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Lampon Pro: Development of a Multifunctional Smart Lamp with Adjustable Lighting, Remote Control, and Fire Safety Features

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Abstract

The need for smart, multipurpose household gadgets is constantly increasing, driven by consumer expectations for improved convenience and security. This study introduces Lampon Pro, a revolutionary smart lighting system that addresses the limits of traditional bulbs by including a variety of sophisticated capabilities. Lampon Pro combines flexible lighting control, remote operation, and an integrated fire alarm system, making it appropriate for a wide range of locations, including homes, educational institutions, and industrial sectors. The development process began with a detailed market research and assessment of customer demands using the Kano model, which identified important desirable features such as flexibility, sustainability, and safety. These insights were subsequently transformed into technical specifications using Quality Function Deployment (QFD), ensuring that they met user expectations. The system's basic functionality is powered by an Arduino-based control unit, which allows for real-time lighting adjustment and fire detection using heat sensors. Stress research and simulations proved the design's structural integrity and reliability. A cost analysis, including a Bill of Materials (BOM) and break-even analysis, shows that Lampon Pro can offer competitive price while providing more functionality than existing market alternatives. This study demonstrates Lampon Pro's potential to reinvent smart lighting solutions by offering varied, energy-efficient, and safe lighting options to modern consumers.

Keywords

Multifunctional lamp, Adjustable lighting control, Quality Function Deployment (QFD), Kano Model, Fire safety integration.

1. Introduction

The invention of the electric light bulb signified an important event in human history, transforming industries, lifestyles, and global economies. This groundbreaking breakthrough ushered in a new era of industrial efficiency and individual ease. Traditional lighting systems have significantly developed, shifting from conventional fluorescent bulbs to energy-efficient alternatives like LEDs, which reflect sustainability and scientific progress. Amid the Fourth Industrial Revolution, the need for multifunctional, automated, and user-friendly lighting solutions has escalated.

These innovations address the urgent requirements of energy efficiency, improved safety, and environmental sustainability. Contemporary smart lighting systems illustrate this transition by including adaptable technology that meet diverse user needs while reducing environmental impact.

The Lampon Pro project signifies a substantial advancement in this progression. Developed via thorough market study and sophisticated design techniques, it has features such as changeable lighting intensity, remote control functionality, and integrated fire alarm systems. The creation of Lampon Pro used Quality Function Deployment (QFD) methodologies and material optimization to guarantee that the product satisfies both functional and aesthetic requirements. The design demonstrates a dedication to user-focused features such as energy efficiency, safety, and environmental sustainability, establishing it as a paradigm of advanced lighting solutions. This research examines the conceptualization and implementation of Lampon Pro, outlining the measures used to incorporate client requirements into a market-ready solution. This study emphasizes the potential of smart lighting systems while contributing to the wider discussion on sustainable and intelligent design practices via the integration of innovation and practicality.

2. Literature Review

The advancement of intelligent lighting systems has emerged as a crucial priority in the pursuit of sustainable and efficient energy solutions. The intricacies of sustainable lighting are shown by the LED dilemma, which demonstrates how light pollution undermines conventional definitions of sustainability. This contradiction necessitates a more sophisticated strategy for developing sustainable lighting systems, since LED technology provides significant energy savings while increasing light pollution (Schulte-Römer et al. 2019). The progress and viewpoints in LED lighting design highlight the need to harmonize technological innovation with commercial requirements. Consumer preferences and technical feasibility must converge to promote the widespread use of LED systems, as emphasized in a review of cutting-edge technologies in LED lighting design (Fu et al.2009). User happiness and energy efficiency are pivotal in the development of intelligent residential LED lighting systems. Incorporating intelligent controls and adaptive technology may maximize energy efficiency while improving user experiences, fulfilling the twin goals of effectiveness and comfort (Byun et al. 2013).

The capability of intelligent systems to adapt lighting dynamically according to environmental circumstances is highlighted in the investigation of smart lighting controls within energy management. These systems achieve substantial energy reductions while maintaining functionality (Martirano 2011). The amalgamation of renewable energy sources with automated control systems to improve energy efficiency and diminish reliance on traditional power networks is shown by the design of solar street lights including auto-intensity control using Arduino (Zahari et al. 2020). Numerous strategies for substituting traditional light bulbs with LED bulbs have been examined, emphasizing the optimization of return on investment. Strategic planning and incremental replacements may significantly enhance cost efficiency and energy conservation in lighting systems (Arpornthip 2020).

