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Improving the Lighting Project Executions with Light-Emitting Diodes in Trinidad and Tobago: A Value Engineering Approach

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Abstract: *Light emitting diodes (LED) are being used increasingly to provide lighting solutions for domestic and commercial lighting. This paper reports the findings on a recent study on the current issues and challenges faced with adopting LED lighting in projects and provides a value-based solution in Trinidad and Tobago (T&T). It identifies the factors affecting LED adoption in lighting projects. It then relates the challenges of LED adoption and the improvement of lighting efficiency in projects by acquiring empirical data via the conduct of interviews and a survey with industry practitioners in T&T. Compared to traditional lighting, LED lighting has superior qualities in various ways such as being energy efficient; has a long lifespan, durable, and is environmentally friendly. As evidenced from the empirical findings, 60% of practitioners agreed that they lacked the knowledge of adopting LED lighting. There have been needs to eliminate the cost barriers and to educate the public on the potential use of LED lighting in T&T. The collation of findings was used to develop 2-phase LED adoption approach incorporating the principles and tools of value engineering (VE). Phase 1 is concerned with lighting solutions analysis with DIALux in the planning phase of a project, whereas Phase 2 is an integrated VE policy for transitioning efficient lighting solutions in projects. These two phases are constituted to overcome the barriers and challenges currently being faced in lighting projects. A post-evaluation survey was undertaken with those who had participated in the previous stage of data acquisition. The post evaluation focused on acquiring practitioners' views on the applicability of the proposed approach in lighting project executions in T&T. Subject to further verification of empirical and case evidence, future work would include testing of the VE-LED approach on a wider scale using lighting projects in the public- and private-sectors separately and collectively in T&T to decrease the current issues and challenges faced with adopting LED lighting across the country.*

Keywords: *Light emitting diodes (LED), lighting projects, Value Engineering, Trinidad and Tobago*

1. Introduction

Energy efficiency practices are greatly increased due to the issues with climate change and high energy pricing (Edirisinghe, 2012). Light emitting diodes (LED) has entered the market and is constantly developing new methodologies and technologies that can be utilised in lighting designs and practices. LED lighting technology has numerous advantages over traditional lighting. It is more energy efficient, has a longer lifetime, has less maintenance requirements, and contributes to reduced climate control costs. LED lighting reduces heat and UV emissions, and it contains no mercury ((Energystar.gov, 2018)). Many projects are aiming for the implementation of cost-saving solutions that are energy efficient. LED lighting is one of the most cost-effective products for achieving this aim (UN Environment, 2017).

In Trinidad and Tobago (T&T), projects undertaken in the public and private sectors require a lot of lighting sources. Traditional lighting has been used in preference to LED lighting. However, traditional lighting fixtures would require high maintenance costs, and produce less lumens per watt. LED lighting would have been used in projects, but sometimes with the wrong application and quantities. There is also an issue that the public is not aware of determining which quality and 'value' of LED lighting to purchase (Ramrose, 2019). Value resides in a sort of appreciation towards a product, service, event or item. The extent to which the client needs to be satisfied and the cost of achieving it will be subject to various risks, making the value calculation uncertain.

Lighting plays an important role in increasing a building's total value, due to its impact on comfort, productivity, and health, to the extent that it is considered on par with energy efficiency (Dehoff, 2012, 2014). Value Engineering (VE) is a systematic study of a project, process or system that seeks the most favourable solution that would prevent any unnecessary cost (Tosca, 2018). This paper investigates the current situations and issues of lighting inefficiency in projects undertaken by the public and private sectors, and incorporates VE into fostering the adoption of LED lighting in T&T.

This paper has seven (7) sections. After the introduction, Section 2 describes the key problems currently faced in lighting project executions in T&T. Section 3 discusses the incorporation of VE into the planning and executions of lighting projects. Section 4 outlines the study methodology and presents the findings. Section 5 shows the development of a proposed VE-LED adoption approach, whereas the results of a post-evaluation survey on the applicability of the approach are presented in Section 6. The paper concludes in Section 7 by underlining the applicability of the approach with some recommendations for future work.

2. LED Lighting and Challenges of Its Adoption in Projects

LED stands for light emitting diode. An electrical current passes through a microchip, which illuminates the tiny light sources we call LEDs and the result is visible light (Energystar.gov, 2018). Appearing as practical electronic components in 1962, LED's have been and are used in applications as diverse as aviation lighting, automotive headlamps, advertising, general lighting, traffic signals, camera flashes, lighted wallpaper, horticultural grow lights, and medical devices (Peláez and Villegas, 2007). As compared to traditional light sources (like incandescent, compact fluorescent lamps (CFLs), tungsten, sodium, and other forms of lighting), LED lighting has many advantages, including lower energy consumption, longer lifetime, improved physical robustness, smaller size, and faster switching (Energystar.gov, 2018).

Several lighting design software (e.g., DIALux, AutoLUX, RELUX, Ulysse, Calculux, etc.) were developed and have been used for analysing photometrics, building information modelling (BIM), and 3D modelling (Wikipedia, 2020). Despite that LED lighting solutions have become one of the cost-effective products and are energy efficient, several challenges are identified for adopting LED lighting in projects (Yu, 2015; UN Environment, 2017). Table 1 depicts a summary of common reasons and types of these challenges.

