UNIVERSITY OF NAIROBI

SCHOOL OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

MASTER OF SCIENCE IN ENERGY MANAGEMENT

RESEARCH PROJECT

“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.”

By:

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September, 2021

DECLARATION

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ACKNOWLEDGEMENT

I would like to acknowledge the help and assistance given to me by the Department of Mechanical Engineering of the University of Nairobi and Mini-Mall management. I would like to thank my supervisors Dr. Peter Moses Musau and Dr. Abraham Nyete of the University of Nairobi, school of engineering for the consistent guidance, support and source of inspiration throughout the project. Special thanks to my family-my husband Shem Odhiambo, children-Jayceon Hawi and Zuriel Lwiso, mom and siblings for their love and support. Thank you to my course mates for their assistance and being a point of reference through the entire research project

ABSTRACT

The quality of light plays a significant role in determining the number of people drawn to shopping malls, which increases sales. The quality of light in shopping malls is dependent on several factors such as the type of fixtures, color rendering index of the lighting, beam angle, the dimming compatibility of the fixtures, and the luminance distribution. LEDs can be used to increase illumination intensity lighting from ceilings. When the installation of the LEDs is correctly done, it helps in minimizing the glare, which encourages mall visitors to stay longer. Besides having a long lifespan, LEDs are energy efficient, therefore, reduces the amount of energy consumption in commercial setups. Nonetheless, the quality of the construction of the building also has an effect on the quality of a lighting scheme. The case study analyzed is for a shopping mall (Minimall-Kisumu) with an aim of making a comparison of the suitability and cost-effectiveness between the existing CFLs and LEDs in the commercial spaces. A layout design was simulated using Dialux where the CFLs were replaced using different LED luminaires in different common areas. The simulated lighting design lowers the amount of energy consumption by 43% and optimizes quality of lighting in common areas of the mall. The simulated and calculated results validate the technical and economical part of the project.

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

Contents

ABBREVIATIONS

AC	Alternating Current
ANSI	American National Standard Institute
CCR	Constant Current Reduction
CIE	International Commission on Illumination
DC	Direct Current
KW	Kilowatts
LED	Light Emitting Diode
PW	Pulse-Width Modulation
UGR	Unified Glare Rating
LPW	Lumen Per Watts

CHAPTER ONE

INTRODUCTION

1.1 Background Information

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 use of recent technologies like LED luminaires and which are energy efficient improves the quality of lighting in shopping malls.

One of the major goals of businesses is to increase their sales. The increase in sales can be achieved by expanding their customer base. Shopping malls are some of the places businesses can expand their customer base because they are frequently visited by many potential customers. The design presented uses LED luminaires as the choice of the fixtures which will be compatible with the structure and the quality of the building. The quality of lighting will be improved using LED luminaires which are energy-efficient and cost-effective. Based on the inspections conducted on the mall, the new design will ensure smooth transitioning from the existing lighting system to an optimized lighting system with minimal changes to the already existing shopping mall structure. The design takes into account the area or specifications of the common areas', the cost of buying fixtures and the cost of labor.

1.2 Problem Statement

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]. Mini-mall has CFLs that have high operational costs. 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.

1.3 Objectives

The key objective of the design is to propose the replacement of the existing lighting system that uses fluorescent lights in the common areas of the shopping mall with LED luminaires.

The specific objectives are:

1) To evaluate the specifications of the fixtures and the cost of installation of the LED luminaires
2) To determine aspects of the installation process such as the distribution of the luminaires per specific area.
3) To minimize overall operation cost of lighting.

1.4 Research Questions

1) How can we adjust the properties of the lighting fixtures to determine the glare and the area being lit by the fixtures?
2) How can we determine the number of luminaires required in the lighting design?
3) How can we determine the optimal levels of operation to minimize costs?

1.5 Justification

The common areas in shopping malls determine how comfortable mall visitors are and the amount of time they spend in a shopping mall, making it one of the important areas of a shopping mall. Due to the different quality of construction, lighting plays an important role in making the malls comfortable and attractive to mall visitors. However, lighting in commercial spaces makes up for more than 30% of the total consumption of energy making it a costly affair. Due to the high electricity bill, the management of different shopping malls in Kenya is forced to resort to certain measures to minimize expenses. Some of these measures include scheduling or switching off the lights in common areas which makes the mall unattractive and uncomfortable to mall visitors. The design aims at providing an optimized lighting system that utilizes LED luminaires. The design provides specifications of the replacement of lamps based on the number of lamps per area, labor costs and the new design of the lighting system. The LED lights operate on very low voltages and can last up to ten times longer than the incandescent bulbs. The light from LEDs is directional (180 degrees) [4], therefore is suitable for common areas like parking lots and driveways. The color temperature of create ambiance and can be mounted from different heights of ceilings. When the correct wattage is chosen for the LEDs, it helps in minimizing the glare reducing chances of visual impairments making the mall comfortable. Shopping mall lighting is essential in conveying information about products. It also boosts service concept, and brand culture to customers. By doing so, sales of goods and services are promoted. It also establishes a brand image and in return, draws more attention to the mall.

1.6 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 the quality of lighting in commercial buildings of different construction quality in commercial buildings. The theoretical scope was based on previous literature that is in line with the objectives of this proposal. An effective layout of the luminaires was simulated using Dialux and the costs calculated to determine the economic viability of the project.

1.7 Expected Results

The optimization of lighting quality is expected to impact an increase in the number of mall visitors due to improved visual comfort and satisfaction amongst mall users. The replacement of traditional lighting system with LED luminaires is expected reduce the lighting expenses in common areas by 35-50% through reduction of electric energy consumption in common areas of the shopping mall.

1.8 Beneficiaries

The lighting system design is set to benefit the following parties:

1) The management of shopping malls, since the design will give them an alternative that is optimized, cost-effective, and of high quality.
2) Business owners, since more people will be drawn to the mall, thus it will increase their chances of getting customers.

3) Mall users since, the environment will be more comfortable they will be encouraged to stay longer and conduct their shopping without a rush.

1.8 Project Organization

The project consists of five main chapters. The first chapter makes up of the introduction part, which outlines the background information of the study, statement of the problem, research questions, scope of study, expected results and the beneficiaries of the project. The second chapter is the review of previous literature that is in line with the objectives of the new design. The third chapter is the methodology that will be used in the project. The fourth chapter analyzes the results of the simulated and calculated data. The fifth chapter gives the summary, conclusions and the recommendations drawn from this project.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The aim of this chapter is to provide a general outline of an optimized lighting system model in commercial spaces, with interest in shopping malls. In the recent past, the quality of lighting shopping malls has been one of the key determinants of consumer behavior. In the past decade, new shopping mall owners are investing in new lighting technologies. This chapter focuses on the theoretical review of previous literature that anchors this project. It also provides a summary of research gaps and finally, it gives an overview of a lighting system design that uses LED luminaires to improve the quality of lighting in common areas' of shopping malls. Various studies have been conducted to explore the various the design variables that affect the lighting conditions in commercial buildings. The review has resulted to the defining of five key design variables which provide an outline for this chapter as listed below:

1) Type of Lighting Fixtures
2) Illumination Level
3) Color rendering index of the lighting
4) Dimming Compatibility
5) Luminous Efficacy
6) Luminance Distribution

2.2 Type of Lighting Fixtures

According to ANSI, there are a number of classifications of lighting fixtures that can be found in the market which include but are not limited to metal halides, mercury, low and high pressure sodium. The categories of lighting fixtures have multiple sub-categories for power requirements, light distribution characteristics, and the lumen output [5]. There are a number of studies that have examined the type of lighting fixtures and the quality in various commercial buildings. Most of the studies found were conducted in different buildings with some of them being shopping malls. The review of the studies below focuses on a number of studies conducted with research gaps being identified.

In a study conducted in Pakistan, Ayesha conducted a study in commercial setup which analyzed gained energy efficiency [6]. The study cites new a system that replaced conventional lights with energy saving light sources. The case study was a commercial plaza with three floors that operated 12 hours in all the floors [6]. The results indicated that an accurate and effective lighting design could be achieved using Dialux simulation. The results indicated that although the cost of installation is higher, they have longer life. The findings suggested that bright colors give a higher percentage of bright light as opposed to dark colors when used on walls. The results further indicated that 2.240 KW load of conventional lighting was substituted using 1.188KW of LEDs which saved up to 47% of the consumption of electrical energy [6]. The design of the study however, used a uniform lighting scheme for the entire building.

Horgan and Dwan conducted a feasibility study on the commercial use of LEDs in the United States [7]. The study looked at trends in the market as well as the mechanisms of the lighting. The study also conducted a cost-benefit analysis that involved comparing LED lighting with other forms of traditional lighting. Factors put in to consideration were the lifespan of the product, cost of product and the performance of the product. The case study was a residential building which is categorized as a commercial building. The data used was obtained from their research and literature. The results indicate that LEDs are energy efficient and have a longer lifespan than traditional lighting. The study recommends that businesses should think about shifting from traditional lighting to LEDs [7]. The case study however was a residential building which is considered a commercial building while the current study is based on common areas of shopping malls.