The possible hazards associated with low-energy light sources, such as LEDs, underscore the need to reduce blue light exposure to safeguard both energy efficiency and human health (O'Hagan et al. 2016). The enhanced energy economy and durability of LEDs make them a favored option for sustainable lighting solutions, as shown in comparison studies between LED lighting and T5 technology (Karmakar et al. 2016). Active engagement in the study of lighting technologies is crucial for students, highlighting the educational value of comprehending lighting systems and the comparative examination of classic and new light bulbs (Ogrutan et al. 2016).The design and implementation of adaptable smart lighting systems accommodate both incandescent and LED bulbs, answering varied user requirements and environmental situations, particularly in developing nations (Raju et al. 2019). The potential of IoT-based monitoring and control systems to enhance the functioning and efficiency of electrical equipment, such as lights, is examined within the framework of Internet of Things applications (Gupta & Johari 2019). The significance of automated temperature management and alarm systems within the framework of smart lighting is underscored by the design and simulation of these systems using PIC16F887, accentuating their contribution to safety and energy efficiency (Shaati Jahlool 2017).These studies jointly emphasize the several factors involved in the design of smart lighting systems, including environmental implications, user happiness, technical advancement, and educational involvement.

3. Market and Consumer Insights

The worldwide transition to smart home technologies and energy-efficient gadgets has increased the need for novel lighting solutions. The Lampon Pro was designed to meet certain customer demands while exploiting market

deficiencies in the lighting sector. The market now presents energy-efficient light bulbs and smart lighting systems; yet, many of these products are deficient in multifunctionality, affordability, and user-oriented designs. The Lampon Pro seeks to address these deficiencies by including features like adjustable lighting, remote control, and a fire alarm system.

3.1 Consumer Survey

To validate the design and features of Lampon Pro, an extensive survey was conducted across multiple institutions, including universities and industrial sectors. Key insights derived from the survey include:

Demographics:
The majority of respondents were aged 18–27, primarily university students residing in shared accommodations where lighting plays a crucial role in daily activities.
Secondary markets included households, libraries, offices, and industrial settings.

Pain Points:
Headaches and Eye Strain: Many respondents reported issues related to inadequate or overly bright lighting, indicating a strong demand for adjustable light intensity.
Lack of Multifunctionality: Over 53% of participants indicated that their current lighting solutions lacked additional features.
Feature Preferences:
Adjustable light intensity was deemed the most essential feature, followed by fire safety mechanisms and remote operability.
Nearly 70% of participants expressed interest in an exchange policy for outdated bulbs, reflecting a demand for affordability and sustainability.
Price Sensitivity:
Around 42.9% of respondents preferred a price range of 500–700 BDT, highlighting the need for an economically viable product.

3.2 Competitive Landscape

Lampon Pro distinguishes itself in a competitive landscape dominated by names such as Philips, Walton, and RFL. Although these firms provide energy-efficient lighting solutions, they do not possess the multifunctionality that Lampon Pro offers. Lampon Pro distinguishes itself as a unique and adaptable solution by including features such as heat sensors, fire alarms, and remote-controlled adjustable illumination.

3.3 Kano Model Application

The Kano model was applied to prioritize customer requirements for Lampon Pro, identifying features that would deliver the most satisfaction while addressing fundamental needs. Based on survey responses, the features were categorized as follows:

Customer Needs Categorization
1. **Attractive Needs (A):**
Adjustable lighting intensity: Seen as a highly desirable feature that enhances user experience.
Remote control functionality: Adds convenience and flexibility.
Fire alarm system: Perceived as an innovative and valuable safety feature.
2. **Must-Be Needs (M):**
User-friendliness: Fundamental to customer satisfaction; its absence leads to dissatisfaction.
Sustainability: A growing expectation among environmentally conscious consumers.
Longevity and durability: Essential for value perception.
Affordability: Critical for acceptance in price-sensitive markets.
3. **Indifferent Needs (I):**
Environmental friendliness: While appreciated, its absence does not significantly impact customer satisfaction.

The summary of kano model is shown in Table 1. The Kano model emphasized the need of equilibrating "Must-Be" and "Attractive" attributes to guarantee consumer pleasure. Adjustable illumination and fire alarms enhance the appeal

and distinguish Lampon Pro from its rivals, while its user-friendly design and cost position it as a dependable and accessible option for a wide customer demographic.