The challenges of LED adoption apparent in T&T (Ramrose, 2019) are elaborated as follows:

1) *Lack of Policies and Standards* – At present, no national standards have been published for the use of LED lighting in T&T. There have also been a lack of activities and programmes aimed at encouraging the uses and purchases on energy efficiency labelling of lighting and associated products.
2) *Skepticism towards LED Products* - LED is an emerging technology to many industry practitioners who would face many uncertainties to adopt it. There has been no product performance testing standard, leading to poor quality LED products flooding the market in T&T. Many practitioners might have bad experiences with sub-standard LED products leading to a loss of confidence and trust in them.

Table 1. Challenges in adopting LED Lighting in Projects

Challenges	Descriptions	Reasons
Financial	The size of the initial cost compared to other traditional lighting	• Lack of sustainable financing schemes. • The higher cost of LED creates an initial investment hurdle even though there will be favourable payback periods. • Lack of incentives to promote or use LED lighting.
Awareness and Information	Lack of awareness and exposure to information about the benefits of LED lighting.	• Specifications such as lumens and Correlated Colour Temperature (CCT) are new to customers and are difficult to understand. • Purchasing officers, managers, and maintenance personnel lack knowledge of LED lighting. • There is a poor promotion of LED lighting benefits • The public is not aware of the benefits of the LED versus traditional lighting.
Technical	Infrastructure and resources are lacking to promote LED lighting	• Limited resources to develop and implement regulations. • Cheap low quality lighting is available which disrupts customer's choice in selecting the efficient lighting. • Poor power supply affects the performance and longevity of all lighting.
Market	Market structures and constraints that prevent the investment into LED lighting	• High import costs. • Negative impact on local industries. • Limited availability of low costing LED lighting with high quality. • No agreement within the company to change to LED.
Environmental Risk Perception	Concerns of safety towards the environment	• Lack of recycling companies that takes the LED lighting at the end for proper disposal.
Regulatory and Institutional	Political and legal systems not implemented	• Lacking policies that encourage the adoption of LED lighting. • There is no regulatory, verification, monitoring or enforcement of LED lighting in projects.

Source: Abstracted from UN Environment (2017)

3) *Misconception of High Cost* - Installing LED lighting faces challenges in projects due to the project budget restrictions and austerity measures. Many practitioners are reluctant to install LED outdoor lighting because of the high initial cost which clashes with their budget even though it could reduce their maintenance cost in the future.
4) *Insufficient Knowledge and Awareness of LED Applications* - LED has many benefits other than cost and energy savings such as visual comfort, increased productivity and even chronic diseases prevention. The public puts LED lighting as a technical subject even though lighting includes other criteria such as comfort, productivity, health and well-being. Practitioners are not fully knowledgeable in the technicalities, and are also not aware of the use of any lighting design software and LED lighting solutions.

3. Incorporating Value Engineering into Lighting Projects

The generation of values in a building happens when there are different processes connected, which consists of a number of sub-systems such as heat, air conditioning and lighting. In improving the executions of lighting projects, VE aims to reduce the costs and increase the quality of products being used. Benefits include a reduction in the life cycle cost, improvement in quality, and a reduction of environmental impacts. Figure 1 shows a value-generation network in building design. Davoodi (2016) advocates a 5-step scheme for VE modelling of lighting projects. Individual steps are elaborated as follows:

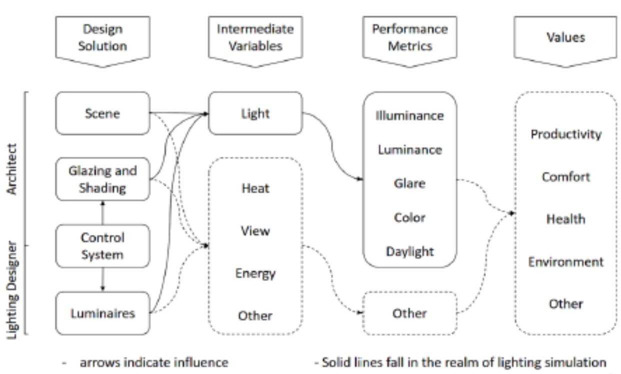

Figure 1. Value-generation network in building design

1) *Problem and System Definition* - Value of lighting should be assessed relative to the needs of the user which makes it quantification complicated. From a quantifiable perspective, values can be classified into four categories: financial, quantifiable, measurable, and observable. Currently, engineers and architects are increasingly using simulation software tools to assess and optimise their design solutions. Lighting simulation tools can be used to calculate the various categories of performance metrics in the value-generation network in building design (Davoodi, 2016). Moreover, it is necessary to define boundaries, depending on what lighting is being studied, and different boundaries can be drawn, for example, for visibility, glare or energy efficiency.
2) *System Analysis* - Lighting can be categorised into 2 subsystems: physical and human. The physical refers to the objective phenomena and the human system concerns the subjective experience of the system user. Although there are a lot of problems that concern the visual effect of lighting, there has been a growing increase on the focus of the non-visual effects of light, such as the circadian effect. Figure 2 shows the systems involved in lighting and how it is analysed.