In a study conducted in Sri Lanka, U A S K Ediigirisinhe examined the link between LED lighting system and its effectiveness in terms of people performance. Such included mood, energy savings, visual comfort, and visual health [8]. The study obtained a sample from a TVET which used T8 fluorescent lamps and a commercial bank using LED lights. The results indicate that LED lighting contributed in the saving of to up to 40 % of the energy consumption which was the lowest among artificial lighting. The color temperature was recorded within the range of 6000K- 6500K [8]. The results showed that more than 65% of the population has given positive feedback on human performance factors like visibility, mood effect, visual health, color appearance, work performance, and the preference level for LED lighting conditions. The study, however, only compares the performance of T8 fluorescent lamps and LED lightings that were available at that time.

2.3 Illuminance Level

There are a number of studies that have examined the illuminance level of lighting fixtures and the quality of lighting in various commercial buildings. Most of the studies found were conducted in different buildings with some of them being shopping malls. The review of the studies below focuses on a number of studies conducted with research gaps being identified.

Yong conducted a study to evaluate the luminance and vertical-eye illuminance thresholds for the visual comfort of occupants in offices which are day lit in San Antonio, Texas [9]. One hundred and twenty different lighting conditions were tested. Illuminance levels were measured both vertically and horizontally. Data was analyzed both quantitatively and qualitatively. The results indicate that the vertical eye illuminance of 351.6 lux shows a large discrepancy from the previously defined visual comfort thresholds of 875 lux and 2,000 lux [9]. The study however was conducted on a closed office space with a set of subjects that was limited in number undertaking computer based office tasks.

Husini, Yazit, Arabi, Ismail and Jaafar conducted a study that investigated the fluctuation level of the illumination and the impact of daylight in an optimal performance zone. The study enacted a qualitative survey to determine the perceptions of the occupants towards visual comfort and glare level. The study employed questionnaire in the data collection. The results indicate that more than 50% of the occupancy in an office room that had a wall to wall ratio of 70% had an effect on the daylight zone [10]. The study also indicates that the acceptable level of illuminance was not achieved. The study focuses on a single office space while current research examines the common areas in shopping malls.

2.4 Color Rendering Index of the Fixtures

Various studies have observed the relationship between quality of lighting and the coloring index of the lighting sources. The review of the studies below focuses on a number of studies conducted with research gaps being identified.

In a study conducted in the Republic of South Korea, Lee and Cecilia investigated the color rendering index recommendation for LED lighting in spaces that needed better color rendition [11]. The study used four LED spectra, (CIE) Ra 76, 79, 83 and 84. The study used Fidelity and Gamut

Index in order to complement the weakness of CIE Ra. The study sampled 194 participants who evaluated retail-related tasks [11]. The participants were issued with questionnaires where a seven-point Likert scale was used where the answers received were converted to -3 to 3 with 0 being the median value. The study employed a descriptive and inferential analysis of the data. The findings of the study show that CIE Ra had impact on brightness perception, preference, arousal and liveliness of individuals. The results further indicate that LEDs that have a CIE Ra of less than 80 received higher scores of brightness perception, preference, arousal and liveliness [11]. The study, however, provides a small range of study that limits the CIE Ra recommendations.

Szabo et al. conducted a study of different lighting sources to determine the preferred color rendering index of lighting sources by shops in Germany. The study employed a series of experiments on color preferences which was conducted on a laboratory. The findings of the study indicate the observers preferred the sources of light that could produce a more conveyed appearance of objects in shops. The spectrum of preference was the one that possessed a high FCI value although its color rendering index was too low [12]. The study focused on appearance of objects in shops, while the current study examines lighting quality in common areas' of shopping malls.

Lin et al. conducted an evaluation experiment which aimed at comparing the color preference among three lighting sources in different lighting applications in China [13]. The study employed a series of psychophysical experiments on color preferences which was conducted on a laboratory. The experiment sampled 24 observers aged between 20 and 34 years. The findings of the study indicate that the color preference of the observers varied across the different lighting applications [13]. The study however did not provide a single measure for the general use of the consumer and also did not provide detailed information in terms of color preference.

Hou et al conducted a study to investigate the impact of the quality of light on the emotion and work performance [14]. The study used the Ra Index and Gamut Index to assist the Ra in order to evaluate the relationship between the quality of light and emotions on work performance. A total of 10 participants, both male and female were randomly selected of ages 18-29 years with no eye diseases. The results were analyzed using variance analysis (ANOVA). The experiments were conducted on a laboratory which was set up as an office. The findings of the study indicate that participants were most likely to produce positive emotions when Ga = 120 and Ra = 80 [14]. The study however was conducted on the laboratory which limits spatial referencing

2.5 Luminous Efficacy of the Fixtures

There are a number of studies that have looked into the relationship between the luminous efficacy of lighting sources and the quality of lighting in various commercial buildings. The review of the studies below focuses on a number of studies conducted with the identification of research gaps.

Albu et al. conducted an analysis to determine the luminous efficacy and the quality of light sources of various office buildings [15]. The study used measurements of the power quality and luminous efficacy which were conducted both with and without dimming of the light sources to ensure the two characteristics of light sources were established. The number of luminaires in the room was simulated using DIALux. The results indicated that LED luminaires possess a substantial luminous efficacy as compared to other lighting used in office buildings [15]. The study however was conducted on office buildings while the current study examines common areas of shopping malls

Giu et al. conducted study to quantify the spectral and luminous efficacy of pc-white LEDs and high-power colored LEDs under CCR and PWM dimming schemes [16]. The study conducted an experimental study to quantify the change where LEDs were suspended at the center of a thermal chamber one at a time. The results indicate that the luminous efficacy was always higher for CCR dimming at dimmed level regardless of the type of the LED [16]. The study was, however, conducted on thermal chambers limiting the spatial requirements for referencing purposes.

2.6 Dimming Compatibility

Various studies have observed the relationship between quality of lighting and the spacing of fixtures. The review of the below studies focuses on a number of studies conducted with research gaps being identified.

Wang et al conducted a study on the implementation of improved power factor AC of LEDs rectifier and LED string [17]. which is controlled and uncontrolled a low switching-frequency metal-oxide semiconductor field effect transistor. The study was achieved through experiments by creating prototypes of the new circuit. The findings of the experiment indicate that the new circuit retains the feature of TRIAC-dimmer compatibility similar to AC-LED lamp for it to fully replace the incandescent bulb without necessarily having to change the lamp holder [17]. The study however proposes a TRIAC dimmer which is controlled by a traditional switch.

Giu et al. conducted study to quantify the spectral and luminous efficacy of pc-white LEDs and high-power colored LEDs under CCR and PWM dimming schemes [16]. The study conducted an

experimental study to quantify the change where LEDs were suspended at the center of a thermal chamber one at a time. The results indicate that the luminous efficacy was always higher for CCR dimming at dimmed level regardless of the type of the LED [16]. The study was, however, conducted using experiments which may exhibit perfect conditions as opposed to actual buildings.

2.7 Luminance Distribution

There are a number of studies that have looked at the association between quality of light and the luminance distribution of lighting fixtures. Most of the studies found were conducted in different commercial buildings with some of them being shopping malls. The review of the studies is focused on a number of studies conducted with research gaps being identified.

Hong et al studied the lighting environment in public spaces of in eight different shopping malls in China [18]. The study employed interview-based qualitative research focusing on people's evaluations of the quality of lighting in the shopping mall center. The study also investigated the relation between the amount of satisfaction of the lighting environment and metrics based on luminance in spaces that experienced both day and artificial lighting. The results showed that there was similarity in the evaluations amongst various groups of different backgrounds and the amount of time spent in shopping malls. The results also suggested that for shopping mall centers, the optimal Lmean value is1000 cd/m2 for a mixed day lighting and artificial lighting environment [18]. The study also recommended 75 cd/m2 as the Lmean value for an artificial lighting environment [18]. The study however is focused mainly on evaluations based on the different points of view of the users.

Kim and Koga conducted two experiments to determine the impact of the background luminance on discomfort glare [19]. The study conducted two tests, visual sensitivity and discomfort glare using Goldman perimeter and glare testing instrument respectively. The results of the experiment indicate the luminance of the immediate background of the source determines the luminance of the discomfort glare and as opposed to the average background luminance as indicated in previous studies [19]. The study however did not provide the range of the local background that affects the visibility and glare.