Table 1. Summary of Kano model for Lampon Pro

Sl. No.	Features	Status
1	Adjustable Lighting Features	Attractive
2	Sustainable	Must be
3	Remote control	Attractive
4	User friendly	Must be
5	Fire alarm	Attractive
6	Heat and smoke sensitive	Attractive
7	Longevity	Must be
8	Environment friendly	Indifferent
9	Economical	Must be
10	Convenient	Attractive

Integrating these insights into the product design and marketing strategy guarantees that Lampon Pro fulfills both explicit and implicit client expectations, therefore setting it for success in a competitive market.

3.4 Objective Tree

The objective tree for Lampon Pro illustrated in Figure 1 delineates its principal goals and subordinate objectives, emphasizing the enhancement of user-friendliness, safety, and environmental sustainability. Primary goals include attributes such as “convenient accessibility”, including remote and manual switching, and “efficiency” via energy-saving and cost-effective designs. Furthermore, the product seeks to use “sustainable materials”, highlighting recyclability, biodegradability, and reduced environmental impact.

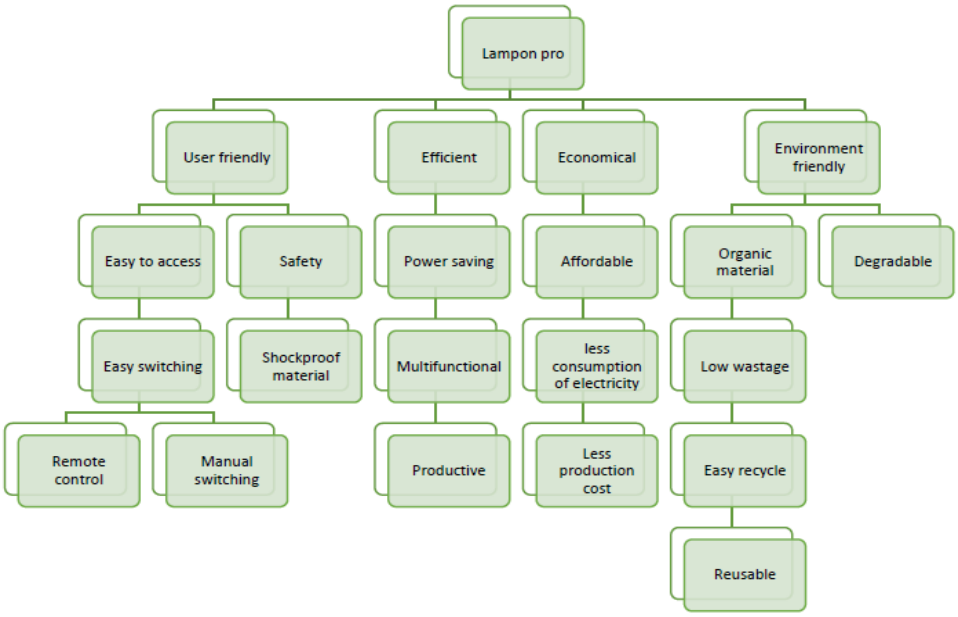

Figure 1. Objective Tree for Lampon Pro

4. Functional Structure Development

The Functional Structure Development of Lampon Pro sought to provide an innovative, multipurpose smart light that meets contemporary customer demands. The procedure included comprehensive study, functional analysis, and the incorporation of sophisticated features such as adjustable lighting, remote control, and fire alarms. By emphasizing client needs and using sustainable materials, the design guarantees safety, convenience, and environmental sustainability.

4.1 Functional Tree

The functional tree shown in Figure 2 of Lampon Pro offers a hierarchical depiction of its principal and ancillary capabilities. The principal functionalities are adjustable luminosity, remote activation, and fire alarm initiation. These functions are subdivided into sub-functions, demonstrating the logical progression of steps necessary to accomplish each process. The power supply allows both manual and remote control switching, while the Arduino microcontroller modulates light intensity and activates the fire alarm upon receiving data from the heat sensor. This organized analysis guarantees transparency in the design and execution process.