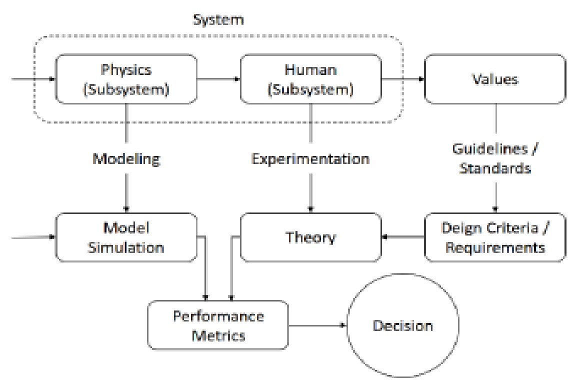

Figure 2. Analysis of systems in Lighting
Source: Abstracted from Davoodi (2016)

3) *Modelling* - Using computer models for obtaining information about a system is advantageous as there is no need to experiment with the original system. There is no threat posed to the system so investigations can be done in broader terms than on the actual system. Hence, results can be generated quickly and alternative paths can be studied and compared before implementation.
4) *Simulation* - One advantage of using computer simulation is lower marginal cost of model construction and simulation. It has an ability to shorten or lengthen the time course of dynamic behaviour (Davoodi, 2016).
5) *Validation* - Validity can be established by comparison of the model results and experimental data. This data can come from literature or from specific experimentation that has been designed to validate the model (Davoodi, 2016).

There are various factors (such as, productivity, comfort, health and environment) that would create value for the customer. There are also intermediate variables (such as light, heat, energy consumption and visual), and other performance indicators (such as luminance, glare and colour of the lighting). In order to evaluate lighting design solution(s) with respect to value, incorporating VE into lighting projects would focus on the physical light and those factors, intermediate and performance variables that would contribute to creating value for the customers/stakeholders. The VE analysis and modelling has been advocated for lighting projects in many studies with recorded success (e.g., Iturbide-Jimenez et al., 2016; Kenall, 2017).

4. Acquiring Empirical Evidence of Lighting in T&T

4.1 Study Methodology

In T&T, traditional lighting is mostly used in preference to LED lighting (Ramrose, 2019). Records showed that the amount of imported fluorescent lamps during the period of January 2011 to August 2016 was some 8.2 million fluorescent bulbs (Batchasingh, 2016). Hence, many industry practitioners have been aware of need to improve the lighting efficiency by adopting efficient LED lighting in projects in both private and public sectors. Many companies would not use LED lighting as they perceived high costs of and/or lacked the knowledge of the benefits of LED lighting.

An attempt was made to acquire empirical data via a 2-step process, using the client database of a leading lighting project company in T&T. The process was composed of interviews and a survey with industry practitioners. It aimed 1) to identify different challenges associated with adopting LED lighting, and 2) to improve the lighting efficiency by adopting the correct usage of LED lighting in projects executed in T&T. The data would be diagnosed and then used to develop a VE-LED adoption approach.

In the initial stage, semi-structured interviews were undertaken to acquire practitioners' opinions on LED lighting adoption and the associated barriers in T&T. These practitioners are of knowledge and experience in LED lighting and holding positions as Procurement managers, Engineers, Quality Managers, Business Development Leads, Contractors and Project Managers in respective clients of the lighting company. The participants are from commercial and industrial companies. They all have given verbal consent to take part in the interview. These companies are located in different parts of Trinidad and the clients were selected based on their buying history of LED lighting within the past 5 years from the lighting company.

A convenience sampling method was chosen. Interviewers were persons who worked for the lighting company where the interviewees were met at their company at their convenience for the interview. Questions were developed to investigate 1) the key components, criteria and/or attributes/parameters of the VE-LED approach, and 2) how to execute/ implement VE-LED initiatives as a sustainable option for lighting project executions in Trinidad and Tobago.

The interview session duration varied for each client between 30 to 40 minutes. The research period was from February 2019 to April 2019. The sessions were not videotaped and only physical written notes were taken. For the second-stage survey, a study instrument was designed with modification of the interview instrument. It was aimed specifically to acquire views from the practitioners of respective client companies on 1) whether the traditional lighting would have met their requirements in projects, 2) how to determine the lighting specifications and quantity, and 3) what challenges would have been faced with the adoption of LED lighting. Amongst the respondents were those who had expressed their willingness to participate but could not make it via the initial step of interviews.

4.2 Results and Analysis

4.2.1 Profile of Representatives

Out of the 100 representatives invited for interviewing, 73 agreed to take part in the study via either face-to-face interview or the survey method. The overall response rate was 73%. Most representatives had busy schedules. Of them, 44 were able to meet face-to-face whereas 29 did the survey. The results depict a combination of the results gathered from the survey and face-to-face.