2.8 Summary of Research Gaps

The table 2.1 gives a summary of the gaps in the reviewed literature

Table 2.1 Research Gaps

Author	**Title**	**Findings**	**Research Gap**	**My Approach**
Muneeb [6]	Gained energy efficiency in commercial setup through replacing conventional lights with energy saving lights	The results further indicated that 2.240 KW load of conventional lighting was replaced by 1.188KW of LEDs which saved up to 47% of the consumption of electrical energy.	The design used a uniform lighting scheme.	Different areas of the commercial plaza should have different lighting recommendations
Yong [9]	Luminance and Vertical Eye Illuminance Thresholds for Occupants' Visual Comfort in Daylit Office Environments	The results indicate that the vertical eye illuminance of 351.6 lux shows a large discrepancy from the previously defined visual comfort thresholds of 875 lux and 2,000 lux.	The study however was conducted on a closed office space with a limited number of subjects	The number of subject should be increased for the purposes of validating the findings
Lee and Cecilia [11]	Color rendering index recommendation for LED lighting in spaces that needed better color rendition	The findings of the study show that CIE Ra had impact on brightness perception, preference, arousal and liveliness of individuals.	The study, however, provides a small range of study that limits the CIE Ra recommendation	A wider range of study should be used to improve accuracy of the CIE Ra
		The study indicates	The study however proposes a TRIAC dimmer which is	With the current

Wang et al [17]	A study and implementation of improved power factor AC of LEDs.	that the new circuit retains the feature of TRIAC-dimmer compatibility similar to AC-LED lamp for it to replace the incandescent bulb without changing the lamp holder	controlled by a traditional switch	technology there are LEDs much more advanced dimmer controls
Albu et al [15]	Luminous and power quality analysis of office building light sources	The results indicated that LED luminaires have a greater luminous efficacy as compared to other luminaires used in office buildings	The study focuses on office buildings while the current study examines common areas of shopping malls	The results are limited to indoors while common areas may include outdoor parking and driveways
J. Hong et al [18]	An evaluation of the lighting environment in the public space of shopping centers	The results show that the optimal Lmean value is 1000 cd/m2 for a mixed day lighting and artificial lighting environment, and 75 cd/m2 as the recommended Lmean value for an artificial lighting environment	The study however is focused mainly on evaluations based on the perception of users.	Other factors such as non-visual effects of light should be put into consideration

2.9 Conceptual Framework

A conceptual framework puts forward number of ideas or variables that are essential in understanding a particular area of study. It is of importance that the reliability and skepticism of the variables are kept under close scrutiny [20]. The conceptual framework below puts in context the relation between the independent and dependent of the design variables.

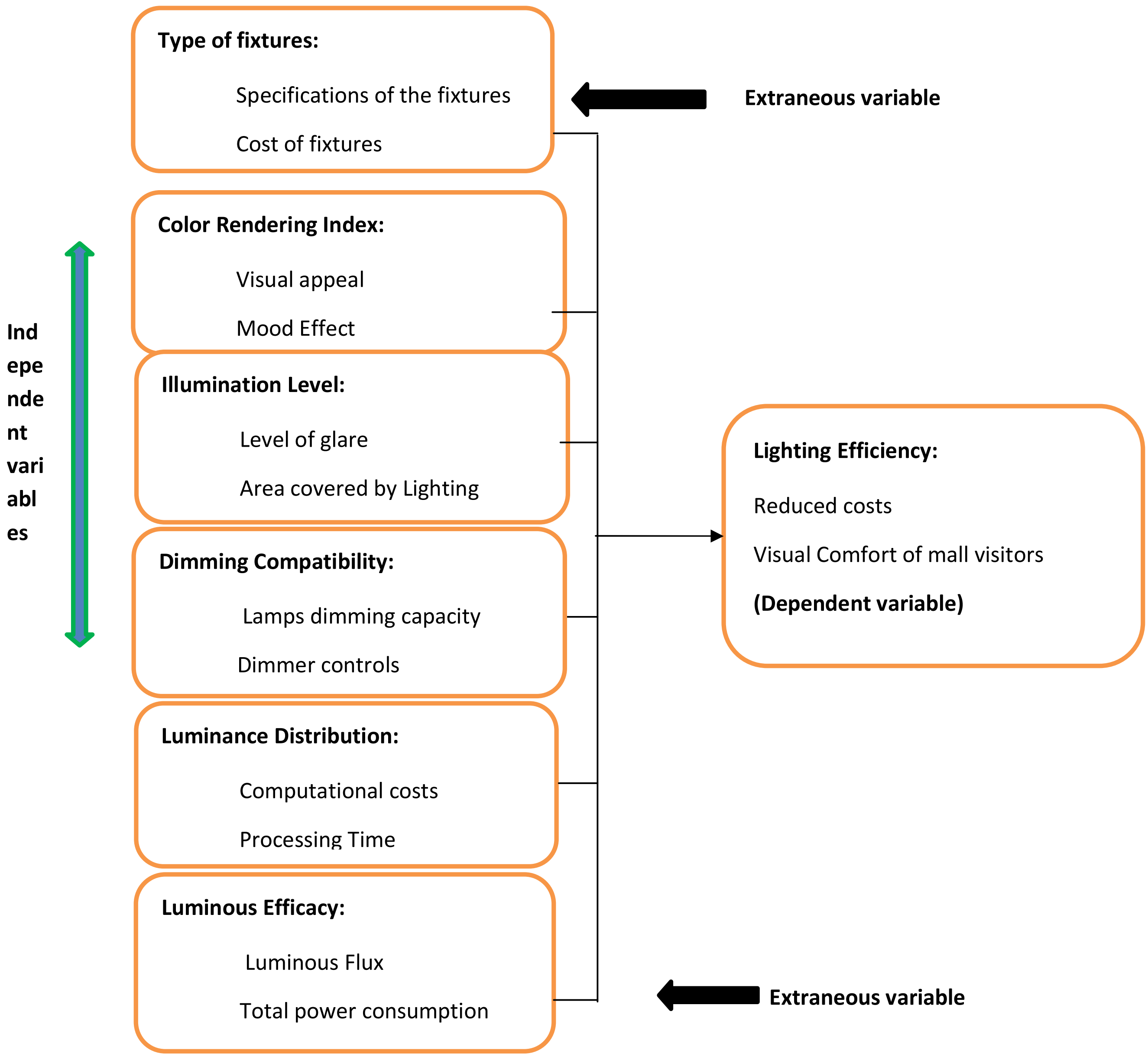


Figure 2.1 Conceptual Framework

The conceptual framework presented displays the relation between the determinants and the quality of lighting. The design has hypothesized the key determinants as type of fixtures, color rendering index of the lighting, illumination level, the dimming compatibility of the fixtures, and the luminance distribution. The dependent variable, which is the quality of lighting is to be assessed by; visual comfort of mall visitors, satisfaction levels, and growth in the number of mall users.

Table 2.2 Operationalization of Variables

Variable	Definition	Measurable Indicators
• **Types of fixtures**	An electric device which has an electric lamp that produces illumination	• Specification of the chosen fixtures • Cost of the chosen fixtures in the market • Number of luminaires per given area
• **Illumination Level**	The amount of light that is measured on a surface	• Reflection level of surfaces • Light Intensity
• **Color rendering Index**	The ability of a source of light to reveal actual colors of objects in comparison to natural light	• Visual Appeal • Mood Effect • Color Appearance
• **Dimming Compatibility**	The ability of light sources to lower the intensity of light output	• Color Temperature • Energy saved
• **Luminous Efficacy**	The ability of light to emit visible light given a certain amount of power	• Electrical power consumption
• **Luminance Distribution**	The measure of light travelling in a given direction	• Visual acuity • Distribution of brightness
• **Quality of Lighting**	The effectiveness and accuracy of light sources	• Visual comfort of mall visitors • Growth in the number of mall visitors • Satisfaction Level

2.10 Chapter Conclusion

Quality of lighting is important in determining the business performance of shopping malls. This can be achieved through the use modern technology like LED luminaresin order to achieve energy efficiency gains. Factors such as types of fixtures in terms wattage,CRI, dimming compatibility and luminance distributions play a crucial role to ensure better lighting quality and reduction of energy consumption.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter has explained in-depth the methodology that was used in this research project. It has described in detail the lighting system design and the simulation of the lighting system using DiaLux. The case study was of a shopping mall which has six identical floors (Mini Mall - Kisumu).

3.2 Lighting System Design

This lighting system 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 locations, how to minimize glare, maximizing light uniformity, lamp replacement, energy and cost reduction

3.2.1 Selection of Site

The design is new for the common areas of a shopping center (Mini Mall - Kisumu). The common areas include selected in this research project were corridors, washrooms, staircases, and sitting areas. The shopping mall lights operate for 8 hours. Since all the six floors are identical the design simulation was done for one floor which is applicable to all the other floors. The height of mounting the luminaires was 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 3.7.

Table 3.1 Measurement of each Section 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)

3.2.2 Selection of Light Fixtures

It is important to minimize lighting expenses at the same time maximizing the quality of lighting in common areas of shopping malls. When selecting the lighting options, it is important to compare the available sources in the market in terms of lumen output, life span, and cycle of maintenance, CRI, and distribution of lighting.

Table 3.2 shows a comparison between the traditional lamps and LEDs.

Table 3.2 Comparing Traditional Sources of Light with LEDs [21]

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 the table above, it is evident that LEDs are the most efficient light fixtures in terms of costing and energy consumption. The design proposes the replacement of the existing light sources for the washrooms, hallways, entrance, staircase and the sitting area with LED luminaires as shown in table 3.2.

Table 3.3 Selection of Light Fixtures for each Section

Common Area	Existing Light Source	Replacement Lamp
Corridor	Tornado T3 (in cover globes)	StoreFlux gen3 rim GD601B 1 xLED17S/840 WB
Washrooms	Tornado T3 (in cover globes)	V-TAC 20W LED Downlight SAMSUNG CHIP Movable 3000K
Staircase	Tornado T3 (in cover globes)	StoreFlux gen3 rim GD601B 1 xLED17S/830 MB
Entrance/Sitting Area	Tornado T3 (in cover globes)	ST770T StyiDEvo x LED49S/840

Figure 3.1 shows the existing tornado T3 (in cover globe) and the new lamp replacements in the common areas of the shopping mall.

