Energy Efficiency Gains by LED Luminaires in Common Areas' of Shopping Malls Through Transition From Fluorescent Lamps to LEDS: A Case of *Mini-Mall,* Kisumu, Kenya

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Abstract - The change in commercial lighting can be identified with the introduction of recent technologies like LED luminaires which are energy-efficient. The case study analyzed is for a shopping mall with an aim of making a comparison of the suitability and cost-effectiveness between the existing CFLs and LEDs in the shopping mall. A layout design has been simulated to determine the number of required luminaires where the CFLs have been replaced using different LED luminaires in different sections. The design is expected to lower the amount of energy consumption by 43% and optimize quality of lighting in common areas of the mall. The estimated payback period is 1.2 years which validates the design that uses LED luminaires for commercial setups.

Keywords: LED luminaires; Illumination; Common Areas; luminance; Energy-Efficient; Dimming Compatibility; Color Rendering

I. INTRODUCTION

The commercial and industrial sector in Kenya contributes to more than 70% of the total electric energy demand [1]. Commercial lighting has been one of the most dynamic services throughout the years with the aim of reducing the amount of energy consumption. The change in commercial lighting can be identified with the introduction of recent technologies like LED luminaires which are energy-efficient. In shopping malls, lighting is one of the key determinants of consumer behavior. The quality of lighting determines how attractive and comfortable mall visitors are [2]. The quality of lighting will be improved using LED luminaires which are energy-efficient and cost-effective. The lighting design takes into account the area or specifications of the common areas', the cost of buying fixtures and the cost of labor. The lighting in shopping malls plays a significant role in determining consumer behavior. However, the lighting in a building is a dominant consumer of electric energy with most businesses having to pay high electricity bill. Lighting in commercial buildings usually makes up for more than 30% of the total electrical energy consumed [3]. Upgrading from traditional lighting to high-efficiency lighting is usually perceived to be costly. Due to this assumption, most shopping malls in Kenya are still using the traditional lighting system which is in actual sense costly and does not provide an atmosphere that is attractive and comforting to mall visitors.

Paper Organization: The rest of the paper is organized as follows: Section II gives Methodology, Section III is the Case Study, Section IV is the presentation of Results and Analysis, while Section V is the Conclusion and finally, there is a list of references used.

II. METHODOLOGY

A. Scope

The geographical scope was focused on common areas' lighting in shopping malls with traditional lighting in Kenya (Kisumu). The contextual scope was focused on energy efficiency and the quality of lighting in commercial buildings. The theoretical scope was based on previous literature that is in line with the objectives of this project. An effective layout of the luminaires was simulated using Dialux Software.

B. Lighting System Design

The lighting design aims at providing visual comfort to mall visitors in a manner that is economical. The design takes in to consideration the selection of the fixtures, identification of common areas, measurement of the identified sections, how to minimize costs, maximizing light quality through lamp replacement and building simulation.

C. Selection of Site

The design is selected for the common areas of a shopping center (Mini Mall - Kisumu). The visual comfort of common areas of shopping malls determines how long mall visitors spend in malls. The shopping mall lights operate for 8 hours each day. Since all the six floors are identical the design shown was made for one floor which is applicable to all the other floors. The height of mounting the luminaires has been selected as 3m. The common areas of the mall have been identified as the corridors, washrooms, entrance and sitting area. Each section measurements are listed in Table 1.

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Table 1: Measurement of each common area of the shopping mall

Common Area	Measurements
Corridors	28m by 1.2m (12 units)
Washrooms	1.8m by 1.2m (12 units)
Staircase	2m by 1.25m (12 units)
Entrance/Sitting Area	24m by 6m (1 unit)

D. Selection of light fixtures

It is important to minimize lighting expenses at the same time maximizing the quality of lighting in the shopping center. When selecting the lighting options it is important to compare the available sources in the market in terms of lumen output, life span, cycle of maintenance, CRI, and distribution of lighting. A comparison between the traditional lamps and LEDs is shown in [4, Table (2)].