4.2.2 Satisfaction of the Traditional Lighting Used

It was found that all participating client companies have some type of traditional lighting being used either fluorescent tubes or halogen bulbs or incandescent. Some clients have already bought LED lighting from the lighting company either on a small scale or large scale but not all clients were using LED lighting on their projects (as seen in Figure 3). However, the main factor that affects the selection of traditional lighting over LED lighting is cost. 60% of the clients agreed or strongly agreed that cost was the main factor that affected the selection of LED lighting.

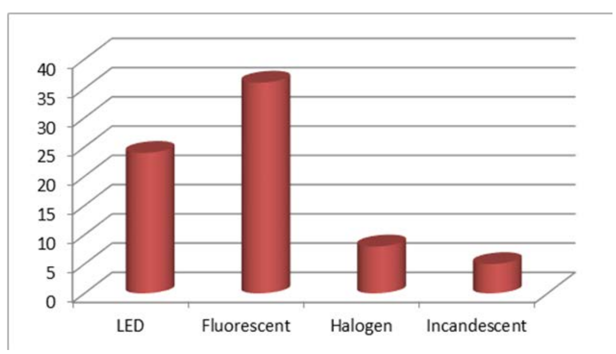

Figure 3. Types of Lighting Products Currently Used

Besides, more than half of the participants said 'no'. Hence, those participants saying 'yes' were the ones that already used LED lighting, and even a few said they were satisfied with the traditional type of fixtures (see Figure 4).

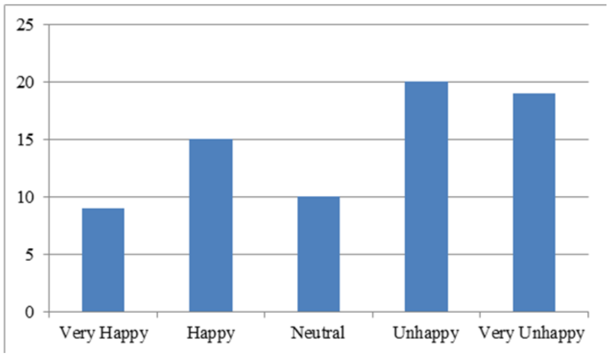

Figure 4. Number of Participants on the Level of Satisfaction of Lighting Products

4.2.3 LED versus Traditional Lighting Used in Projects

Clients were asked about the projects their company has undergone that needed lighting. When asked if they knew how many lighting fixtures a project needed, some participants said 'yes' but could only provide a rough estimate. Some were almost certain as they had their lighting drawing but not 100% sure if it would give the amount of brightness required. The participants indicated that in order to estimate how much lighting their project needed, their method was to ask an expert, hire a firm to do the lighting plans, or just try to follow past projects. Besides, participants shared views on the current needs of LED versus traditional lighting in projects. These include:

1) Cost, as traditional lighting is cheaper.
2) Most familiar with traditional lighting; LED is new to some.
3) Persons are not aware of the dangers of traditional lighting.
4) Persons are not educated on the benefits of LED lighting, and
5) Traditional lighting is more readily available.

4.2.4 Experience with LED lighting and DIALux

All participants claimed that they were familiar with LED lighting. The main benefit they were aware of that LED lights are environmentally-friendly. Most participants did not know any other additional benefits that would be brought to the project. They were also asked if they ever used LED lighting in past projects. Some claimed that their companies have used LED in projects to their satisfaction. Others implemented LED lighting, but did not take into consideration the correct amount of lighting and the suitable wattage to use.

Another question asked was if their respective companies preferred using LED lighting. 67% claimed that their organisations would take the cheapest lights upfront which would usually be non-LED lighting. Many participants have not realised that traditional lighting would fail faster than LED lighting, and more money would have to be spent to replace it. Some said that they were not aware of the benefits of using LED lighting. Once the advantages were explained to the company, this would increase the chance of using LED. Some stated that education and training would help promote the use and benefits of LED lighting in projects.

Some eighty percent (i.e., 59 participants) were not aware of the use of the DIALux programme in planning and design of lighting products (see Figure 5). Many clients and practitioners have requested for a DIALux analysis before they buy and install any lighting. DIALux is a free software developed by DIAL for professional light planning (Dial, 2019; Airfal, 2019). In addition, some were aware of what lux was required for some projects but were not sure of the exact quantities of lighting fixtures. A total of 24 participants (i.e., 20 percent) had experience with the DIALux programme that could work out the number, style and wattage of lighting needed. It would be helpful to show participants the exact number of fixtures to buy, and the costs and benefits before any decision to be made on the purchase of lighting fixtures.

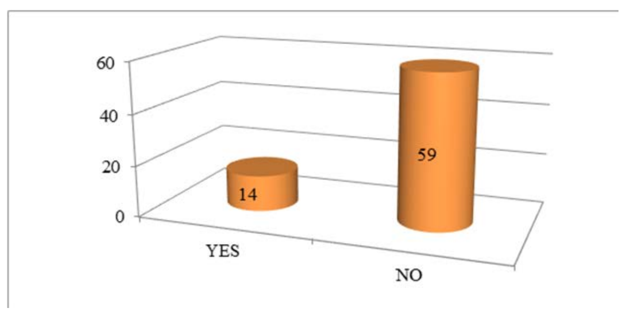

Figure 5. Number of Participants Used DIALux

Some participants saw the need, but others did not see it necessary. Those who said 'yes', their companies are involved in a green initiative (i.e., to implement LED lighting) as they knew it would be environmentally-friendly. These participants were also concerned about what T&T should do to preserve the environment. Moreover, these participants argued that there must be some sort of standards or regulations for selling LED lighting. According to the clients and practitioners, this would be helpful to ensure a high standard of quality lighting on the market which would make a major impact and improvement on the lighting efficiency in projects.

