, all fifteen panel boxes are equal in distance, the value for the voltage drop calculated would be the same. Almost all of the panel box attained a staggering 2.97% voltage drop, which is in critical level. On the other hand, one panel box managed to attain a 1.79% voltage drop which is due to the fact that it only covers a distance of 264m.

In Case 4, it is noteworthy that panel Box 4 had to accommodate a distance of 840m which resulted in a high number of 42 streetlights. As a result, the branch circuit experienced a substantial increase in current flow. Despite employing a larger wire size to mitigate this issue, the voltage drop surpassed the acceptable threshold of 3%.

In Case 5, a setup similar to Case 4 was adopted, with the main distinction lying in the number of streetlights required for the design. Notably, solar road studs were integrated specifically for the curved section of the Mega Dike Access Road. In terms of the streetlights themselves, it is worth noting that all of the panel boxes attained a maximum of 2.42% of voltage drop. This indicates that case 5 successfully computed a minimal voltage drop.

4.2 Dialux Evo 11 Simulation Results

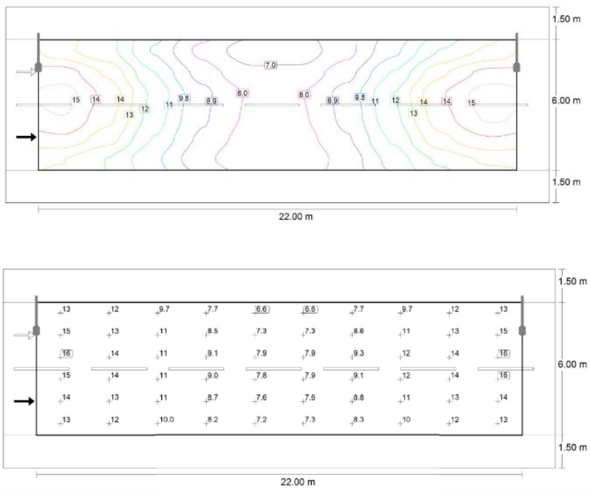

Figure 9. Uniformity Ratio Results for Case 1 and 3

Figure 9 depicts the lux level values that fall at every part of the road. In this simulation, the following parameters were followed; 22m of pole spacing; 6m road width; 8m mounting height; 5000 lumen outputs for each luminaire; and 50W rated power. The minimum lux level simulated is 6.36 lux while the maximum lux level attained is 15.4 lux, on average, lux level is maintained at 10.5 lux level.

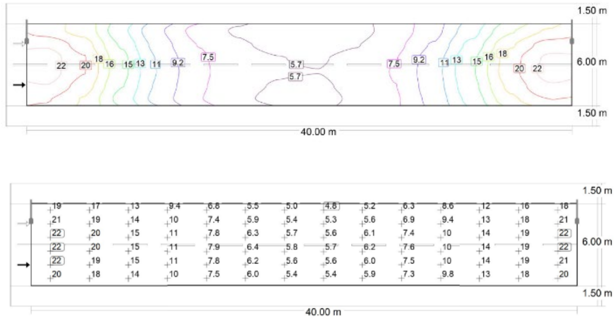

Figure 10. Uniformity Ratio Results for Case 2 and 4

Figure 10 illustrates the lux level values that fall within the vicinity of two poles. In this simulation, the following parameters were followed; 40m of pole spacing; 6m road width; 8m mounting height; 12500 lumen outputs for each luminaire; and 100W rated power. The minimum lux level simulated is 4.83 lux while the maximum lux level attained is 22.5 lux, on average, lux level is maintained at 11.7 lux level.

For Cases 1 and 3, both of these designs share the same attribute with their illuminance outputs. Both of these cases surpass the minimum illuminance level of 5 lux. In addition, both of these cases managed to attain a satisfactory level of uniformity ratio, which is 0.60. On the other hand, Cases 2, 4, and 5 failed to meet the minimum illuminance level of 5 lux, managing only 4.83 lux for their designs. However, these three cases managed to be in line with the minimum requirement of the uniformity ratio, maintaining a 0.40 for their uniformity ratio.

Table 2. Summary of Illuminance levels

	Minimum Lux	Uniformity Ratio	Remarks
Case 1 and 3	6.36 lux	0.60	Accepted
Case 2, 4, and 5	4.83 lux	0.40	Not Accepted

4.3 Economic Analysis

Cases 1 and 2 demonstrate the highest initial investment costs, as they capitalize on the proximity of two police stations to the Mega Dike Access Road, utilizing them as two of the three primary control panels for the design. In addition, these cases encountered substantial voltage drop levels, necessitating the implementation of larger wire sizes to accommodate this issue. Consequently, the overall design incurred elevated material and equipment expenses. Conversely, Cases 3 and 4 leverage the use of freestanding panel boxes, minimizing the adverse effects of voltage drop on each panel box. By incorporating multiple panel boxes, the length of each branch circuit is significantly reduced, resulting in a substantial decrease in voltage drop values. Case 5 shares similarities with Case 4, utilizing 100W luminaires and freestanding panel boxes. However, Case 5 distinguishes itself by integrating solar road studs into specific sections of the road, slightly reducing material costs.