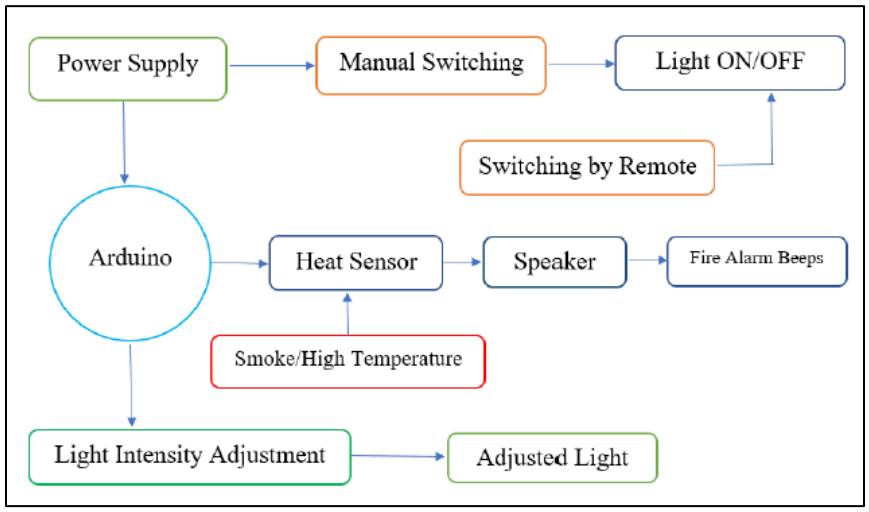

Figure 2. Functional Tree diagram for Lampon Pro

4.2 Functional Structure

The functional structure shown in Figure 3 delineates the movement of materials, energy, and information among the components of Lampon Pro, integrating mechanical and electrical activities. Essential inputs, including power supply, infrared (IR) signals, and heat or smoke detection, influence the lamp's outputs, which include light modulation, remote control capabilities, and alarm activation. The framework incorporates elements such as the Arduino, heat sensor, and LED system to convert user instructions into executable outputs. This comprehensive depiction guarantees smooth interaction among components, enhancing efficiency and dependability.

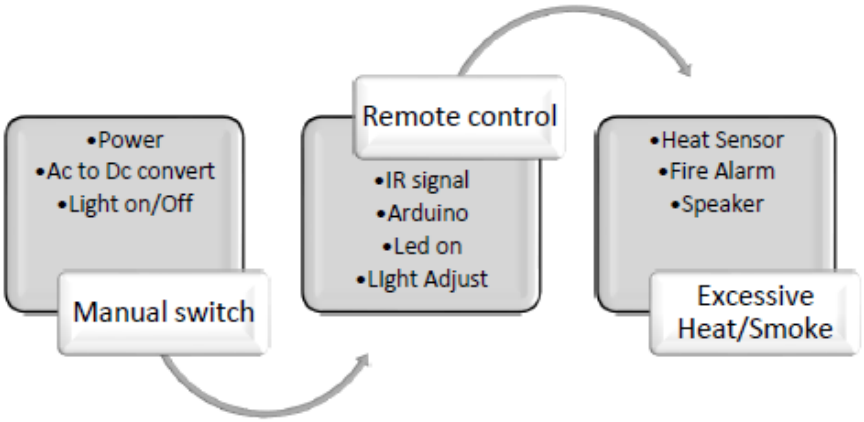

Figure 3. Function Structure Diagram for Lampon Pro

4. Quality Function Deployment (QFD)

The QFD process was employed to translate customer needs into technical requirements for the design of Lampon Pro. The QFD framework ensures that the product aligns with consumer expectations by systematically identifying and prioritizing key features. Using the House of Quality, customer requirements such as adjustable lighting, fire alarm, remote control, and eco-friendly design were mapped to functional specifications like LED systems, heat sensors, and wooden bodies

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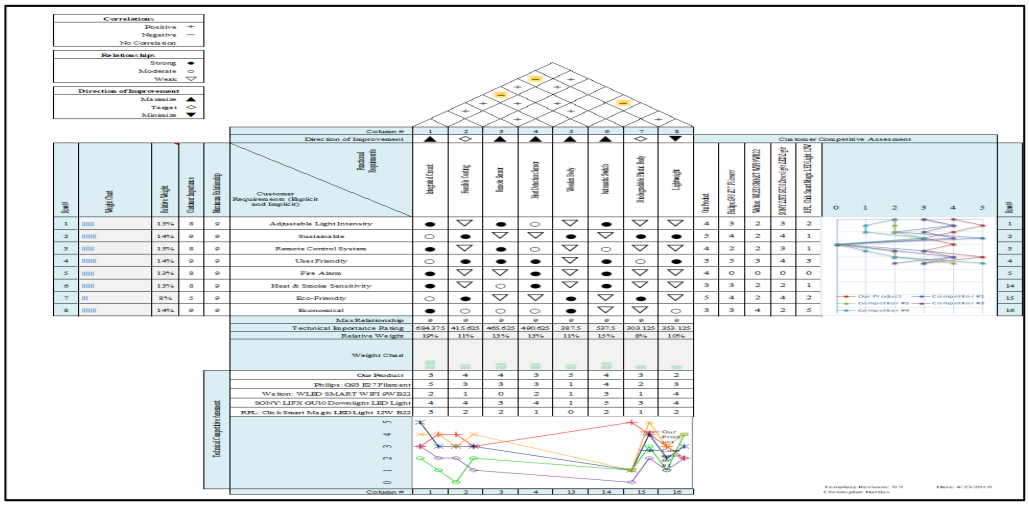