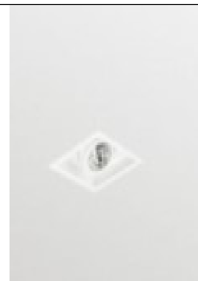
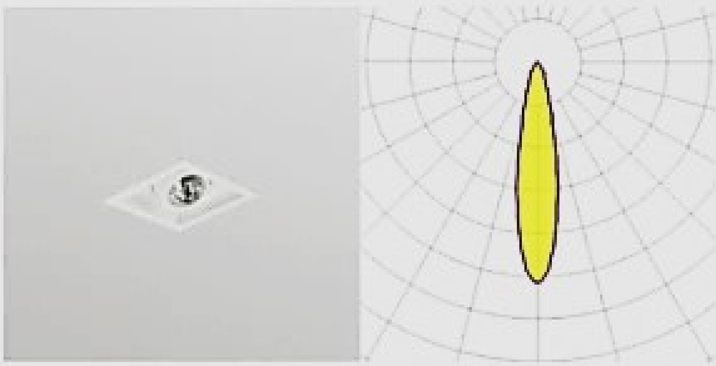
Existing Fixtures in Common Areas	**Corridor Replacement**	**Washroom Replacement**	**Staircase Replacement**	**Entrance Replacement**
				
Tornado T3 (in cover globe)	StoreFlux gen3 rim GD601B 1 xLED17S/840 WB	V-TAC 20W LED Downlight SAMSUNG CHIP Movable 3000K	StoreFlux gen3 rim GD601B 1 xLED17S/830 MB	ST770T StyiDEvo x LED49S/840 MB

Figure 3.1 Lamp Replacement in Each Section

3.2.3 Properties of the Selected Luminaries

Philips

GD601B StoreFlux gen3 rim GD601B 1 xLED...

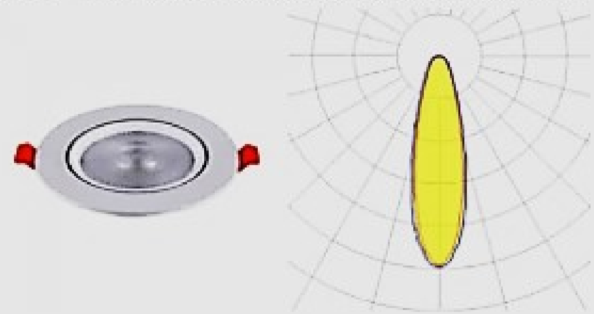


Size (L x W x H)	179 x 179 x 103 mm
Mounting mode	Ceiling recessed
Equipment	1 x General service incandescent lamp 0W
CCT	3000 K
CRI Ra	99
Total flux	1709 lm
Total power	14.3999996185303 W
Luminous efficacy	119 lm/W

Figure 3.2 Lighting and Mounting Properties for Staircase

V-TAC

842 V-TAC 20W LED Downlight SAMSUNG C...

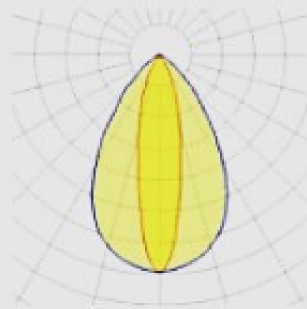


Size (D x H)	170 x 30 mm
Mounting mode	Ceiling mounted
Equipment	1 x LED 20W
CCT	3000 K
CRI Ra	80
Total flux	1800 lm
Total power	20 W
Luminous efficacy	90 lm/W

Figure 3.1 Lighting and Mounting Properties for Washroom

Philips

ST770T StyliD Evo ST780T 1 xLED49S/840...

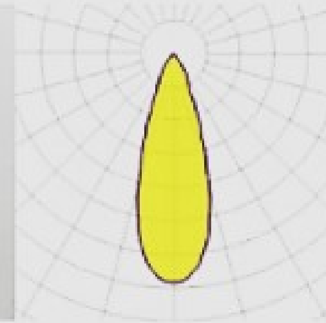


Size (D x H)	120 x 146 mm
Mounting mode	Ceiling mounted
Equipment	1 x General service incandescent lamp 0W
CCT	3000 K
CRI Ra	99
Total flux	5192 lm
Total power	40 W
Luminous efficacy	130 lm/W

Figure 3.1 Lighting and Mounting Properties for Entrance/Sitting Area

Philips

GD601B StoreFlux gen3 rim GD601B 1 xLED...



Size (L x W x H)	179 x 179 x 103 mm
Mounting mode	Ceiling recessed
Equipment	1 x General service incandescent lamp 0W
CCT	3000 K
CRI Ra	99
Total flux	1803 lm
Total power	14.3999996185303 W
Luminous efficacy	125 lm/W

Figure 3.1 Lighting and Mounting Properties for Corridor

Comparison for CRI

Table 3.4 Comparing CRI of the Sources of Light

Common Area	Recommended CRI for Section	CRI for Existing Light Source	CRI for Replaced Light Source
Corridor	>80	80	99
Washrooms	>80	80	80
Staircase	>80	80	99
Sitting area	>80	80	99

Luminous Efficacy

The efficacy of the lighting design can be determined by measuring the total lumens of the luminaire by watts in order to determine the overall efficiency of the lighting system. The selected lamps have an efficacy of 125 LPW, 90 LPW, 119LPW and 120 LPW respectively

Table 3.5 Luminous Efficacy of the Fixtures

Common Area	Fixture	Luminous Efficacy
Corridor	StoreFlux gen3 rim GD601B 1 xLED17S/840 WB	125 LPW
Washrooms	V-TAC 20W LED Downlight SAMSUNG CHIP Movable 3000K	90 LPW
Staircase	StoreFlux gen3 rim GD601B 1 xLED17S/830 MB	119 LPW
Entrance/Sitting Area	ST770T StyiDEvo x LED49S/840 MB	120 LPW

Dimming compatibility

The selected fixtures can be dimmed in order to operate at much lower light levels. The fixtures can be dimmed using drivers smoothly to almost zero light with very little or even no color shift. However, with time, the light fixtures become less efficacious due to dimming which is caused by driver losses as a result of energy use.

Illuminance Level

Table 3.6 Illuminance Level [22]

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

Correlated Color Temperature

Table 3.7 Comparison of the Color Temperature of Light Sources

Common Area	Recommended CCT for Section	CCT for Existing Light Source	CCT for Replaced Light Source
Corridor	3000K – 5000K	2700K	3000K
Washrooms	2700K – 3000K	2700K	3000K
Staircase	3000K – 5000K	2700K	3000K
Entrance/Sitting area	3000K – 5000K	2700K	3000K

3.2.3 Layout Design

The number of Luminaires can be calculated using the Lumen Method or by simulation using Dialux Software.

$$N = \frac{E \times A}{F \times n \times UF \times MF}$$

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 [23].

Calculations of the illumination, E, can be done using either inverse square law or lambert's cosine law. Factors to consider include:

Using Inverse Square Law:

$$Illuminance, E = \frac{I}{d^2}$$

Where I is the luminous intensity and d is the distance between the surface and the source.

Using Lambert's Cosine Law:

$$Illuminance, E = \frac{1}{h^2}\, cos^3\Theta$$

Where h is the height of the source from the surface in meters and Θ is the angle of inclination of the surface.

The UF from the data of the manufacturer or calculated using the formula:

$$Utilization\ Factor = \frac{Total\ lumens\ reaching\ the\ working\ plane}{Total\ lumens\ from\ source}$$

Determine the MF factor using the formula:

$$Maintenance\ Factor = \frac{Illumination\ under\ normal\ lighting\ conditions}{Illumination\ when\ everything\ is\ clean}$$

In order to achieve the recommended illumination level for each common area, DiaLux simulation was used to determine the number of luminaires needed and the layout design for each section. Each common area has a different lighting recommendation; therefore, the number of luminaires varies in each section.The mounting height chosen for each common area used in simulation was 3m. The maintenance factor for each common area was 0.80. The layout design for each common area was simulated using DiaLux. Each common area maintained the same layout design except for theentrance/sitting area whichhad different lighting points as per the simulation results.