Table 2: Comparing Traditional Sources of Light with LEDs [4]

Type of Light	Output (Lumen/ Watt)	Estimated Lifespan (Years)	Cycle of Maintenance
LED	20-120	34	Nil
HPS	80-100	2	17
CFL	50-100	1	34
Incandescent	20	6 months	60

Looking at the comparisons between LEDs and traditional lighting, it is evident that LEDs have high power characteristics and they are a good fit to replace the traditional lightings in common areas' of shopping malls. From [4, table (2)], it is evident that LEDs are the most efficient light fixtures in terms of costing and energy consumption. The design the replacement of the existing light sources for the washrooms, hallways, entrance, staircase and the sitting area with LED luminaires as shown in Figure 1.

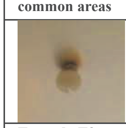
Existing Lights in common areas	Corridor Replacement	Washroom Replacement	Staircase Replacement	Entrance Replacement
				
Tornado T3 (CFLs in cover globe)	StoreFlux gen3 rim GD601B 1 xLED17S/840 WB	V-TAC 20W LED Downlight SAMSUNG CHIP Movable 3000K	StoreFlux gen3 rim GD601B 1 xLED17S/830 MB	ST770T StyiD Evo x LED49S/840 MB

Figure 1: Existing and New Replacement of Light Sources

The selected lamps have a Ra>80, an efficacy of 125 LPW, 90 LPW, 119LPW and 120 LPW respectively. To reduce the discomfort glare, the selected light fixtures have a UGR value of 22-25.The recommended illuminance level for each section is shown in [5, table (3)]

Table 3: Illuminance Level [5]

Common Area	Recommended Illuminance Level (lumen/m²)	Average Illuminance Level of the common area
Corridor	50 -100	50
Washrooms	100-300	150
Staircase	50-100	100
Entrance/Sitting area	200-300	200

III. CASE STUDY

The case study is of the lighting design of Mini-mall (Kisumu) with main focus on the lighting of the common areas. The common areas of the mall have been identified as the corridors, washrooms, entrance and sitting area. Each common area has a different lighting recommendation; therefore the number of luminaires varies in each section.

The number of Luminaires can be calculated using the Lumen Method or by simulation using Dialux Software. The Lumen method is calculated using [6, eq. (1)]

$$N = \frac{E \times A}{F \times n \times UF \times MF} \qquad [6]$$

Given that N is the number of lamps, E is the average illuminance, A is the area of the working plane, F is the light output from the lamps, n is the number of lamps per luminaire and UF is the utilization factor and MF is the maintenance factor [6].

In this case study, the number of the required luminaires was simulated using Dialux Software. Simulation was done for one floor since there are 6 identical floors for all common areas except for the entrance/sitting area. The data for the selected lamp output was obtained from Dialux's database of manufacturer's product data. The amount of energy consumed each day (KWh) was calculated based on the simulated results. The mall operates for 15hours each day with an average of 8hours of lighting in common areas. Table 4 gives a summary of the amount of energy consumed by the current CFLs and the amount of energy that will be consumed by the selected LED luminaires when the lighting design is implemented.

Table 4: Comparison of the amount of Energy Consumption of the existing CFLs with the chosen LED Luminaires

Type of Light	No. of Luminaires	Total Wattage	Units (KWh) Consumed each day
Tornado T3 32W	79	2.5428KW	2.5428 x 8 = 20.3424
StoreFlux gen3 rim GD601B 1 xLED17S/840 WB	60	0.864KW	0.864 x 8 = 6.912
V-TAC 20W LED Downlight SAMSUNG CHIP Movable 3000K	12	0.24KW	0.24 x 8 =1.98
StoreFlux gen3 rim GD601B 1 xLED17S/830 MB	12	0.1728	0.1728 x 8 = 1.3824
ST770T StyiD Evo x LED49S/840 MB	4	0.16KW	0.16 x 8 = 1.28

IV. RESULTS AND ANALYSIS

A. Simulated results for the number of luminaires needed and lamp's lumen.

The number of luminaires required in each section was simulated using DiaLux software. Table 5 shows the simulated data the number of luminaires that are required for each common area and the lamp's lumen for the selected fixtures.