Figure 4. House of Quality

This technique underscored the technical significance of diverse aspects, facilitating the optimal allocation of resources to essential components. The competitive assessment under the QFD framework revealed Lampon Pro's superiority over current goods by fulfilling unaddressed consumer needs. By emphasizing user feedback and functional alignment, QFD facilitated a strong and consumer-oriented product design.

5.1 Customer Requirements – "Voice of the Customer"

The Voice of the customer (VOC) phase gathers and converts client requirements into technical specifications. Customer comments on Lampon Pro emphasized the importance of features like adjustable lighting, fire alarms, and remote control. The demands were assessed using a Kano Model and awarded relative significance on a scale from 1 to 10, with elevated scores denoting essential attributes such as sustainability, user-friendliness, and cost-effectiveness.

5.2 Functional Requirements

The functional requirements outline the components essential for achieving the technical and operational objectives of Lampon Pro. The specifications were formulated based on consumer input and included components such as an LED system for adjustable lighting, a heat sensor for fire detection, and a remote-control system for user comfort. Design arrows indicated considerations: upward arrows denoted enhancements to maximize aspects such as energy efficiency, while downward arrows signified regions suitable for simplicity or cost savings. This study enhanced the lamp's essential features to achieve a balance between performance and practicality.

5.3 Roof / Correlation Matrix

The Roof/Correlation Matrix described the interactions among product attributes, indicating whether they facilitate or hinder one another. Relationships were represented using symbols:
"+" denotes positive interactions
null indicates no significant effect
"-" signifies negative consequences
The use of a heat sensor enhanced the fire alarm system but required meticulous evaluation of material compatibility to prevent overheating. This study guaranteed integrated functionality and reduced compromises throughout the design phase.

5.4 Relationship Matrix

The Relationship Matrix further clarified the connection between consumer demands and technological attributes. This matrix classified links as strong, medium, or weak, ensuring that essential features like adjustable lighting and remote control were closely linked to major technological components, like the LED system and Arduino microcontroller. This comprehensive mapping facilitated effective resource allocation, concentrating on elements that most significantly influenced consumer happiness.

5.5 Competitive Evaluation

The Competitive Evaluation analyzed Lampon Pro against comparable market items to evaluate its strategic competitiveness. A score system ranging from 1 to 5 was used, wherein: 1 signifies extreme unhappiness, whereas 5 denotes extreme pleasure. The scores for Lampon Pro and its competitors were assessed for each client criteria. The investigation indicated that Lampon Pro surpassed competitors in fire safety and flexibility, although highlighted the need for enhancements in cost and environmental sustainability. This assessment yielded practical ideas to enhance the product and bolster its market standing.

6. Specification and Design Analysis

The Specification and Design Analysis of Lampon Pro focuses on detailing its components, structural design, and mechanical performance. This section highlights the main components used in the lamp, its 3D assembly design, and the stress-strain analysis conducted to evaluate its durability and reliability. These elements ensure that the product meets functional and safety standards while maintaining aesthetic and ergonomic considerations.

6.1 Main Components

The primary components of **Lampon Pro** include:
Body: Constructed from wood for sustainability and corrosion resistance.
Chamber: Made of Polycarbonate (PC) for lightweight and high-impact resistance.
Internal Elements: LED bulbs, Arduino microcontroller, IR remoting sensor, heat sensor, and MP3 speaker module, AC to DC driver.

Both electrical and mechanical specifications of Lampon pro is shown in Table 2.