Layout Design for Corridor

Figures 3.2.1, 3.2.2, 3.2.3 show the layout design for the corridor as simulated by DiaLux

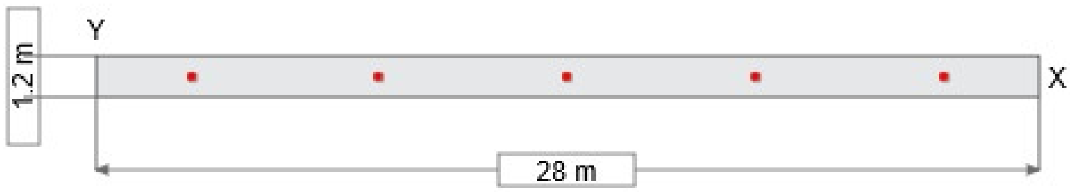


Figure 3.2.1 FloorPlan View of Corridor

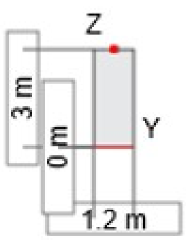


Figure 3.2.1 Front View of Corridor

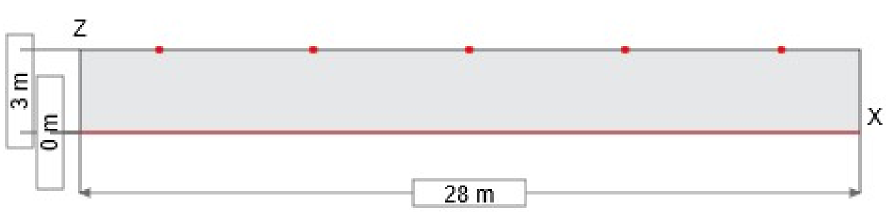


Figure 3.2.1 Side View From the Left of Corridor

Layout Design for Entrance/Sitting Area

Figures 3.2.4, 3.2.5, 3.2.6 show the layout design for the Entrance/Sitting Areaas simulated by DiaLux

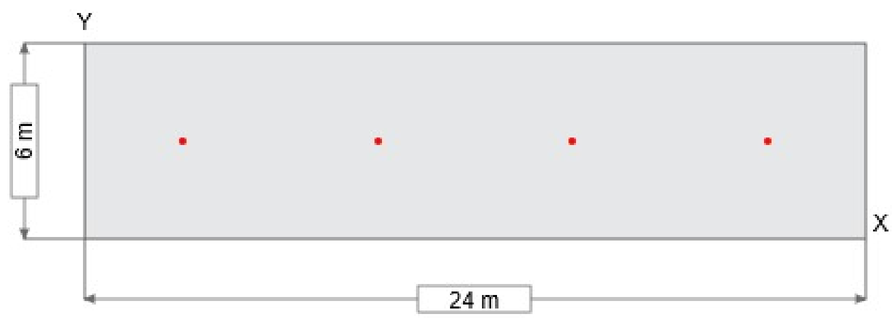


Figure 3.2.4FloorPlan View of Entrance/Sitting Area

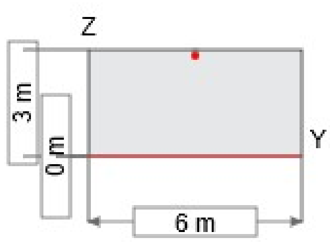


Figure 3.2.5Front View of Entrance/Sitting Area

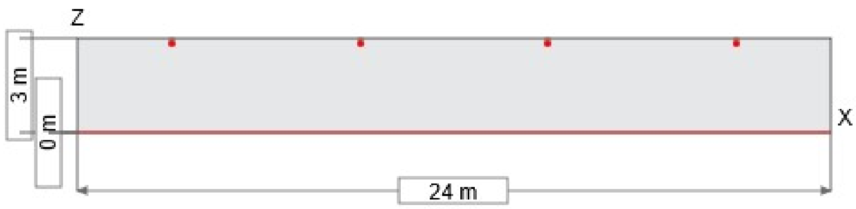


Figure 3.2.6 Side View From the Left of Entrance/Sitting Area

Layout Design for Washroom

Figures 3.2.7, 3.2.8, 3.2.9 show the layout design for the washroom as simulated by DiaLux

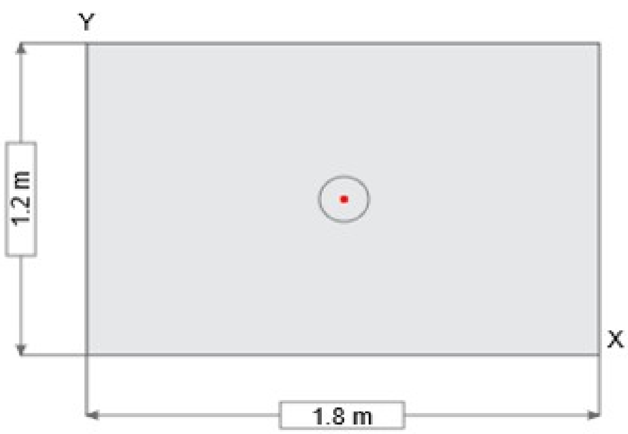


Figure 3.2.7 Floor Plan View of Washroom

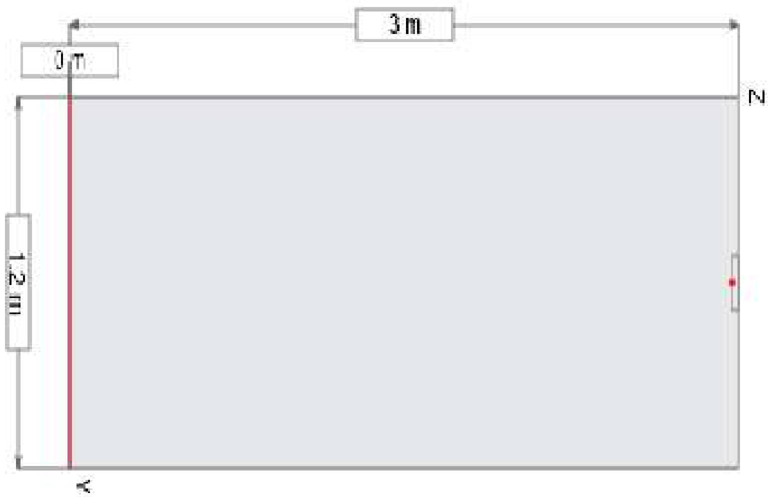


Figure 3.2.8Front View of Washroom

Figure 3.2.9 Side View from the Left of Washroom

Layout Design for Staircase

Figures 3.2.10, 3.2.11, 3.2.12 show the layout design for the staircase as simulated by DiaLux

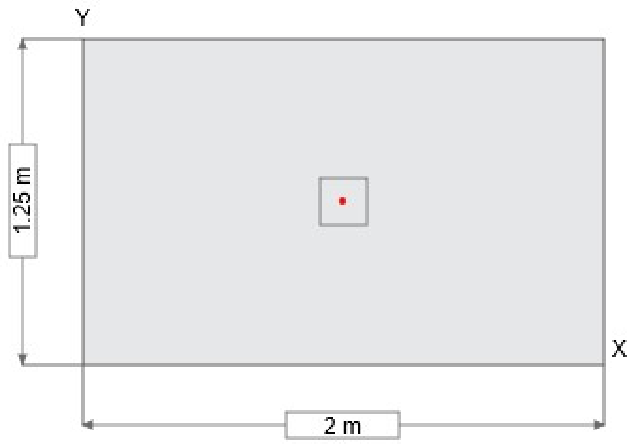


Figure 3.2.10FloorPlan View of Staircase

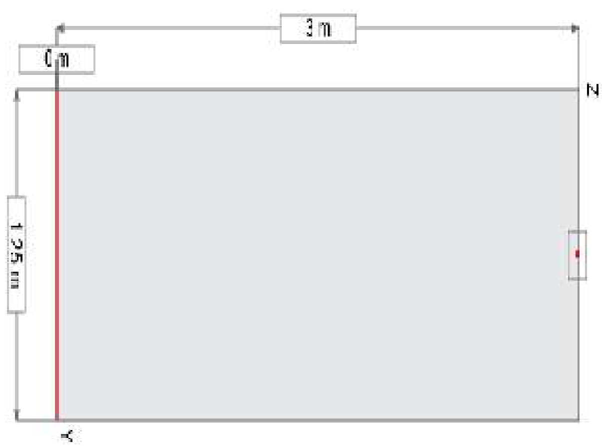


Figure 3.2.11Front View of Staircase

Figure 3.2.12 Side View from the Left of Staircase

Table 3.8 Comparison of the existing Tornado T3 with the chosen LED Luminaires

Type of Light	**No. of Luminaires**	**Total Wattage**	**Units 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 StyiDEvo x LED49S/840 MB	4	0.16KW	0.16 x 8 = 1.28

3.2.4 Installation of Hardware

The load of lighting at the mall is 2.5428 KW which is substituted by the lighting load of 1.4368KW from the LED luminaires. The mounting height used in the design of the LED luminaires is 3m from the floor.

3.2.5 Energy Reduction Calculations

LED luminaires reduces the energy consumptions without giving up the quality or levels of lighting. In the new design, a lighting load of 2.5428KW of the existing lights will be replaced by a lighting load 1.4368KW of LED lighting which results to a 43.5% reduction in energy consumption.