To ascertain the recurring cost of the designs, an analysis was conducted considering the operational hours of the streetlights. Each design assumes an 11-hour daily operation. In Cases 1 and 3, the designs consist of a total of 710 luminaires, utilizing 50W LED streetlights, resulting in an annual power consumption of 11,715 kW. Conversely, Cases 2 and 4 feature 396 luminaires with 100W LED streetlights, consuming a total of 13,068 kW per year. Notably, Case 5 demonstrates the lowest annual power consumption due to the incorporation of solar road studs.

The analysis of the life cycle costs over a 30-year period highlights the varying financial implications of each case. Cases 1 and 2, displayed the highest initial investment costs, resulting in the highest life cycle costs due to the substantial expenses incurred in addressing voltage drop issues and larger wire sizes. On the other hand, Cases 3, 4, and 5 demonstrate relatively lower life cycle costs. Among them, Case 5 emerges as the most cost-effective option, benefiting from its lower initial investment and annual operational costs. By integrating solar road studs and utilizing freestanding panel boxes, Case 5 achieves a favorable balance between functionality and economic efficiency.

Table 3. Life Cycle Cost

Scenario	Initial Investment Cost (IV)	Life Cycle Cost (LCC)
Case 1	₱84,437,015.95	₱112,640,370.24
Case 2	₱88,921,543.89	₱121,759,376.99
Case 3	₱34,498,452.69	₱67,845,313.70
Case 4	₱27,855,306.88	₱66,982,760.26
Case 5	₱25,654,187.97	₱62,646,464.57

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In summary, this study proposes five distinct electrical system designs for streetlights that can be utilized on the Mega Dike Access Road. The proposed designs are supported by calculations for suitable pole spacing, illumination, and voltage drop. Furthermore, the economic analysis of each design was also taken into consideration.

- Case 1 provides significant ease of control due to the fact that there are only three locations of control for the whole system design. However, due to having only three main control panels, the design would need to integrate more branch circuits which results in the problem with voltage drop. Three control panels would need to incorporate long and large sizes of wire in order to satisfy the standard set by the PEC of voltage drop percentage not exceeding 3%.

- Case 2 provides similar output as Case 1, difference can be seen with the quantity of needed streetlights, by using higher wattages of streetlights, the system would have a huge amount of current flowing through each wire. Therefore, resulting in having much larger sizes of wire in order to stabilize the voltage drop encountered by the system.
- Case 3 presents an electrical system design which incorporates the application of freestanding panel box, which makes room for having fewer amount of branch circuits per panel box. By having multiple panel boxes, each wire used would not have to travel long distances in order to arrive at the furthest streetlight controlled. Thus, the design would need to incorporate smaller sizes of wire in order to stabilize the value of the voltage drop encountered by the system.
- Case 4 takes into consideration the same design with case 3, however the difference can be seen with the power output of each streetlight. In this case, 100W LED streetlight were taken into consideration which allows room for fewer needed streetlights in the design. Just like in case 2, a higher amount of current would flow through each wire, which also results into incorporating large sizes of wire. By having large size of wires, the impedance of the wire would be low enough in order to stabilize the voltage drop caused by the current.
- Case 5 is the same setup with case 4, the difference can be seen with the application of solar road studs which makes the total power consumption per year the least out of all the cases presented in this study. However, solar road studs can’t replicate the total use case scenario of a normal LED Streetlight. Solar road studs could only provide a guideline for the road.

In conclusion, cases 3, 4 and 5 are more practical to implement, these designs do not require large sizes of wires in order to stabilize the voltage drop encountered by the system. Case 5 satisfies a lot of parameters needed for the system requirements; voltage drop did not exceed 3%; uniformity ratio is equal to 0.4; and life cycle cost is the least among all the cases. However, it failed slightly in terms of the minimum illuminance level, only achieving 4.83 lux, which is slightly less than the minimum standard of 5 lux.

5.2 Recommendation

In accordance with the results gathered, the following recommendations are offered to future researchers.

- The integration of solar street lights in order to disregard the concern with the voltage supply and voltage drop.
- The integration of CCTVs in the system design in order to provide additional security alongside the Mega Dike Access Road.
- The coordination with Local Government Unit (LGU) about the implementation of one of the five cases presented in this study.

- Provide a structural analysis of the poles needed in the design.

In order to have a safety clearance for trucks, consider a pole height of 12m for the Porac to San Fernando part of Mega Dike Access Road.

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