Table 2. Specifications for Lampon Pro

Electrical Specification	Heat Sensor	1
	Arduino	1
	IR Remoting Sensor	1
	Led Bulbs	5-10
	MP3 Player Module Speaker	1
	AC to DC Driver	1
	Power Supply	220V 50Hz
Mechanical Specification	Wooden Body	1
	Plastic Chamber	1
	Screw	2
	Weight	612.65 grams
	Volume	730444.8 cubic millimeters
	Surface Area	68446.59 square millimeters

6.2 3D Design Assembly

The 3D assembly of the Lampon Pro illustrated in Figure 5 demonstrates the integration of all components, including the wooden body, plastic chamber, and internal electronics. The isometric representation of the assembly emphasizes its small form and efficient configuration, facilitating production and enhancing user comfort.

Figure 5. Assembly of Lampon Pro

6.3 Stress-Strain Analysis

The stress-strain analysis of Lampon Pro was conducted on SOLIDWORKS® to evaluate the structural integrity and mechanical performance of its key components, including the body, chamber, and overall assembly. This analysis ensured that the product could withstand operational stresses while maintaining durability and safety.

Body Analysis: The body of Lampon Pro was subjected to a simulated static load. The results showed a maximum stress of **73.2 MPa**, which is well below the material's yield strength of **193 MPa**, providing a sufficient factor of safety. The displacement analysis revealed minimal deformation of **0.0025 mm**, confirming the structural rigidity of the body under load. Figure 6 illustrates the static simulation of stress-strain analysis on the main body.

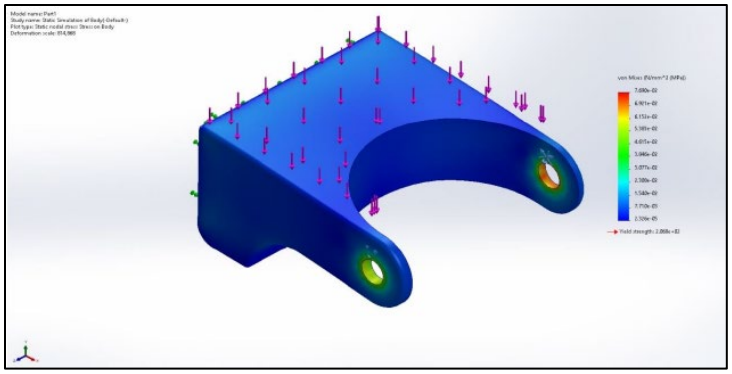

Figure 6. Static Simulation of Stress-Strain on Body

Chamber Analysis: The chamber was subjected to stress and strain testing shown in Figure 7 to evaluate its capacity to safeguard interior components. The peak stress observed was **22.5 MPa**, far lower than the yield strength of polycarbonate, which is **66 MPa**. The displacement was **0.0043 mm**, confirming the chamber's stability under standard operation.

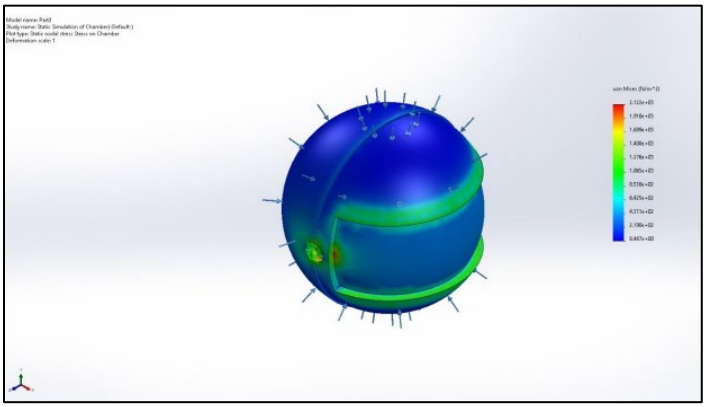

Figure 7. Static Simulation of Stress-Strain on Chamber

Assembly Analysis: The stress distribution and strain levels were examined to assess the collective performance of all components in the entire assembly. The assembly experienced a maximum stress of **39.8 MPa**, with a safety factor above **2.5**. The total displacement was **0.0065 mm**, demonstrating that the integrated product can withstand operating and environmental forces without failure. Figure 8 illustrates this analysis.