4.3 Discussion of Findings

Compared to traditional lighting, LED lighting has superior qualities in various ways such as energy efficiency, long lifespans, durability, and being environmentally friendly. However, LED lighting was not the main type of lighting used in T&T. The present status of the application of LED lighting is that either it is not being used at all, or if it is being used then the wrong application would have been installed. This would be attributable to a lack of proper tools and methods that should be used before the actual purchasing of LED lighting for a project. Some client companies also lack the knowledge of LED lighting and long-term benefits of using LED products.

As evidenced from the empirical findings, 60% of the clients and practitioners agreed or strongly agreed that the cost prevented them from using LED lighting. More than half of the respondents said they were unhappy with the traditional lighting. There have been needs to eliminate the cost barriers and to educate the public on the potential use of LED lighting. One initiative was to develop some sort of policies and standards that could ensure good practices of quality lighting in projects across the country.

Moreover, the use of the lighting design software was not known to the majority of participants. Many participants suggested that lighting design software (like DIALux, among others) should be introduced and be a crucial step in the planning phase of a project. Based on the DIALux results, benchmarking and cost-benefit analyses would be done to compare the costs and benefits of the LED lighting solution as compared to that of traditional lighting.

5. A Proposed VE-LED Adoption Approach

There have been many obvious challenges and barriers faced by many clients, companies and practitioners. This necessitates the initiative to explore an energy efficient LED lighting as a sustainable option in T&T. A VE framework was adopted, with an aim to reduce cost, improve quality, increase reliability and availability, enhance customer satisfaction, improve organisational performance, identify further issues and develop recommended solutions. With incorporation of VE concepts and principles, a 2-phase VE-LED adoption approach was developed to facilitate lighting project executions.

5.1 Phase 1: Lighting Solutions Analysis with DIALux Software

For designing and proposing any project solutions that need lighting, a thorough analysis and diagnosis of lighting requirements and fixtures are to be performed with the aid of DIALux and/or other lighting design software. The DIALux analysis could rectify issues in determining the number and style of lighting, the installation position, and the most suitable lux range of the lighting. The system could also be useful to do simulations of lighting need (Ramrose, 2019).

Phase 1 follows the VE methodology to achieve the best results for the clients/practitioners in the phase of the product design and development (see Figure 6). There are procedural elements to be executed for DIALux analysis (Ramrose and Pun, 2020) as follows:

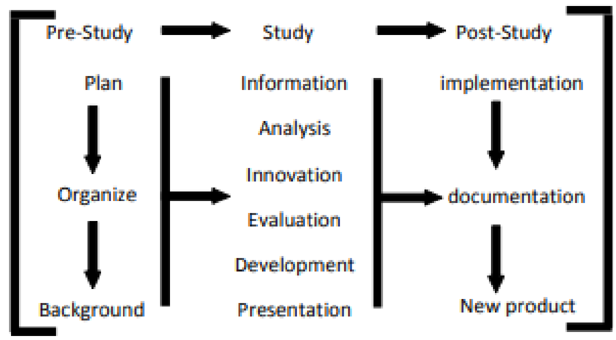

Figure 6. Lighting (Product) Design and Development Process
Source: Abstracted from Iturbide-Jimenez et al. (2016)

1) *Information Step*: Information is to be gathered from the project practitioners and/or clients. This includes, for instance, specifications, standards, and demands/needs (e.g., the layout, installation and maintenance conditions);
2) *Analysis Step*: Information and requirements of the project are to be analysed and the functions to be diagnosed. This would address the required lux with conditions (like quantities, colour and furnishing), the luminaires, lighting system and sources, and the controls needed to increase comfort and improve energy usage.
3) *Creative Step*: Ideas are to be generated in different ways to accomplish the required function needed from the light, which is the lux or how many fixtures are needed, and the style or wattage;
4) *Evaluation Step*: Synthesise the ideas and concepts and select the most suitable lighting design with the DIALux lighting system. Financial evaluation is to be made by calculating the entire life cycle cost from the investment to operation to maintenance and a Function/Cost Analysis is to be done to ascertain the purpose(s) and determine value versus cost of the lighting solution.
5) *Development Step*: Select and prepare the best alternative for improving value, where the correct number of fixtures is chosen, the position of each light is determined and the most appropriate style and wattage is selected to achieve the needed lux value; and
6) *Presentation Step*: Document the results of lighting analysis, solutions and recommendations and present them to stakeholders (e.g., project

practitioners and clients). This entails documentation of the selected lighting solution prepared to include installation drawing, control and assembly instructions as well as the list of the amount of lighting needed to achieve the objective(s).