3.2.6 Cost Reduction Calculations

Despite the cost of installation being quite high, LED reduces lighting expenses in due to low consumption of energy. The shopping center lights in common areas operate for 8 hours every day, and the rate of electricity for each unit taken is Ksh13.5

The cost of electricity consumed by the existing T3 bulbs per year = $20.3424 \times 13.5 \times 365 =$ 100,237.176

The cost of electricity to be consumed by the new LED lighting design= $11.5624 \times 13.5 \times 365 =$ 56,973.726

Estimated cost savings per year = 43,263.45

Table 3.9 Summary of Consumption Costs

Information	Amount (KES)
Current cost of consumption	100,237.176 (C)
New cost of consumption	56,973.726 (P)
Estimated cost savings per year	43,263.45 (C-P)

Initial Investment on the existing lighting design = KES 86,500

Investment for the new lighting design = KES130,100

Difference in the cost of installation = KES43,600

Estimated payback period = 43,600/35,824.896 = 1.2 years

Table 3.10 Summary of Investment costs

Information	Amount (KES)
Initial Investment Cost	86,500 (N)
Investment cost for lighting design	130,100 (Y)
Difference in cost of Installation	43,600 (Y-N)
Estimated Payback Period	43,600/35,824.896 = 1.2 years (Y-N) / (C-P)

3.2.8 Discomfort Glare

One important factor in any lighting scheme is that any lighting design should be comfortable in terms of different visual perspectives. It is important to note that visual discomfort affects mall users as it affects visual comfort in a physical and psychological manner, and in most cases involves developing unconscious fatigue and neck and shoulder strains. The recommended UGR values for the common areas range from 22-25. The selected light fixtures have a UGR value of 22-25.

3.2.9 Emergency Lighting

The chosen luminaires are battery backed; high efficiency is guaranteed and the charging time is 36 hours. It provides a seamless solution as they switch on automatically in cases of power outages and can last up to a working time of 3 hours.

3.2.10 Testing and Validation

The illumination level, CRI, level of glare, and the uniformity of lighting will be measured on test points to measure the improvement in the quality of lighting level after installation. The amount of electric energy consumption will be monitored after a month and compared with previous monthly consumption levels. The actual cost of installation will be compared with the initial cost of installation and the fixtures will be checked for any breakages or faults.

3.3 Summary of Methodology

Figure 3.6 shows a Flowchart indicating the strategy used in the methodology of the new lighting design in this study

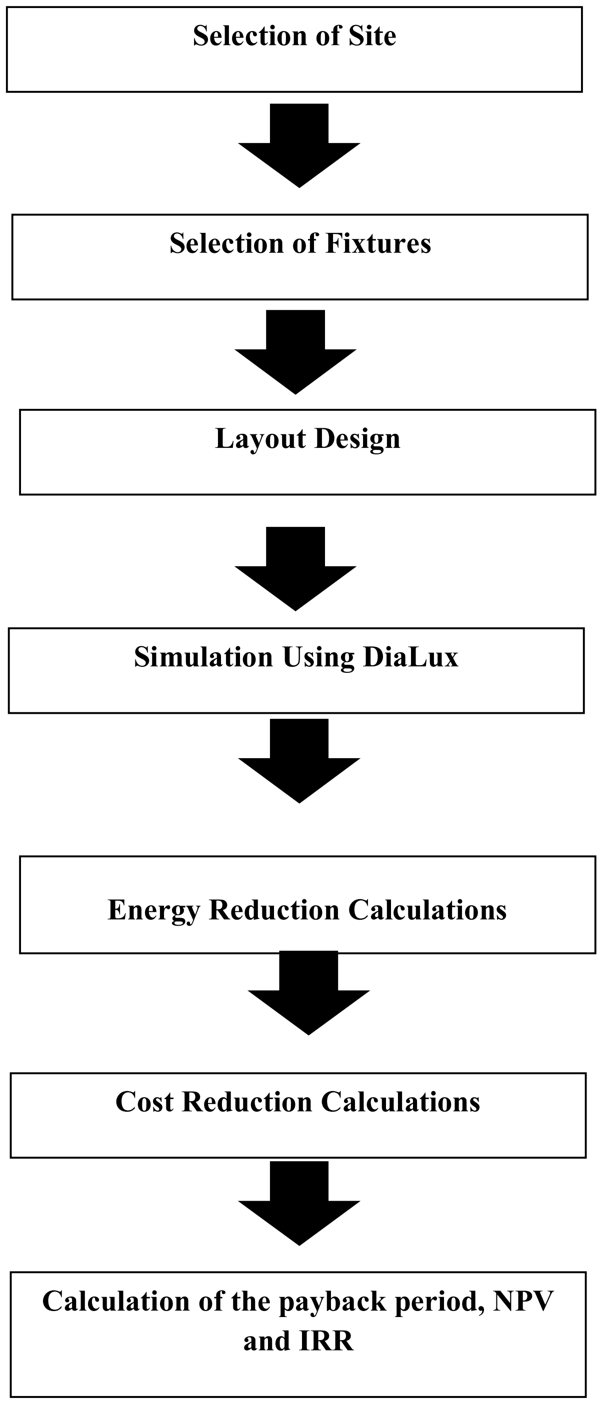


Figure 3.6 Flow Chart showing the Lighting Design Process

3.3 Assumptions

The lighting design process is carried out on the following assumptions:

i. The LED luminaires selected for each common area have the same orientation since they are the same for each section.
ii. The LED luminaires are to be arranged in a uniform array and have the same mounting height
iii. The lighting distribution selected for each of the common areas is expected to achieve optimum lighting levels

3.4 Chapter Conclusion

In order to achieve optimum lighting level and energy savings, a well thought design process must be put in place. The lighting design in this research study was simulated using DiaLux software to determine the number of luminaires in the layout design. The energy efficient gains and payback was also calculated to determine whether the design was viable or not. A 43% energy savings was achieved and a payback period of 1.2 years with positive NPV and IRR of 13% was achieved which validate the results of this study.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

The fourth chapter of this project focuses on the presentation and analysis of the simulated and calculated data of the new lighting system design.

4.2 Simulated Results for the Number of Luminaires needed and Lamp's Lumen.

Table 4.1 shows the tabulated and simulated data for the lumen of the fixtures and the number of luminaires that are required for each selected common area.

Table 4.1 Lamp's Lumen and Required Luminaires

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

The relationship between the lumen of the fixtures and the area of the common area is shown in Figure 4.1

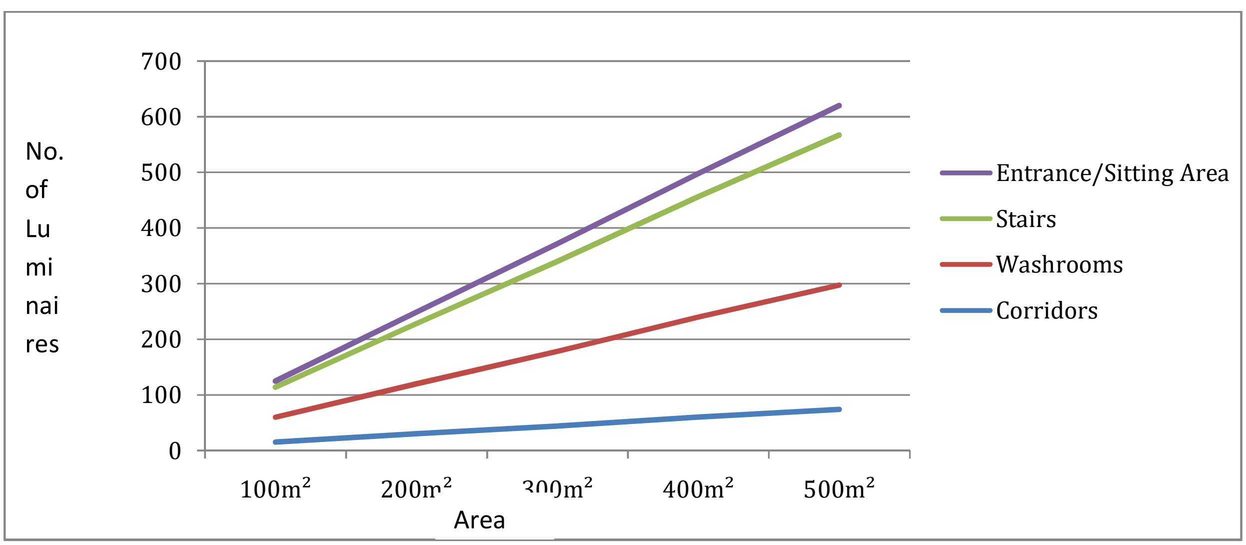


Figure 4.1 Relationship between Area and Number of Luminaires

Table 4.1 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 in Figure 4.1. The lumens of the luminaires are 1803lm, 1800lm, 1709lm and 5192lm 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.

4.3 Replacement of Luminaires

The selected luminaires in the washrooms, staircase and corridors can be implemented in the already existing light points, except for the for the entrance/sitting area where the layout design changes since the minimum requirements for the illuminance level will not be met if implemented in the existing light points.

Figures 4.2, 4.3, 4.4 and 4.5 give a summary for the simulated results using Dialux.

Replacement of Luminaires for the Corridors

Figure 4.2 shows the simulated results for the replacement of luminaires in corridors using Dialux. Since there are 6 floors with two corridors, one side having the above specifications we multiply 12 by 5 to get the total number of fixtures.

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 4.2: Simulated Results for Corridors

Replacement of Luminaires for the Washrooms

Figure 4.2 shows the simulated results for the replacement of luminaires in washrooms using Dialux. Since there are 6 floors with two washrooms on each floor, we multiply 6 by 2 to get the total number of fixtures.