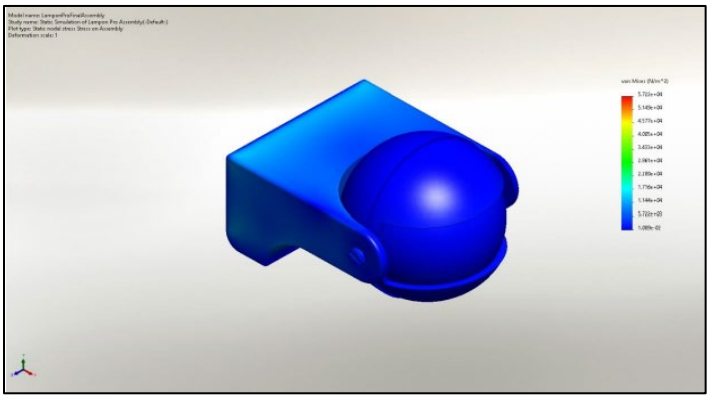

Figure 8. Stress Analysis on Assembly

7. Financial Analysis

Financial analysis is one of the most critical analyses for developing a product. It indicates the feasibility of a product. In a cost analysis, many cost elements are dissected into smaller ones, and each detail is examined. For Lampon Pro, a bill of materials is produced, and then several cost elements are considered under fixed and variable costs.

7.1 Bill of Material (BOM)

Table 3 shows the BOM. It details the quantity, materials, and unit costs for the parts needed to make the Lampon Pro. According to the table, Arduino accrues the most expensive, followed by Heat Sensor, IR Remoting Sensor and LED Bulb Circuit. Screw costs the least to build up, followed by Frame and AC to DC Driver.

Table 3. BOM of Lampon Pro

Sub Assembly		Quantity	Material	Unit Cost (BDT)	Total Cost (BDT)	% of Cost
Body	Frame	1	Wood	50	50	5.97
Chamber	Heat sensor	1	Electrical component	100	100	11.93
	Arduino	1		400	400	47.73
	IR remoting sensor	1		100	100	11.93
	LED bulb circuit	1		100	100	11.93
	AC to DC driver	1		80	80	9.55
Screw	Screw	2	SS 304	4	8	0.95
Total					838	100.00

7.2 Lifecycle Costs

The total expenses of the Lampon Pro are evaluated during a 5-year lifespan. It encompasses Production Costs, Marketing Expenses, Research and Development Costs, Distribution Expenses, Customer Service Costs, Facility Expenses, Additional Overhead Costs, and End-of-Lifecycle Costs. All these expenses may be classified as either fixed costs, variable costs, or a combination of both. The overall lifecycle cost is illustrated in Table 4.

Table 4. Lifecycle Cost of Lampon Pro

	Fixed Costs (BDT)						Variable Costs (BDT)
	1st Year	2nd Year	3rd Year	4th Year	5th Year	Lifecycle	Per Unit Cost
Production							
Maintenance	25000	20000	15000	10000	10000	80000	150
BOM							838
Labor Cost	50000	50000	75000	75000	75000	325000	
Utilities	25000	25000	25000	25000	25000	125000	5
Insurance	50000	50000	50000	50000	50000	250000	
Total Production Cost	150000	145000	165000	160000	160000	780000	993
Marketing							
Awareness	175000	150000	150000	80000	50000	605000	
Accessibility							100
Total Marketing Cost	175000	150000	150000	80000	50000	605000	100

Table 4. Lifecycle Cost of Lampon Pro (continues)

	Fixed Costs (BDT)						Variable Costs (BDT)
	1st Year	2nd Year	3rd Year	4th Year	5th Year	Lifecycle	Per Unit Cost
R&D							
Design	10000					10000	
Improvement		5000	5000	5000	5000	20000	
Total R&D	10000	5000	5000	5000	5000	30000	0
Distribution							
Logistics Management	100000	75000	75000	75000	50000	375000	
Avg. Shipping							100
Total Distribution Cost	100000	75000	75000	75000	50000	375000	100
Customer Service							
Repairing Workshop	10000	5000	5000	5000	5000	30000	
Free 1st month Adjustment							100
Total Customer Service cost	10000	5000	5000	5000	5000	30000	100
Facilities Expenses							
Permission	30000					30000	
Machineries	600000					600000	
Assembly Plant	400000					400000	
Micro-controller Lab	300000					300000	
Depreciation	50000	40000	30000	30000	25000	175000	
Total Facility Expenses	1380000	40000	30000	30000	25000	1505000	0
Additional Overheads							
Administrations	20000	20000	20000	20000	20000	100000	
Patents	5000					5000	
Lawsuits		2500	2500	1500	1500	8000	
Software License	1000	1000	1000	1000	1000	5000	
Total Overhead Cost	26000	23500	23500	22500	22500	118000	0
End of Lifecycle							
Decommissioning					50000	50000	
Waste management					7000	7000	
Total EOC Cost					57000	57000	0
Total Accumulated Cost	1851000	443500	453500	377500	374500	**3500000**	**1293**

Total fixed cost is found 3500000 BDT and variable cost per unit product is found 1293 BDT. The estimated sales scenario is added in Table 5.

