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EcoNova+: An AI-Powered Web-Based E- Waste Repair and Green Shopping Advisor with Lifecycle Tracking

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***Abstract* --** Right now, the world is facing a serious challenge with the rapid increase in electronic waste (e-waste). Only 22.3% of 62 million tonnes have been recycled in those 62 million tonnes approximately one third 20 million tonnes of e-waste comes from household equipments. Studies indicates that both extending lifespan of device and greater collection for repair and reuse can reduce e-waste landfilling significantly. Many people throw away devices that could be repaired or reused this leads to major environmental problems. Lack of awareness causes improper use of sustainable products. EcoNova+ is an AI- powered web-based platform designed to overcome this issue by promoting smarter and more sustainable use of electronics. The system works as a repair advisor, which guiding users to fix their old gadgets, find nearby repair centers and a green shopping assistant, which helps to choose eco-friendly products when buying new ones. It also includes a lifecycle tracking feature that helps users monitor their electronic devices which have been in use, and when they might need a maintenance it helps them by notifying it. By combining artificial intelligence and cloud technologies, EcoNova+ makes electronic device management more efficient and accessible. Using machine learning algorithms, the platform analyzes product data, repair options, and environmental ratings to give users personalized recommendations. Ultimately, EcoNova+ aims to encourage sustainable consumer habits in sustainable shopping, reduce electronic waste, and support the global move toward a green society, showing how AI can help technology, sustainability, and consumer responsibility to build a greener digital future.

Keywords—E-Waste Generation, Artificial Intelligence, Green Shopping, Repair Recommendation, Life Cycle Tracking, Sustainability

1. INTRODUCTION

In the past decade, the rapid growth of the consumer electronics market has significantly impacted modern digital life through its drastic increase. However, their rapid production and disposal have led to a serious environmental issue: electronic waste (e- waste). According to global sustainability reports, e-waste is one of the fastest growing waste streams worldwide, with millions of tonnes of e-waste generated each year due to early disposal, less knowledge about easy repair options and limited recycling. The widening gap between technological progress and sustainable use has increased the need for effective e-waste generation solutions.

To tackle this issue, researchers have started looking into Artificial Intelligence (AI) as a powerful tool for sustainable repair, diagnostics, and lifecycle optimization of electronic devices. Nazli Terzioğlu pointed out how AI-driven consumer electronics repair can improve diagnostic accuracy and simplify repair support while supporting digital circular economy aims [1]. However, her study also found various barriers, including inadequate repair knowledge, unhealthy maintenance of devices, and limited value of repairs, which inhibit widespread adoption. Similarly, L. Arnemann et al. studied AI-supported product repair and redesign using unsupervised machine learning to enhance data retrieval and fault identification [2]. They noted that testing in real human- device interactions was still limited. These findings suggest that while AI has great potential for automating repairs, turning theoretical ideas into practical digital solutions is still a work in progress.

These studies closely match EcoNova's goal of using AI for automated classification, repair guidance, and lifecycle management of consumer electronics.

2. LITERATURE SURVEY

A. *Comprehensive Analysis of Research Papers*

The Comprehensive analysis of 6 research papers is shown in below table. This analysis includes key areas such as AI- powered diagnostics for electronics repair, product life maintenance, and predictive maintenance. The algorithms or models used, the main issues resolved, the salient characteristics, and the particular research gaps noted in the "Conclusion & Future Work" sections are all described in detail in each entry.

Author & Year	Title	Algorithms / Models	Challenges	Key Features	Gap (Conclusion & Future Work)
Nazli Terzioğlu (2025)	*AI-powered consumer electronics repair towards a digital circular economy*	AI capabilities for diagnostics and repair support	Multifaceted barriers to repair, including technical knowledge, emotional factors, and perceived value	Enhanced urban planning accuracy and improved decision-making frameworks	Improve predictive analytics and facilitate sustainable urban development [1]
L. Arnemann et al. (2025)	*Information retrieval for AI-supported product repair and re-design*	Unsupervised Machine Learning	Repair data retrieval complexity, identifying meaningful failure patterns for redesign	AI application in product repair and redesign	Limited evaluation in real human- device interactions [2]
Izabela Rojek et al. (2025)	*Artificial Intelligence Applications in Industry 4.0: intelligent manufacturing and electronic repair*	ML or AI models for prediction and diagnostics	Data complexity, model accuracy, integration into production lines	AI-driven predictive analytics, diagnostics, and repair decision support	Lacks quantitative outcome metrics across repair scenarios [3]
Angela Barriga et al.	*AI-powered model repair: an experience report—lessons learned, challenges, and opportunities*	ML and reinforcement learning methods	Automating model repairs, ensuring accuracy, handling model inconsistencies	Analysis of lessons learned, identification of current challenges and opportunities	Model validation on complex failures not addressed [4]
AV Shreyas Madhav et al	*Application of AI to enhance collection of E- waste: A potential solution for household WEEE collection and segregation in India*	Deep Learning (VGG-16, Mod-ResNet50)	E-waste categorization, dataset limitations, robotic integration	rCubeBot for AI-driven e-waste sorting, high image classification accuracy	Need for expanded datasets and improved real-time deployment [5]