5.2 Phase 2: Instituting Integrated VE Policy into Lighting Project Executions

Phase 2 focuses on developing standards and policies that should be implemented, as well as the testing criteria which would ensure quality LED lighting products be offered on the market. Its core components constitute developing standards, policies, processes, and getting and managing resources (Ramrose, 2019). Figure 7 shows these five (5) components that are listed and elaborated, as follows:

1) Standards and regulations,
2) Supporting policies,
3) Financing schemes,
4) Monitoring, verification and enforcement, and
5) Environmental health and safety.

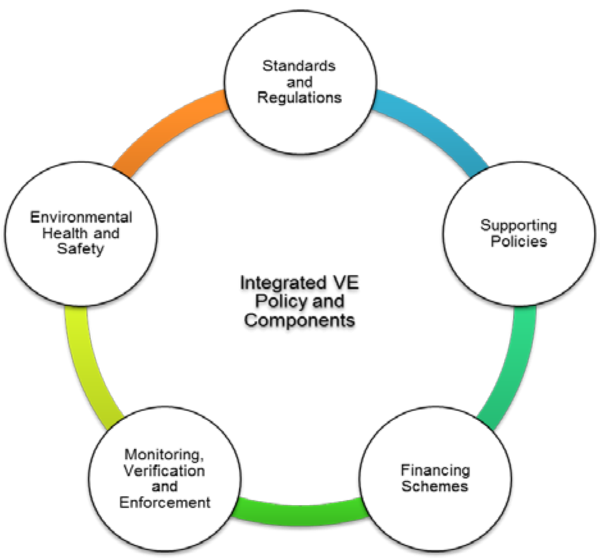

Figure 7. Components of Integrated VE Policy
Source: Abstracted from Ramrose (2019)

5.2.1 Standard and Regulations

Standards and regulations are policy measurements that a product must meet. Through effective policies and enforcement, they would ensure quality lighting products are being implemented into the market in a controlled way. The Government should look into what is deemed high quality lighting products and set a standard which includes the energy requirement, lifetime, power and lighting quality. Figure 8 depicts a set of the lighting regulatory requirements.

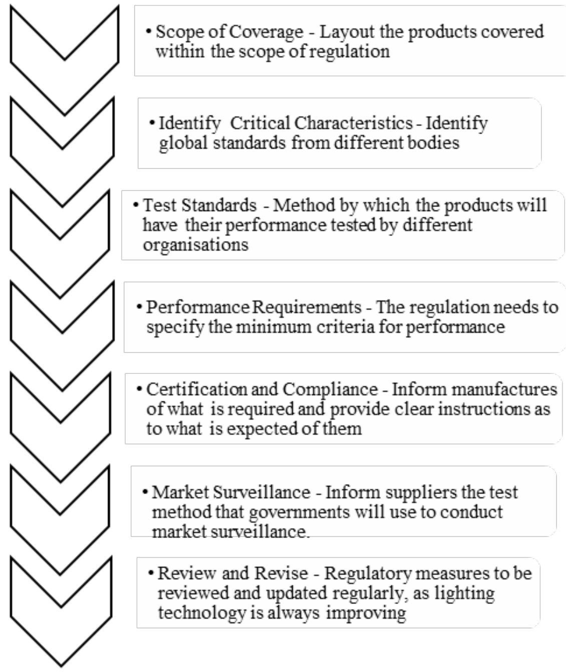

Figure 8. Lighting Regulatory Requirements

Moreover, a sequence of processes for establishing the requirements are:

1) *Establish a legal framework* - Review Legislation and develop a framework to have a legal basis and political commitment for mandatory standards and labelling.
2) *Appoint an agency* - Develop standards and labelling plan and assign an agency responsible for implementing the plan.
3) *Create a stakeholder group* - Identify the relevant persons who are interested and invite them to take part in the process.
4) *Data collection* - Establish what data are needed and develop a plan for data collection.
5) *Economic analysis* - Use cost analysis to determine the resources needed.
6) *Testing* - Sync testing with international protocols.
7) *Set levels* - Determine the technical feasibility and economically regulatory level, invite stakeholders to comment and refine, get political endorsement, publish regulatory notice, and specify a date it would be in effect, and
8) *Review and update* - Periodically review and update the levels to ensure it is updated and relevant.

5.2.2 Supporting Policies

These are concerned with product labelling, communication, and education. Product labelling is one of the cost-effective energy efficient measures. There are different types of labels, for instance:

1) *Informative labels* – To provide data on the lighting fixture and its performance,
2) *Endorsement labels* – To meet or surpass specific criteria and would be recognised as a premium, and
3) *Comparative labelling* – To facilitate the comparison of products and show their ranking.

The education and communication focus on providing stakeholders with information and enabling them to be aware of the benefits. Public awareness and education campaigns would help LED lighting be understood and faster adopted as changes in end user behaviour would help them. This would provide clients/practitioners with the knowledge about efficient lighting and the benefits would help promote a general acceptance and create a positive public environment for energy efficiency. The main objective is to bring across the message that should be simple and relevant to the stakeholders (including businesses, end-users, media, government and institutions). Table 2 shows the target groups of stakeholders and the topics for discussion that would help with their involvement in promoting energy efficiency.

