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Entrepreneurship for Engineers

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Take Home Assignment (Group)

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I Introduction

Pedal-powered bicycles, or push cycles as they are commonly known in some parts of the world, have been transporting humans from place to place for over 150 years. Consisting of a metal frame mounted on two wheels driven by the pedals through a gear and chain system [1], they are considered an economical, efficient, eco-friendly, and healthy means of transport [2] [3] [4]. However, with the development of motor transport and its associated infrastructure, cyclists have additional safety considerations especially when travelling at night.

One main consideration is an adequate lighting system for travelling at night. Bicycle lighting systems allow cyclists to illuminate the path ahead of them, while also enabling the cyclist and bicycle to be visible to other motorists [5]. This system is instrumental in preventing accidents and therefore is a requirement for cyclists in many countries and regions [6] [7].

The most common form of bicycle headlight is a simple flashlight mounted on the handlebars in a fixed direction. However, this simple system has certain drawbacks which can be improved upon in order to maximize its safety and usefulness [5]. One issue is that fixed-direction headlights may blind oncoming travelers if fixed at too shallow an angle [8], or alternatively provide inadequate illumination if fixed at a steep angle. The optimal angle therefore changes based on the situation. Another issue is that the required light intensity differs based on the situation, with more remote areas generally requiring higher levels of intensity for better illumination of the surroundings.

These limitations can be mitigated through the use of a motorized adjustable headlight that can regulate brightness automatically based on the surrounding light conditions, and adjust beam direction using a small actuator. This would optimize visibility for the cyclist, improving both safety and convenience.

II Innovation and Value Proposition

This adaptive bicycle headlight provides a significant advantage over traditional bicycle headlight systems by optimizing beam direction and brightness in order to improve rider visibility and thereby reduce risk. It does this through three main mechanisms:

- **Adaptive Brightness** – Uses *Pulse-Width Modulation* in order to vary the brightness of the LED headlight over 64 levels of intensity
- **Servo-Based Beam Adjustment** – Allows for the adjusting of the beam about a 45° angle in the vertical axis, and a 30° angle in the horizontal axis
- **Sensor Driven Automation** – Uses a *Light Dependent Resistor (LDR*) to determine ambient lighting conditions and provide that as input to the system.

Additionally, the system exists as a single module that can be easily mounted on the handlebars, making setup convenient and simple for all users. A simple thumb control is present in order to adjust the beam direction with minimum hassle. A waterproof casing ensures that the system is operational in all types of weather, reducing safety risks in low visibility conditions such as rain or fog.

This provides a variety of benefits for consumers, such as:

- **Enhanced Safety** – Better visibility in differing lighting environments reduces the risk of accidents, increasing the ability of cyclists to cycle in the nighttime. [9]
- **Convenience** – Servo-controlled adjustments remove the need for manual tuning.
- **Cost-effectiveness** – The modular design allows this headlight to be much cheaper than a full smart bike system, making it attractive to cyclists and delivery fleets.
- **Energy Savings –** By using variable brightness in different conditions, the system conserves battery energy and longevity. [10]

This system has broad commercial appeal, with urban cyclists, delivery fleets, and even bike rental services benefiting from the system.

By combining practicality, affordability, and technological innovation, this adaptive bicycle headlight represents a compelling value proposition for both consumers and commercial stakeholders, establishing a clear pathway toward commercialization and market adoption.

III Market and Industry Analysis

The global bicycle industry has grown rapidly in recent years as a result of rising fuel costs, increasing urban congestion, and heightened environmental awareness. Cycling has become a preferred mode of transportation in many regions, supported by government policies that promote sustainable mobility and road safety. According to Grand View Research (2024), the global bicycle market is projected to reach USD 112.8 billion by 2030, driven by strong adoption in urban transportation and recreational fitness sectors [11]. In parallel, demand for cycling safety accessories has increased significantly, particularly lighting systems that improve visibility during night-time travel or poor weather conditions.

Despite the rising popularity of cycling, safety remains a major concern. The World Health Organization (2023) reports that thousands of cycling-related fatalities occur each year globally, with inadequate visibility cited as a key contributing factor [12]. Many countries require bicycles to have headlights and tail-lights; however, traditional fixed-beam lighting systems often provide limited visibility or cause glare to oncoming drivers. As a result, intelligent lighting accessories represent a rapidly expanding market segment focused on improving operational safety through adaptive technology.