TABLE I. Literature Review Summary of Related works

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3. Problem Statement

The rapid growth of electronic devices usage among peoples and technological advancements has led to a drastic increase in electronic waste (e-waste) globally. Most consumers replace old gadgets on a regular basis unaware that they could be easily fixed, leading to nearly 12% of household e-waste generation worldwide and toxic materials of that electronic is quite harmful to the environment. Despite numerous recycling initiatives, the lack of awareness, limited repair culture, and absence of accessible green shopping options leads to worsen the problem. Currently, there is no integrated platform that helps a user from buying domestic electronics to maintain through effective maintenance, until offering help while it repaired. Apart from that it simultaneously educates users. As a result, valuable resources go to waste, and environmental damage escalates. The EcoNova+ system aims to bridge this gap by developing an AI-powered web-based platform that helps users repair, recycle, and make green purchasing decisions while tracking the entire lifecycle of electronic products. This approach promotes sustainability, reduces e-waste, and supports a green economy.

A. E-Waste Growth and Environmental Impact

Rapid increase in discarded less faulty domestic electronics due to lack of perfect guidance.

- Disposal of electronics causing soil and water pollution through heavy metals.

B. Lack of Consumer Awareness and Repair Culture

- Limited awareness of local repair guidance.
- Consumers prefer replacing rather than repairing devices.
- Insufficient education about eco-friendly product selection and recycling.

C. Gaps in Existing Systems

- Current e-waste recycling systems are lacking a clear guidance and it is fragmented.
- Absence of platforms that combine repair guidance, green shopping, and lifecycle tracking.

D. Need for AI-Based Green Solutions

- Artificial Intelligence can recommend eco-friendly alternatives and repair suggestions by understanding the exact problem through NLP.
- Predictive models can analyze product lifecycle and advise when to repair or update.
- AI integration helps automate awareness, sustainability tracking, and smart recommendations, which leads to proper A to Z platform.

E. Proposed Solution: EcoNova+ Platform

- Development of a unified web-based platform that enables users to:
  - Identify repair steps for electronic products and give an idea whether it could be reused or not.
  - Discover eco-friendly and sustainable shopping alternatives while shopping.
  - Track lifecycle of each product and suggest maintenance.
- Supports users to get understanding and units through a connected ecosystem.

Fig. 1. Core Modules of EcoNova+

4. Algorithms and Models

This section describes the core algorithms and models intended for implementation in the development of the AI Repair Assistant system. The project integrates natural language processing, decision-making frameworks, to provide an awareness of a product's environmental impact and future repairability.

A. Natural Language Processing for Intent Classification

- The diagnostic system's lies in an intent classification module which interprets users' problem descriptions to categorize the type of issue they are experiencing. This is accomplished through fine-tuning a transformer- based language model, specifically BERT (Bidirectional Encoder Representations from Transformers).

B. Rule-Based Decision Tree for Diagnostic Guidance

Following the classification of the problem type, the system employs a rule-based decision tree to guide users through a series of diagnostic questions and troubleshooting steps. The decision tree is encoded as a structured JSON in database, defining nodes with questions, possible user responses, and next steps.

This approach ensures:

- Interpretability: Each decision and step in this process is clear and can be adjusted to fit your needs, so you always know why something happens.
- Safety: If things get complicated, the system stops and advises you to get professional help to keep you and your device safe.
- Efficiency: For common and simple problems, you get quick understanding and easy-to-follow guidance that helps you fix issues.