Table 5. Estimated sales for five years

Year	Sales unit
1	500
2	700
3	900
4	1200
5	1500

7.3 Break-Even Analysis

The Break-Even Analysis determines the sales volume required for Lampon Pro to cover its total costs and start generating profit. This analysis provides crucial insights into the financial feasibility of the product by evaluating fixed costs, variable costs, and pricing strategies. It serves as a guideline for setting sales targets and achieving profitability.

Let, *BEPx* = Break Even Point in Units
BEP$ = Break Even Point in Taka
S = Selling price per unit = 2800 Taka
Q = Total number of units produced = 4800
v = Variable cost per unit product = 1293 Taka
TR = Total Revenue = (*S* × *Q*) = Total Sales = 13440000 Taka
FC = Fixed Cost = 3500000 Taka
VC = Variable Cost = 6206400 Taka
TC = Total Cost = *FC* + *VC* = 9706400 Taka
Break Even Point occurs when TR = TC
BEPx = *FC/(S-v)* = 3500000/ (2800-1293) = 2322.49 = 2323 units
BEP$ = ***BEP***x*S = 2323*2800 = 6504400 Taka
Profit = *TR-TC*= (13440000-9706400) = **3733600** Taka

The Break-Even Point (BEP) for Lampon Pro will be achieved by selling 2323 units, generating a revenue of 6504400 Taka. Beyond this point, the product will yield a profit, with total earnings of 13440000 Taka against total costs of 9706400 Taka, resulting in a net profit of 3733600 Taka. The graph for Break-even analysis is shown in Figure 9.

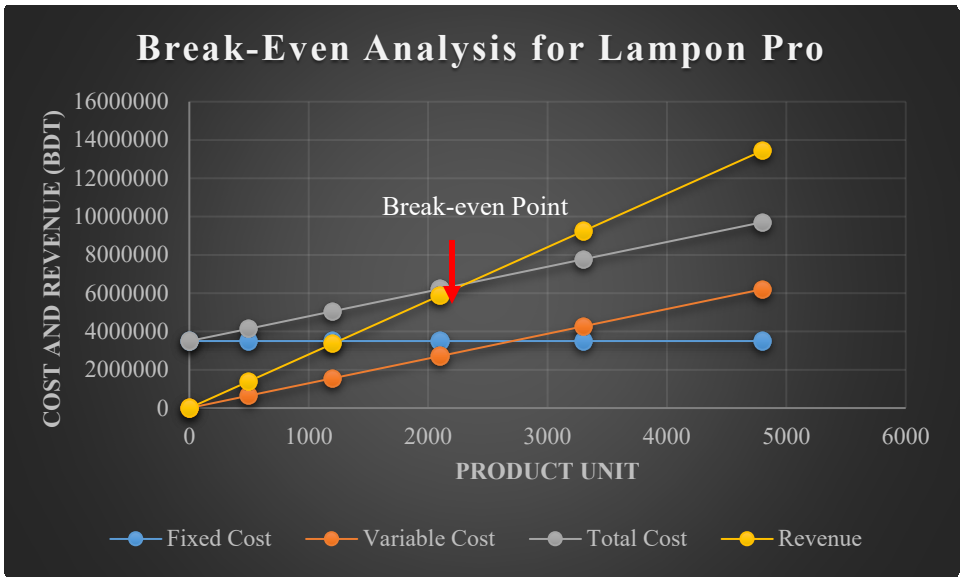

Figure 9. Break Even Analysis for Lampon Pro

8. Conclusion

The development of Lampon Pro signifies a notable progression in smart lighting solutions with the incorporation of multifunctionality, user convenience, and safety attributes. The product was customized to efficiently satisfy customer requests using a systematic design process that included market research, Quality Function Deployment, and stress-strain testing. The use of sustainable materials and efficient production procedures amplifies its attractiveness in the contemporary eco-conscious market. Financial assessments, including the break-even point and profitability evaluation, validate the product's economic feasibility. Lampon Pro has the capability to surpass customer expectations, providing a practical and inventive solution for contemporary lighting requirements.

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