5.2.3 Financing Schemes

This entails the financing of energy efficient light and overcoming the cost barrier of adopting LED lighting. There are two (2) main sources of financing, including:

1) *Government Financing* - Source of financing would be created to help support energy efficient educational programmes, and
2) *Private-sector Financing* – This offers an incentive to invest in energy efficient lighting.

Both public and private sectors would be assisted through financial schemes and repayment mechanisms. For instance, a loan could be made to individual utility customers for enabling the purchase of energy efficient lighting and solutions (such as energy audits, system designs and lighting designs). The public-private-partnership (PPP) mechanism would allow the government to fund and operate services through contracts with private companies. This would offer an opportunity to take on large scale projects with private sector expertise and financing while still being in charge of key decisions.

5.2.4 Monitoring, Verification and Enforcement

The legal framework for an energy efficient enforcement is dependent on the national governance structure and the monitoring, verification and enforcement process. Figure 9 depicts a typical model of the process. This framework must have detailed responsibilities to ensure smooth transition. It could give the authority for an agency to issue fines and block the sale of products that are not legitimate from entering the market. It is anticipated that benefits would be attainable for the three (3) main categories of stakeholders, as follows:

1) *Consumers* – To have the products that are legitimate,
2) *Businesses* – To provide a level playing field which encourages investment and technological innovation, and
3) *Policy Makers* – To help achieve economic and environmental objectives.

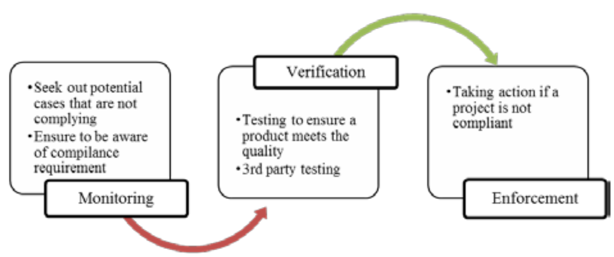

Figure 9. A Process Model of Monitoring, Verification and Enforcement

Table 2. Target Audiences, Topics and Areas of Involvement

Target Audiences	Topics	Areas of Involvement
Institutions/ Government	• Ensuring efficient standards and product quality	• Provide support to any regulatory and legislative initiative • Support policy implementation • Evaluate and monitor processes • Review which tariff should be used to clear LEDs and enforce its consistent use.
Business	• Promoting LED • Corporate responsibility • Reducing electrical consumption	• Key players in promoting sustainable policies • Provide best products to customers
End Users	• Acquire information to make informed decisions about the savings when using LED lighting • Promote LED lighting	• Acceptance and utilisation of LED based on first-hand experience and affordability • Provide information about buying habits • Increase the consumption of LED lighting
Media	• Increase awareness and develop knowledge about LED lighting among customers and businesses	• Share information on LED to consumers. • Assist governments in implementing policies • Publish formal and informal educational and training materials

The government must monitor, verify and enforce regulations and standards to ensure the policies and programmes for the adoption of LED lighting. This contains having products registered, testing products and verifying/enforcement of standards and policies, as follows:

1) *Product Registration* - Suppliers would register products that are compliant with the regulatory authority. Test results are submitted on the product which are used to certify that the product performance meets regulations before placing on the market. The registration is designed to meet the needs of various stakeholders.
2) *Testing* - LED lighting must be tested and measured in order to certify its compliance. This would ensure good quality products are being used in projects and encourage persons to adopt LED lighting. Their uncertainty would be decreased as providing proven results of the LED lighting would eliminate any misconceptions.
3) *Regulatory Enforcement* - There are different levels of regulatory enforcement, and actions must be taken for non-compliance. These penalties and powers of enforcement authority should be set out in law.

5.2.5 Environmental Health and Safety

This initiative is concerned with issues of environmental health and safety (EHS). It focuses on the life cycle of the lighting from production to its usage to the end of its life. The material could be recycled, recovered or reused to ensure the full value of the light is used. Raising consumer awareness includes, for instance, 1) no mercury in lighting products that would minimise health and safety risks, 2) no glare and flicker which would not affect users' vision, and 3) no effects that would disrupt their circadian rhythms. This initiative allows proper collection of LED lighting that needs to be disposed of in an environmentally safe way. Hence, by assuring good quality lights and verifying the lighting compliance, the customers' buying decision would gravitate more towards the selection of LED.