The decision tree traversal algorithm works by matching user responses at each node and advancing through the tree until a final solution or escalation recommendation is reached.

C. Geospatial Algorithms for Repair Shop Recommendation

When issues cannot be resolved via DIY steps, the system directs users to local repair centres using geospatial analysis. Locations of verified repair shops are stored with latitude and longitude coordinates.

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To provide proximity-based recommendations, the system calculates distances between the user's location and each repair centre using the Haversine formula, which determines the great-circle distance between two points on a sphere given their longitudes and latitudes:

$$d = 2r\ arcsin(\sqrt{sin^2\left(\frac{\Delta\phi}{2}\right) - \cos\phi 1\ \cos\phi 2\ \sin^2\left(\frac{\Delta\phi}{2}\right)})$$

where ϕ and λ represent latitudes and longitudes respectively, and r is Earth's radius.

The system filters and ranks repair shops within a specified radius, ensuring users receive relevant and convenient options.

D. Weighted Scoring for Eco-Friendly Product Recommendations

The EcoNova+ module provides an ecoScore that is determined by combining several factors, the EcoNova+ module recommends environmentally friendly products. These elements include energy efficiency ratings (Energy Star) for each product, environmental certifications (such as EPEAT), and repairability (derived from iFixit scores).

The ecoScore is computed using following combination:

$$EcoScore = 0.4 \times Repairability + 0.3 \times EPEAT + 0.3 \times EnergyStar$$

Repairability: Evaluates how simple it is to fix the device by considering factors like parts availability and repair documentation.

EPEAT: The Electronic Product Environmental Assessment Tool, or EPEAT, is a global certification that rates products according to how environmentally sustainable they are throughout their lifecycle.

EnergyStar: The U.S. Environmental Protection Agency's EnergyStar certification designates goods that meet strict energy efficiency, and reduce power consumption, and greenhouse gas emission.

This approach enables the system to provide transparent, quantifiable guidance, helping users make environmentally conscious purchasing decisions.

E. Scheduling and Notification Algorithm for Lifecycle Maintenance

To extend the life of devices, the system includes a lifecycle maintenance module that tracks device purchase and service dates. Preventive maintenance notification are scheduled with simple date arithmetic algorithms.

This multi-algorithm approach leverages the strengths of modern NLP, classical decision trees, geospatial computation, and weighted scoring to deliver a comprehensive assistive system for household electronic device care. The combination of machine learning and rule- based techniques balances accuracy, interpretability, and user safety.

5. Proposed System

The proposed system, EcoNova+, is an AI-powered web- based platform that encourages responsible and sustainable domestic electronic usage. It act as one-stop shop where customers buy, repair and get maintenance remainders. The main objective of EcoNova+ is to reduce the growing problem of electronic waste (e- waste) by encouraging users to extend the lifespan of their devices rather than discarding them in repairable conditions. Through advanced artificial intelligence and machine learning algorithms, the system analyzes user input description, product information, and device conditions to provide personalized repair suggestions, eco-conscious shopping options, and lifecycle tracking for each product.

Key Features of the Proposed System

A. AI-Based E-Waste Repair Advisor:

EcoNova+ uses an AI model trained to recommend repair steps or techniques for malfunctioning or fault electronic devices on user's data and product repair maunals. product repair manuals and user-generated data to suggest repair methods for faulty or outdated electronic devices. The system provides step-by-step repair instructions, or nearby repair shop recommendations if needed expert intervention, and alternative part replacement options.

B. Green Shopping Recommendation Engine:

The platform also integrates a recommendation system that suggests eco-friendly or energy-efficient alternatives for the product user searching. These suggestions are based on lifecycle analysis, product ratings, and verified sustainability standards to ensure genuine "green" shopping experiences.

C. Lifecycle Tracking System

With EcoNova+ users can monitor the entire lifecycle of the electronic device — from purchase to disposal. The system sends reminders for maintenance, repair, or recycling when the product nears the end of its usable life, encouraging responsible e-waste management.

D. Web-Based Interface

Since EcoNova+ is built as a responsive web application, it can be accessed on any devices like desktops, tables and mobile phones. For all users interface from different technical backgrounds, it is designed to be simple and easy to navigate.

E Data Analytics and Insights The system collects anonymous data on repair trends, product durability, and recycling habits. These insights can be used by manufacturers, policymakers, and researchers to develop more sustainable products.