Competitor Landscape and Existing Solutions

A number of commercial bicycle lighting systems currently exist, ranging from basic LED headlights to premium smart lighting products. Established brands such as Garmin, Lezyne, CatEye, Knog, Blackburn and Gaciron produce high-performance lighting accessories that emphasize brightness, durability, battery efficiency, and weather resistance [13] [14] [15]. Some modern systems integrate features such as ambient light-based automatic brightness control and brake-light activation. For example, Gaciron offers a unit combining a headlight with an adjustable-volume electric horn, and several smart rear lights now include automatic brake detection. [13]

However, these solutions typically provide only partial functionality. Most high-end headlights do not have servo-based beam rotation, which is useful for cyclists when navigating uneven terrain, and to avoid blinding other oncoming motorists and cyclists. While some premium electric bicycles include integrated smart lighting modules, retrofit systems with comparable functionality remain limited and expensive.

Therefore, a clear commercial gap exists: no widely available product currently integrates adaptive beam direction, sensor-driven brightness control, and dynamic headlight intensity in a single modular retrofit system. This creates an opportunity for the proposed Smart Adaptive Bicycle Lighting System, which brings high-end safety technology to conventional bicycles at a significantly lower cost.

IV Business Model Canvas

This Business Model Canvas outlines the framework for commercial deployment of the Smart Adaptive Bicycle Lighting System, including the organizational, financial, and value-driven foundations necessary for successful market entry.

Customer Segments

The primary target market includes urban cyclists and commuters who need to prioritize personal safety and night-time visibility. Secondary markets include delivery riders working for platforms such as Uber Eats / PickMe, who frequently carry out deliveries at night, and therefore require improved illumination. Additional segments include cycling enthusiasts, rental bicycle services, tourist trail operators, and bicycle retailers.

Value Proposition

The system delivers safety enhancements by integrating both adaptive brightness and servo-based beam direction into one compact module. Unlike traditional fixed-beam headlights, this device automatically adjusts to environmental conditions, improving visibility and reducing driver distraction. The modular retrofit design supports installation on any bicycle without modification, making it more affordable than fully integrated smart-bike systems.

Channels

Product distribution will occur through online retail platforms, physical bicycle accessory stores, and partnerships with delivery fleet operators. Demonstration-based marketing through cycling events, exhibitions, and university innovation showcases will support product adoption.

Customer Relationships

Customers will be engaged through self-installation guides, warranty services, online support channels, and community engagement via social media. Feedback-based product updates will support long-term retention.

Revenue Streams

Revenue will be generated through direct unit sales, bulk procurement agreements with fleet providers and rental services, and accessory and spare part sales. Licensing opportunities with bicycle manufacturers may represent a long-term revenue expansion pathway.

Key Activities

Key activities include product design and development, component procurement, manufacturing, field testing, branding, marketing, supply chain management, and post-sales support.

Key Resources

Core resources include engineering expertise, component suppliers, logistics networks, intellectual property assets, finance, and distribution partnerships.

Key Partnerships

Primary partnerships will include electronic component suppliers, manufacturing facilities, retail distributors, cycling clubs, delivery service companies, and academic research collaborators.

Cost Structure

Major cost elements include raw materials, electronics manufacturing, assembly, tooling, packaging, logistics, marketing campaigns, research and development, employee salaries, and warranty handling. As production volume scales, per-unit manufacturing cost is expected to reduce through economies of scale.

V Feasibility and Implementation

Technical Feasibility

The smart bicycle system uses sensors such as light sensors to detect its surroundings. It has a small motor to move the headlight and LEDs that can change brightness. These components are widely available and developed technologies that support easy prototyping and scaling. The control system can be implemented using affordable microcontrollers (e.g., PIC or ESP32), which streamline sensor data processing and actuator control. The waterproof shell is an additional benefit for user safety, as it allows the device to perform reliably under different weather conditions. Furthermore, the modular design makes it easier to adapt current bicycles without affecting the existing structure of the bike, thereby improving usability and adoption potential.

Operational Feasibility

With automated brightness adjustment based on sensor inputs, the system's operation is designed to reduce manual effort. User customization is supported through a straightforward manual control for beam adjustment. Due to its simplicity of installation and compatibility with the majority of bicycle types, the gadget is accessible to a wide range of user segments. Common electronic components can be serviced as needed, and maintenance requirements are minimal. Reliability and user satisfaction will be improved based on user feedback and improvements to the design of the system.

Economic Feasibility

LDR sensors, servos, and LEDs are all reasonably priced when purchased in large quantities. With the achievement of economies of scale, manufacturing and assembly costs will decrease, particularly if alliances with manufacturers and suppliers are formed. Because it increases nighttime safety for an affordable price, the smart headlight system has commercial appeal for urban bikers, delivery fleets, and rental businesses. Additionally, adjustable brightness saves energy by extending battery life and lowering maintenance expenses. Its commercial appeal is enhanced by growing urban riding habits and rising consumer demand for accessories that improve safety.