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

Figure 4.3: Simulated Results for Washroom

Replacement of Luminaires for the Staircases

Figure 4.2 shows the simulated results for the replacement of luminaires in staircases using Dialux. Since there are 6 floors with two chests of stairs on each floor, we multiply 1 by 12 to get the total number of fixtures

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 4.4: Simulated Results for Staircase

Replacement of Luminaires for the Entrance/Sitting Area

Figure 4.2 shows the simulated results for the replacement of luminaires in Entrance/sitting Area using Dialux

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 4.5: Simulated Results for Entrance/Sitting Area

Table 4.2 shows a data worksheet for the replacement of the Luminaires. It indicates the specifications of the common areas, the estimated costs and the savings that can be attained through replacing the existing design with the new lighting design.

Table 4.2 Lamp's Lumen and Required Luminaires

Initial Design					
Common Area	*Area*	*Life Rating*	*Units*	*Price*	*Lamp Efficacy*
Corridor	403.2m²	8000hours	60	45000	70LPW
Washrooms	25.92m²	8000hours	12	9000	70LPW
Staircase	30m²	8000hours	6	4500	70LPW
Entrance/Sitting area	144m²	8000hours	1	750	70LPW
No. of Lamps per Luminaire	1				
Electric Input	2.5428KW				
Cost of Labor	Ksh. 26,000				
New Design	*Area*	*Life Rating*	*Units*	*Price*	*Lamp Efficacy*
Corridor	403.2m²	30000hours	60	21,600	125 LPW
Washrooms	25.92m²	50000hours	12	40,800	90 LPW
Staircase	30m²	50000hours	12	15,200	119 LPW
Entrance/Sitting area	144m²	50000hours	4	22,500	120 LPW
No. of Lamps per Luminaire	1				
Electric Input	1.4368KW				
Cost of Labor	Ksh. 30,000				

4.4 Layout of the Luminaires and Spacing

Table 4.3 shows the number of luminaires in each common area as simulated by DiaLux

Table 4.3 Layout and Spacing

Common Area	**Area (m²)**	**Ratio of Length and Width**	**Number of Luminaires (Units)**
Corridors	403.2m²	15:2	60
Washroom	25.92m²	3:2	12
Staircase	30m²	2.5:2	12
Entrance/Sitting area	144m²	1.3:1.06	4

When the spacing of Luminaires is done in a proper way, the ideal number of luminaires is determined as well as maximizing the ability to light the area. In the corridors, the lights are new to be installed 2 feet from the wall 15ft apart. The staircases and the washroom will be installed 2ft and from the wall since only 1 lamp is installed in both areas, 3m and 2.5m apart respectively. At the entrance/sitting area, the lights will be installed to 4ft apart to ensure maximized and good quality lighting.

4.5 Quality of Lighting

The new design identifies different lighting parameters such as CCT, Ra and illuminance level which have a significant impact on the quality of lighting. A CRI index of 80 is ideal for visual comfort of mall users. A CCT>3000K is recommended for creating an ambient environment to mall users and illuminance level for each section was selected according to the recommended level for each section.

The selection of fixtures used in this new design was carefully selected by putting the above parameters into consideration. It was done so to ensure the quality of lighting is optimized to ensure the visual comfort of mall users. All the selected fixtures had a Ra >80, CCT> 3000K to ensure an ambient environment and visual comfort to mall users. The illuminance level for each common area was considered using the recommended level of illuminance for each section.

Using a Likert scale where 0 represents very bad lighting conditions and 10 represents excellent lighting conditions, the visual comfort of mall users can be evaluated with respect to the given parameters.

4.6 Technical Validation

In order to validate the technical part of this project, Dialux software was used. The different common areas were modeled and the various lighting levels expected to be achieved after luminaire installation for each common area was simulated. 12 corridors were identified, 12 washrooms, 1 entrance/sitting area and 12 staircases.

Figure 4.6 shows a comparison between the calculated and estimated amount of electric energy consumption of the existing and the new lighting design in the various common areas.

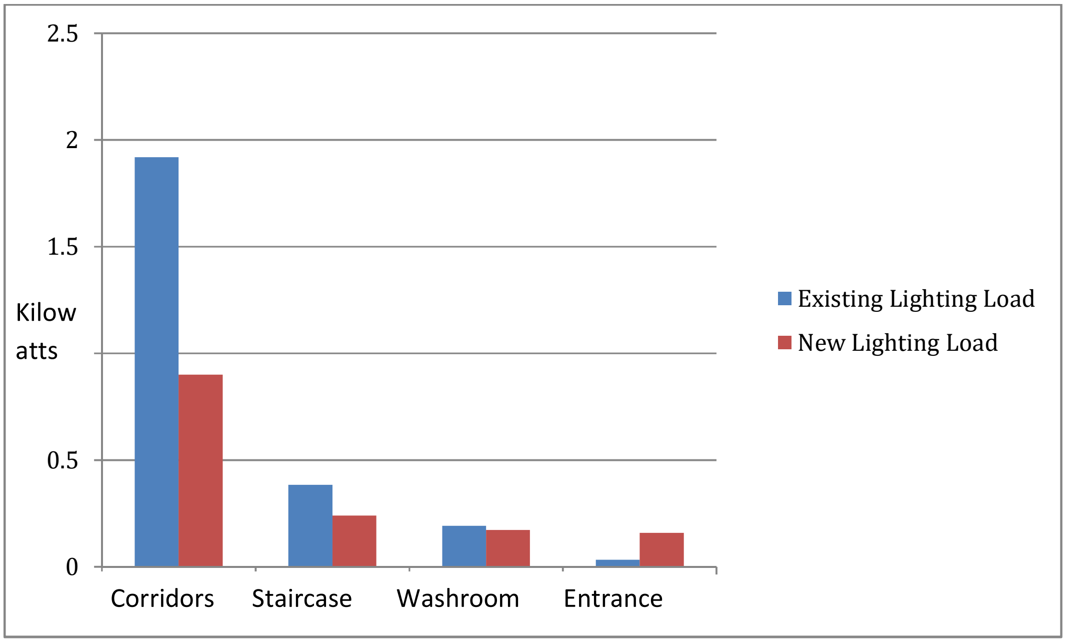


Figure 4.6 Comparison Between Existing and New Lighting Load

From figure 4.6, we can observe that there is a significant decrease in the amount of electrical energy usage with the implementation of the new 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. The simulation results validate the technical suitability of the selected luminaires for each common area of the shopping mall.

4.6 Economic Validation

Table 4.4 shows the amounts of cost reduction that can be achieved with the replacement of the existing lighting design with the new lighting system design. The new design aims at improving the quality of lighting in the common areas. Apart from improving the quality of lighting, the new lighting design can be used to achieve energy saving thus a reduction in overall cost. The cost savings achieved from this design is up to 43% of the current electric energy consumption. Although the cost of implementing the new design is quite high, the estimated payback period of 1.2 years, positive NPV with an IRR of 13% validates the design.

Payback Period

Table 4.4 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

Net Present Value and IRR

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

NPV was calculated with i=0.08 (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 still there will be an additional gain. An 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.

4.7 Case Validation

The research study indicates a maximum savings of 43% through fluorescent to LED luminaires transition. The energy savings in this project was compared to other related studies that have replaced fluorescent lamps with LEDs in buildings as shown in table 4.5

Table 4.5 Minimall Energy Savings Vs Related Studies

Related Studies	% Energy Reduction
Muneeb et al.	47%
U A S KEdiigirisinhe	40%
Ghiisi et al.	45.5%
Avella et al.	47.5%

It is clear from table 4.5 the energy savings range was from 35-50% as indicated from related studies. This research study was expected to achieve the lighting performance within this range. The design has been able to achieve energy savings of up to 43% which validates the results of the study.

4.8 Chapter Conclusion

In this project, the total existing load of 2.5428KW is replaced by a lighting load 1.4368KW amounting to a 43% decrease in energy consumption levels. There is a significant decrease in the amount of electrical energy usage with the implementation of the new lighting design. The cost savings achieved from this design is up to 43% of the current electric energy consumption.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

Chapter five of this research project focuses on the summary of the project, the conclusions drawn from the lighting system design, and the recommendations for the lighting design within the shopping mall. This chapter further gives suggestions for further research work within commercial spaces.

5.2 Summary

The quality of lighting in shopping malls plays a great role in determining consumer behavior. However, in many instances, for expenses minimization, shopping malls seem to put more consideration on the consumption of electric energy at the expense of quality lighting. This project sought to examine the key factors that mall visitors deem necessary for fostering their mall experience and can overall predict the business performance of shopping centers. The project examined parameters such as illuminance level, discomfort glare, Color Temperature and the Color Rendering Index of selection of lighting fixtures.

The project adopted a technical approach with simulated data being considered for the research. The project relied on Dialux to generate the simulated data. The layout design was to determine the number of luminaires needed for each common area. The results indicate that the amount of electric energy consumption can be reduced by up to 43% with the implementation of the lighting system design. Findings note that although the cost of implementation, an estimated payback period of 1.2 years validates the economic suitability of the project.

5.3 Conclusions

The project's key objective to propose the replacement of the existing lighting system that used conventional lighting with LED luminaires was simulated successfully using Dialux. In addition, energy efficiency gains and lighting quality optimization were analyzed.