Table 5: Lamp's Lumen and Required Luminaires

Common Area	Area (m^2)	Lamp's Lumen (lm)	Number of Luminaires (Units)
Corridor	403.2m²	1803	60
Washrooms	25.92m²	1800	12
Staircase	30m²	1709	12
Entrance/Sitting area	144m²	5192	4

The relationship between the lumen of the fixtures and the area of the common area is shown in Figure 3.

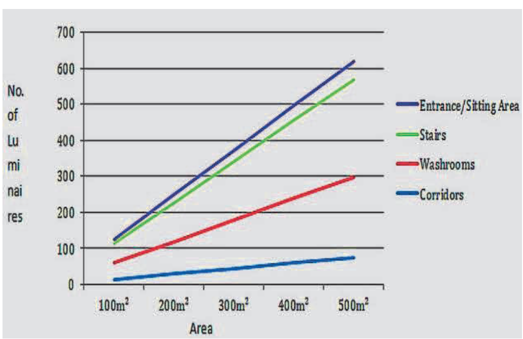
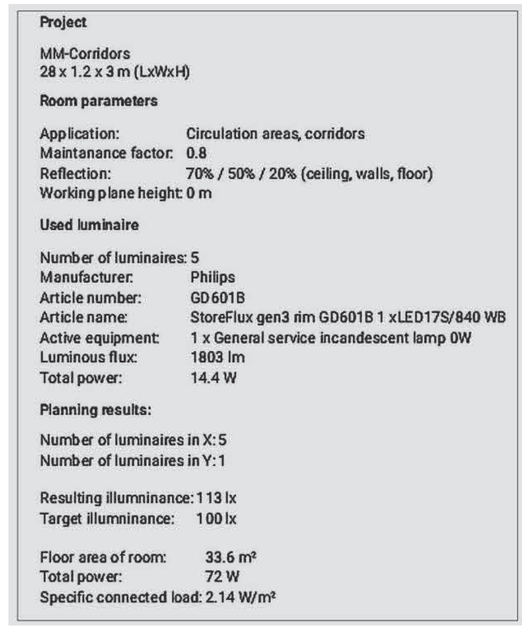


Figure 3: Relationship between Area and Number of Luminaires

Table 5 shows the simulated results for the number of fixtures needed for a specific common area with the varying lumen per luminaire. The relationship between the area of the common area, luminaire's lumen, and the number of fixtures has been illustrated Figure 3. The lumens of the luminaires are 1803lm, 1800lm, 1709lm and 3600lm respectively. From the given results, we can clearly note that the main factor that can lead to a significant amount of cost savings with regard to electric energy consumption is the characteristics of the luminaire. These characteristics include the lamp's lumen and the electrical input. The various lumens of the luminaires consume different amounts of electric energy. An increase in lumen leads to an increase in electrical input.

B. Replacement of Luminaires

The figures 4, 5, 6 and 7 show data worksheets for the replacement of the Luminaires of each common area as generated from DiaLux simulation. The selection of fixtures used in the lighting design was carefully selected by putting parameters such as CCT, Ra and illuminance into consideration. The results indicate the specifications of the common areas, the lamp data for the selected luminaires, the number of luminaires simulated for each common area, the resulting illuminance for each area and the specific connected load for each section.