Implementation Plan

- Build an initial prototype that includes all the sensors, actuators, and control logic.
- Test the prototype outside in different lighting and weather conditions to make sure the sensors and motors work well.
- Improve the design by making the casing waterproof, designing the mounting system for stability, and improving the user interface based on feedback from testing.
- Produce a small batch of the system for early market trials and demonstrations to potential customers.
- Launch the product through online stores, bike accessory shops, and partnerships with delivery companies.
- Provide ongoing support after the launch, including installation guides and customer feedback channels.

VI Financial Projection and Funding

A preliminary financial projection was developed to estimate the expected costs, revenue, and profitability of the Smart Adaptive Bicycle Lighting System over the first three operational years.

All values are in USD, due to the majority of the parts being sourced from outside Sri Lanka

Manufacturing Cost per Device:

Component	Cost (USD)
Servo Motor	$2
Battery	$6
LED Flashlight	$8
Microcontroller	$3
Casing	$3
Total	**$21**

Fixed Logistics cost per device - USD $4 (Total – USD $1200 for 300 units)

Final Variable Cost: USD $25 (Rs. 7500)

Proposed Initial Funding Target: USD $11,250

This funding would be utilized for:

- Bulk component purchase and initial manufacturing (USD $7,500 – 300 Units)
- Waterproof casing mold development (USD $1,000)
- Branding, packaging, logo design (USD $500)
- Marketing and promotional campaigns (USD $ 750)
- Pilot testing with delivery fleets or bike rental services (USD $1,500)

Proposed Retail Price: USD $35 (Rs. 10,500)

Fixed Costs per Annum:

• Marketing : $1,000

• Operational Costs : $1,000

Total Annual Fixed Costs (CF Annual): $2,000

Financial Projection Table

(Assuming a scaling to 500 units in the 2^{nd} year, and 800 in the 3^{rd})

Year	Costs	Revenue	Profit
1^{st}	$11,250	$10,500 (300 Units)	**-$750**
2^{nd}	$25 x 500 + $2,000 = $14,500	$17,500 (500 Units)	**$3,000**
3^{rd}	$25 x 800 + $2,000 = $22,000	$28,000 (800 Units)	**$6,000**

Break Even Point (BEP)

Per Device Profit (2^{nd} Year) = $35 – ($25 + $2000/500) = $6

No. of Units needed to be sold in 2^{nd} year to break even = $750/$6 = 125 units

Therefore, we can see that the Break Even point will be in the 2^{nd} year of sales, when 425 total units have been sold.

Potential Funding Sources

- **Angel Investors:** Especially those supporting sustainable mobility startups
- **Crowd funding Platforms:** Kickstarter or Indiegogo
- **Government Innovation Grants:** Sustainability-focused innovation funds
- **University Incubator Programs:** May include technical support
- **Corporate Partnerships:** Delivery platform companies, hotels, etc.

This structured funding strategy will help scale the product from prototype to commercial distribution efficiently and sustainably.

VII Social and Environmental Impact

Social Impact

By increasing visibility, especially at night or in inclement weather, the smart bicycle safety system greatly improves rider safety. This can improve public health and safety by lowering the frequency of accidents and injuries. By promoting cycling as a safer form of transportation, the product may encourage more people to use it for regular purchases and travel, which encourages active lifestyles. Additionally, it enhances workplace safety and welfare by supporting delivery personnel who are more vulnerable during night hours.

Environmental Impact

The system promotes a sustainable, economical, and ecologically friendly form of transportation by encouraging safer cycling. Adoption of bicycles may decrease dependence on automobiles, which can reduce carbon emissions, air and noise pollution, and urban traffic congestion. The energy-efficient design of the system, especially the variable-brightness LEDs, reduces power consumption, lowering resource usage and electrical waste. Additionally, the product's modular retrofit design eliminates the need to produce brand-new bicycles, saving materials and reducing environmental impact.

VIII Conclusion and Reflection

The Smart Adaptive Bicycle Lighting System provides an innovative solution to a persistent safety challenge faced by cyclists. By integrating servo-based beam adjustment, adaptive brightness control, ultrasonic sensing, and modular installation, the system enhances visibility, reduces manual intervention, and significantly improves rider safety. Its value proposition is strengthened by affordability, energy efficiency, and compatibility with both personal and commercial bicycle fleets.

Through the development process, it became clear that successful entrepreneurship requires more than a technical solution - it demands market understanding, financial planning, user-centered design, and continuous improvement based on feedback. This project highlighted the importance of balancing innovation with practicality, ensuring that the product remains simple, reliable, and cost-effective for widespread adoption.

This project demonstrates how engineering knowledge can be transformed into a commercially viable product that creates meaningful social and environmental impact. The experience has strengthened skills in product development, market analysis, financial forecasting, and implementation planning-laying a solid foundation for future entrepreneurial endeavors.

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