It is crucial to minimize electric energy consumption since it will reduce the monthly and annual expenses for electric energy consumption. It is also important to determine the ideal lighting conditions for different common areas to avoid any visual impairment that may arise due to poor lighting conditions. It can be concluded that a well implemented lighting system design that aims at optimizing the lighting quality in shopping malls can be cost effective and increase business performance in the long run.

Based on the simulated results obtained from Dialux, the ideal number of luminaires is determined based on the dimensions and lighting factors of the common areas. The cost of electric energy expenses will be reduced.

5.4 Recommendations

The new lighting 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, positive NPV and IRR of 13%. The project draws the following recommendations:

1) To ensure the lighting quality optimization, businesses should consider a number of factors such as the selection of luminaires and a suitable layout design.
2) To reduce the amount of electric energy consumption in the commercial sectors, businesses should strongly consider the option of switching from traditional lighting to current technologies like LED lighting
3) To increase the quality of lighting in shopping malls, businesses should consider looking at other parameters of LED lighting other than their potential light savings
4) Transition from fluorescent to LED is recommended to reduce costs and create a good ambience for Mini-mall visitors

5.5 Areas for Further Research

The research suggests that due to the high cost of electricity and unreliability of Kenya Power, further research work should be undertaken to examine how we can use solar energy in commercial spaces instead of relying on HEP. The research suggests that a further study should be conducted to examine the usage of technology such as motion sensors and to improve quality of light and control the usage of power.

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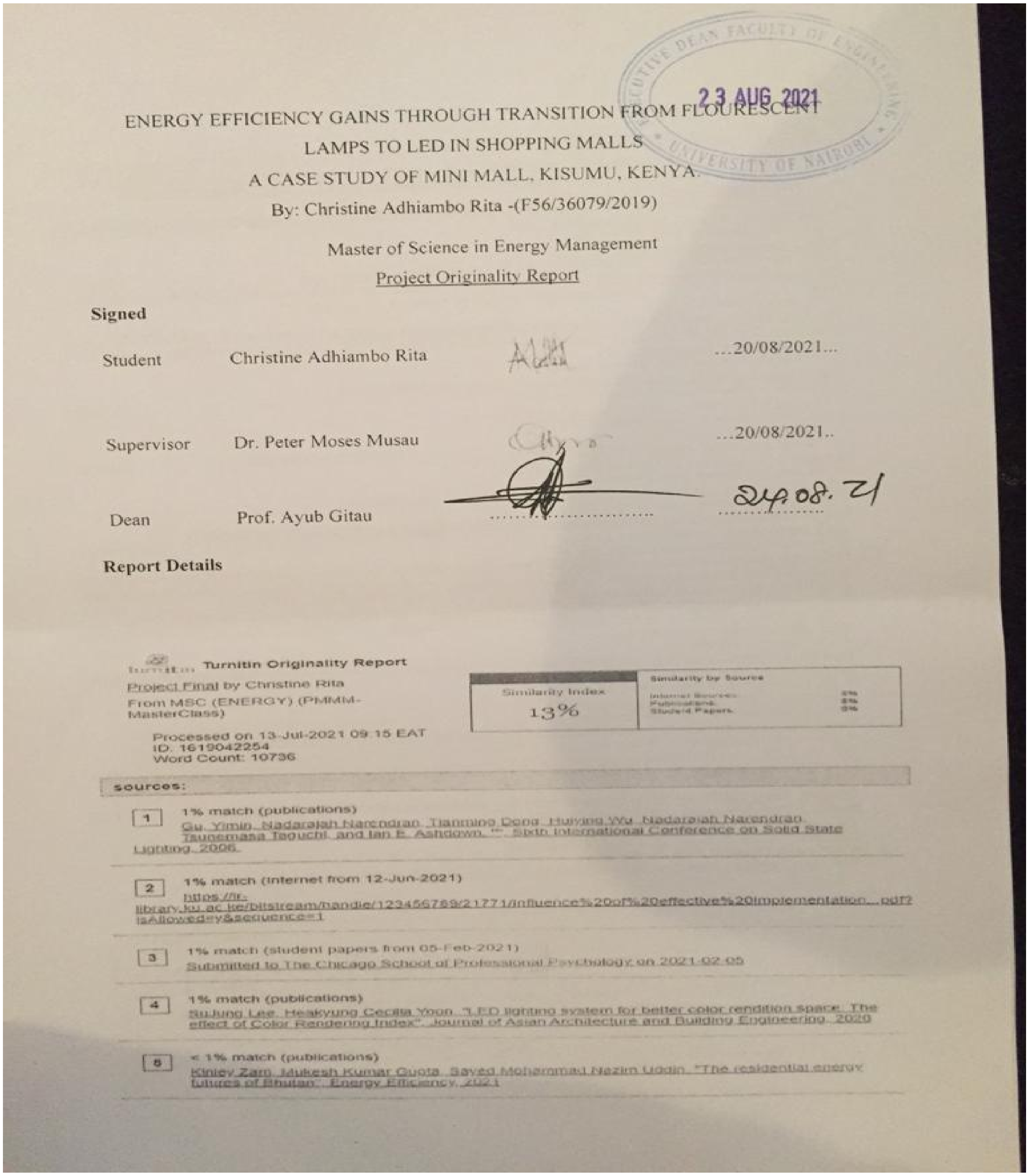
APPENDICES

Appendix A: Originality Report



ENERGY EFFICIENCY GAINS THROUGH TRANSITION FROM FLOURESCENT LAMPS TO LED IN SHOPPING MALLS

A CASE STUDY OF MINI MALL, KISUMU, KENYA.

By: Christine Adhiambo Rita -(F56/36079/2019)

Master of Science in Energy Management

Project Originality Report

Signed

Student	Christine Adhiambo Rita		...20/08/2021...
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Appendix B: IEEE Paper

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.

978-6654-0311-5/21/$31.00©2021 IEEE

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.

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)]

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

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.

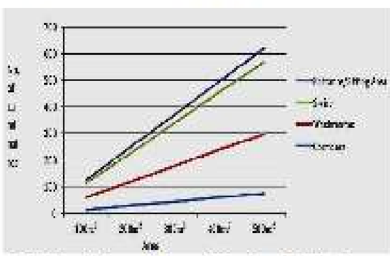
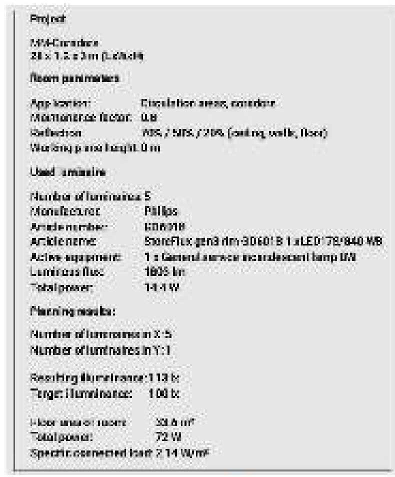


Figure 3: Relationship between Area and Number of Luminaires

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
Maintenance 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: 606018
Article name: StoreFlux gen3 rim-306018 1 xLED 17S/840 WB
Active equipment: 1 x General service incandescent lamp UN
Luminous flux: 1803 lm
Total power: 14.4 W

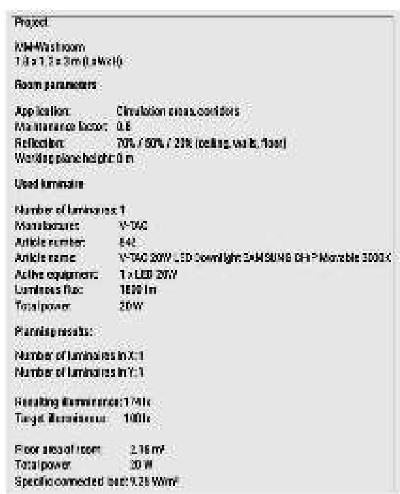
Planning results:

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

Resulting illuminance: 113 lx
Target illuminance: 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 3m (LxWxH)

Room parameters

Application: Circulation areas, corridors
Maintenance 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: 20W

Planning results:

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

Resulting illuminance: 174 lx
Target illuminance: 100 lx

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

Figure5: Replacement for Washroom

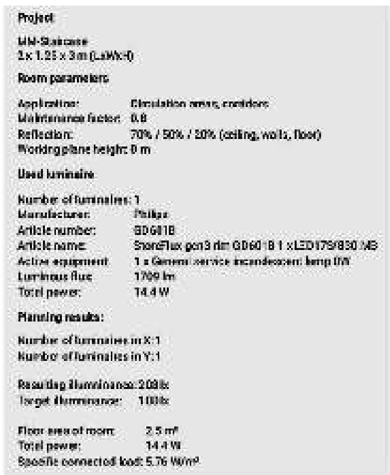


Figure 6: Replacement for Staircase

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.

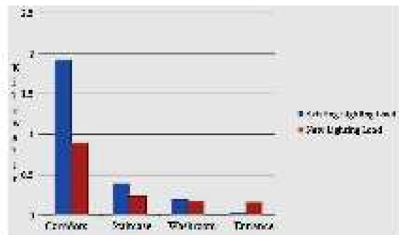


Figure 8: Comparison between Existing and New Lighting Load

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	Expense	Salvage	CashFlow, CFt	$\frac{CFt}{(1+i)^t}$
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.

VI. REFERENCES

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