Project

MM-Corridors
28 x 1.2 x 3 m (LxWxH)

Room parameters

Application: Circulation areas, corridors
Maintanance factor: 0.8
Reflection: 70% / 50% / 20% (ceiling, walls, floor)
Working plane height: 0 m

Used luminaire

Number of luminaires: 5
Manufacturer: Philips
Article number: GD601B
Article name: StoreFlux gen3 rim GD601B 1 xLED17S/840 WB
Active equipment: 1 x General service incandescent lamp 0W
Luminous flux: 1803 lm
Total power: 14.4 W

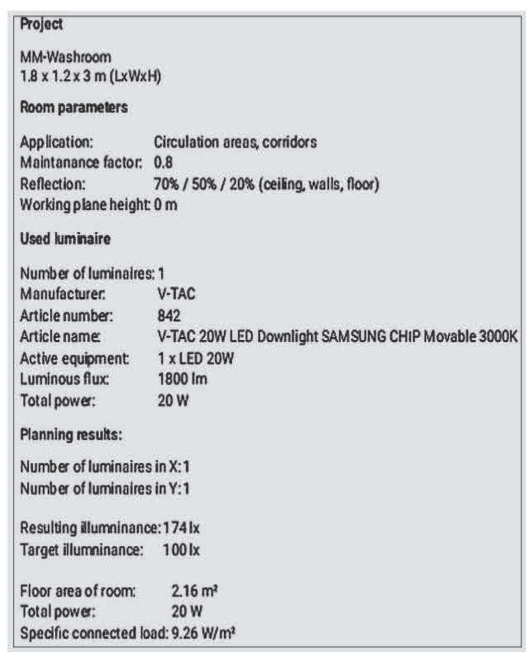
Planning results:

Number of luminaires in X: 5
Number of luminaires in Y: 1

Resulting illumninance: 113 lx
Target illumninance: 100 lx

Floor area of room: 33.6 m²
Total power: 72 W
Specific connected load: 2.14 W/m²

Figure 4: Replacement for Corridors



Project

MM-Washroom
1.8 x 1.2 x 3 m (LxWxH)

Room parameters

Application: Circulation areas, corridors
Maintanance factor: 0.8
Reflection: 70% / 50% / 20% (ceiling, walls, floor)
Working plane height: 0 m

Used luminaire

Number of luminaires: 1
Manufacturer: V-TAC
Article number: 842
Article name: V-TAC 20W LED Downlight SAMSUNG CHIP Movable 3000K
Active equipment: 1 x LED 20W
Luminous flux: 1800 lm
Total power: 20 W

Planning results:

Number of luminaires in X: 1
Number of luminaires in Y: 1

Resulting illumninance: 174 lx
Target illumninance: 100 lx

Floor area of room: 2.16 m²
Total power: 20 W
Specific connected load: 9.26 W/m²

Figure5: Replacement for Washroom

Project

MM-Staircase
2 x 1.25 x 3 m (LxWxH)

Room parameters

Application: Circulation areas, corridors
Maintanance factor: 0.8
Reflection: 70% / 50% / 20% (ceiling, walls, floor)
Working plane height: 0 m

Used luminaire

Number of luminaires: 1
Manufacturer: Philips
Article number: GD601B
Article name: StoreFlux gen3 rim GD601B 1 xLED17S/830 MB
Active equipment: 1 x General service incandescent lamp 0W
Luminous flux: 1709 lm
Total power: 14.4 W

Planning results:

Number of luminaires in X: 1
Number of luminaires in Y: 1

Resulting illumninance: 208 lx
Target illumninance: 100 lx

Floor area of room: 2.5 m²
Total power: 14.4 W
Specific connected load: 5.76 W/m²

Figure 6: Replacement for Staircase

Project

MM-Entrance/Sitting Area

24 x 6 x 3 m (LxWxH)

Room parameters

Application: Circulation areas, corridors

Maintanance factor:0.8

Reflection: 70% / 50% / 20% (ceiling, walls, floor)