Moreover, several EHS parameters are determined to facilitate a smooth LED adoption. These are listed and elaborated as follows:

1) *A Policy and Legal Framework* - There must be a legal framework for waste in terms of electronics, hazardous substance and mercury levels to encourage the use of LED lighting. Once these limits are strictly upheld the use of traditional lighting, in particular, the mercury contained ones would be significantly reduced.
2) *Collection Schemes* – These allow for proper collection of used LED lighting that needs to be disposed of properly as it contains electronic waste. Specific areas are to be assigned for the collection of these items.
3) *Awareness Activities* - A continuous educational campaign to encourage the use of LED and its proper disposal is to be done on a regular basis. The process on how to do it should be explained to the public on all forums such as social media, public campaigns, flyers, brochures, newspaper articles, and TV and radio stations.
4) *Recycling Programmes* - Regulators would explore and adopt methods that are in line with national procedures to encourage the collection and recycling of lighting. Using LED lighting would make it easy to recycle as mercury would no longer be a factor of concern. The recycling programmes would be funded in various ways which are dependent on the nation's condition and resources.
5) *Financing Environmentally-Sustainable Lighting Solutions* - To ensure that used LED lighting is sustainably collected and recycled, the regulations should account for the economy to minimise the cost to user. One method would be that customers get some sort of refund when they return their used LED to encourage the recycling of the products (UN Environment, 2017).

6. Evaluation of the Approach

6.1 Conduct of Post-Evaluation Survey

A post-evaluation survey was undertaken with the stakeholders who had participated in the previous survey and personal interviews. The post evaluation focused on acquiring their views and comments on applicability of the 2-phase VE-LED adoption approach to lighting project executions in T&T.

6.2 Response Rate and Views from Respondents

Out of the 73 practitioners who did the initial stage of face-to-face interviews and survey, 51 persons responded, yielding a response rate of 69.9%. It was found that over 60% (i.e., 31 respondents) agreed that the approach could help remove barriers and bring benefits of LED lighting solutions to users in T&T. The main findings and their implications are summarised as below:

1) *On Standards and Regulations* - Most respondents agreed or strongly agreed that implementing standards and regulations would assist in assuring proper installation of lighting solutions. Most respondents considered product testing and registration as very beneficial and would reduce the availability of poor-quality LED lighting products on the market.
2) *On Supporting Policies* - Respondents agreed on the importance of product labelling with information, endorsements and comparisons to assist in encouraging the adoption of LED lighting, while some disagreed that practitioners in the country would break the law and companies would lie on the labels.

3) *On Public Awareness and Campaigns* - Most respondents agreed with the benefits of the VE-LED initiative and regarded this as a sound idea to promote the use of LED lighting solutions. If the public is exposed to the dangers of traditional lighting, they would gravitate to buying LED lighting. However, respondents thought that it would not make a difference to persons who refuse to change and would stick to traditional lighting.
4) *On LED Lighting Enforcement* - When it concerns matters of health and saving money and the environment, all respondents agreed on this. These factors would be major players driving the use of LED lighting solutions in the country. Benchmarking is to be made to ensure comparison with traditional lighting practices. The majority agreed upon educating the public as the main strategy to encourage and enforce the use of LED lighting.
5) *On the Use of DIALux* – Respondents were made aware that the DIALux software would accurately determine the necessary specifications and quantities of the lighting in projects. The DIALux would show how it could save on cost with the concerns on purchasing accurate lighting fixtures. Most respondents indicated that they would use the tool to aid with making decisions on purchasing or installing lighting solutions. They shared that their company would increase their LED adoption in projects with the use of DIALux.

7. Conclusion

This paper aimed to investigate the current issues and challenges faced with adopting LED lighting in projects and to provide viable value-based solutions in T&T. As evidenced from the empirical findings, 60% of the clients and practitioners agreed or strongly agreed that the cost prevented them from using LED lighting. Many participants suggested that lighting design software (like, DIALux, among others) should be introduced and be a crucial step in the planning phase of a project.

Therefore, a proposed 2-phase VE-LED adoption approach was developed. Phase 1 is concerned with lighting solutions analysis with DIALux in the planning phase of a project. It follows a VE methodology that guides the generation of a viable value-based lighting solution. Phase 2 is an integrated VE policy for transitioning efficient lighting solutions in projects. It consists of 5 major components that include development of standards and regulations, supporting policies, finance schemes, and then the monitoring, verification and enforcement of the practices with EHS initiatives.

Evaluations of the proposed approach were done via the post-evaluation survey with stakeholders. It was ascertained from the practitioners' views of the importance and benefits of the DIALux system and the need for standards, regulations and policies. The majority of respondents were in agreement with the VE-LED adoption approach in overcoming barriers and challenges. Planned adoption of the proposed VE-LED approach would help achieve the optimum balance between quality, function, performance, cost and safety. This would also balance results in the maximum value for any given project without affecting the quality of the LED light, but rather focused on reducing expenses, improving quality and protecting the environment.

For demonstrating the generation and applications of LED lighting solutions, lighting projects of varying nature could be selected and then diagnosed with the DIALux system. Despite that it is anticipated that energy efficient LED lighting would provide a sustainable option for lighting project executions, the components and procedural elements in the two phases of the VE-LED approach would be verified subject to further empirical and case evidence. Future work should include testing of the approach on a wider scale using lighting projects in the public and private sectors separately and collectively in T&T.

This paper demonstrates what society can implement to save on money in lighting projects in both the private and public sectors. It indicates the need for educating the public so that they can implement the correct lighting required to improve their quality of life, as accurate application creates value where it increases comfort for the user while decreasing cost.

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