Working plane height:0 m

Used luminaire

Number of luminaires: 4

Manufacturer: Philips

Article number: ST770T

Article name: StyliD Evo ST780T 1 xLED49S/840 OVL-V

Active equipment:1 x General service incandescent lamp 0W

Luminous flux: 5192 lm

Total power: 40 W

Planning results:

Number of luminaires in X: 4

Number of luminaires in Y: 1

Resulting illumninance: 118 lx

Target illumninance: 100 lx

Floor area of room: 144 m²

Total power: 160 W

Specific connected load: 1.11 W/m²

Figure 7: Replacement for Entrance/Sitting Area

C. *Energy Reduction Calculations*

Figure 8 shows a comparison between calculated and estimated amount of electric energy consumption of the existing and the new lighting design in the various common areas.

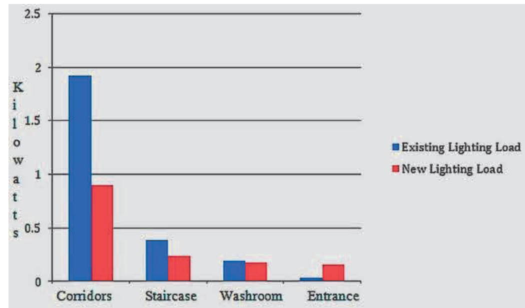


Figure 8: Comparison between Existing and New Lighting Load

From Figure 8, we can observe that there is a significant decrease in the amount of electrical energy usage with the implementation of the proposed lighting design. There is a significant reduction in each common area except for the entrance/sitting area where there is an increase in the lighting load due to the existing poor quality of lighting. The total existing load of 2.5428KW is replaced by a lighting load 1.4368KW amounting to a 43% decrease in energy consumption levels.

D. *Cost Reduction Calculations*

Table 9 shows the amounts of cost reduction that can be achieved with the replacement of the existing lighting design with the new design.

Table 9: Cost Savings

Information	Amount
Current consumption	100,237.176
New consumption	64,412.28
Cost Savings	35,824.896
Initial Investment Cost	86,500
Investment cost for new design	130,100
Difference in cost of Installation	43,600 (Y-N)
Estimated Payback Period	43,600/35,824.896 = 1.2 years

From Table 9, a payback period of 1.2 years was calculated. Table 10 shows a Net Present Value (NPV) was calculated with i=0.08 which is the Central Bank of Kenya (CBK) 2021 rates. The positive NPV indicates that the project is profitable and the capital invested in the project will be paid back. The interest rates will also be paid back and there will be an additional gain. An Internal Rate of Return (IRR) of 13% was generated using excel. This implies that for very shilling spent on the project, Kshs. 0.13 is received in interest each year.

Table 10: Net Present Value

Period	Investment	Savings	Expenses	Salvage	CashFlow, CFi	$\frac{CFi}{(1+i)\hat{}n}$
1st Year	-130,100	0	0	21683.33	-108,416.67	-108,416.67
2nd Year	0	35,824.896	5000	0	30,824.896	26,427.38
3rd Year	0	35,824.896	5000	0	30,824.896	24,469.80
4th Year	0	35,824.896	5000	0	30,824.896	22657.22
5th Year	0	35,824.896	5000	0	30,824.896	20,978.91
6th Year	0	35,824.896	5000	0	30,824.896	19,424.91
		NPV				5,541.55

V. CONCLUSION

The replacement of the existing fluorescent lights with LED luminaires will increase efficiency and minimize electric energy consumption by reducing the total wattage of fixtures used. The case study indicates a 43% reduction in energy consumption in common areas of the shopping mall. The determination of ideal lighting conditions for different common areas plays a key contribution for mall owners to improve the quality of lighting in common areas as per the different lighting recommendations. Through such implementation, an increase in the hours spent on the mall by mall visitors will be achieved and any visual impairment that may arise due to poor lighting conditions will be avoided. From the analysis of the results, it can be concluded that the transitioning from fluorescent to LED is recommended to reduce costs and create a good ambience in shopping malls.

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