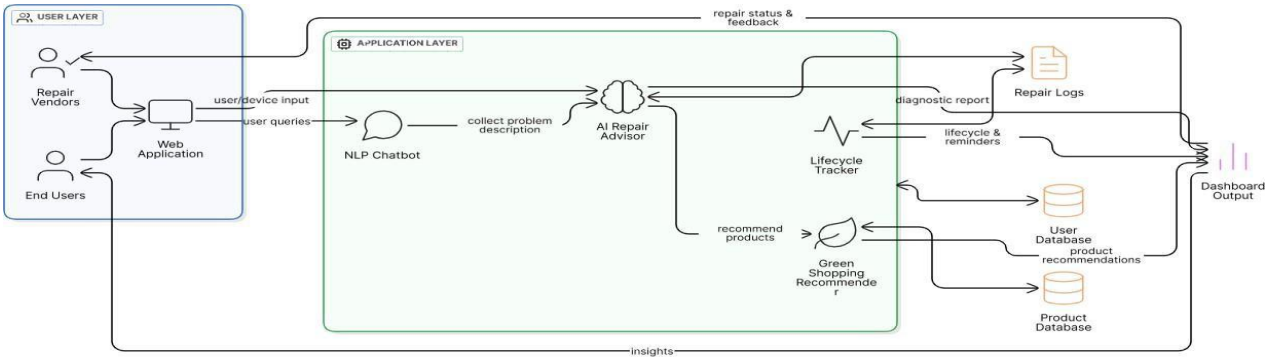

Fig. 2. System architecture of the AI-powered repair and lifecycle assistant

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6. Challenges

A. Data Availability and Quality

EcoNova mostly relies on diverse datasets, such as product repair manuals, e-waste recycling information, and green product databases. However, such data is frequently unavailable in digital formats inconsistent, or incomplete. This restricts the AI model's ability to provide accurate repair suggestions and sustainability assessments.

B. Integration Complexity

API's and databases must be seamlessly integrated in order to connect different modules with completely different purpose. It is technically difficult to achieve seamless data flow between components without lag.

C. Give Data Privacy and Security

EcoNova manages user data such as purchase history, repair logs, and product information. To ensure confidentiality is crucial to make sure this data is encrypted, stored safely and used morally.

D. AI Model Accuracy

The system's performance depends heavily on the accuracy of its AI predictions. Users may be misled by inaccurate repair recommendation or ratings. Continuous training and model optimization are required to maintain reliability.

E. Cost and Resource Requirements

Developing, hosting, and maintaining an AI-powered web application require significant computational and financial resources. Managing servers, data storage, and model updates can increase operational costs, especially as the user base grows.

F. Standardization Issues

E-waste regulations and recycling standards differ across regions and countries. This lack of uniformity makes it hard for EcoNova to provide universally applicable advice or recommendations.

Verification of Green Products

Ensuring that the products recommended as "eco-friendly" are genuinely sustainable is challenging. Many brands engage in "greenwashing," where they falsely claim environmental benefits. Verifying authenticity requires reliable external databases and certifications.

7. Future Enhancements

In the future, EcoNova can be enhanced with several advanced features to make it more intelligent, user-friendly, and globally impactful.Further advancements in **artificial intelligence and machine learning** can improve the system's repair prediction accuracy and sustainability recommendations. Implementing **deep learning and computer vision** can help EcoNova identify damaged parts through image recognition, making diagnostics faster and more reliable. Additionally, the use of **blockchain technology** can enhance transparency by securely recording each product's lifecycle — from manufacturing to disposal — ensuring traceability and building trust among users and manufacturers.
In the future, EcoNova can also collaborate with **manufacturers, authorized repair centers, and recycling agencies** to offer verified services, spare parts, and certified eco- friendly products directly through the platform. To encourage sustainable behavior, a **gamification and reward-based system** can be introduced, allowing users to earn points or discounts for recycling or repairing devices instead of discarding them.

8. Methodology

A. Core Lifecycle Tracking Methodology

- Product Registration: Users register an electronic item (e.g. phone, laptop or any devices).
- Data Points: Purchase Date, Original Price, Estimated Lifespan, Device Category (from a predefined list), and an Eco-score (a unique metric calculated based on its material composition/manufacturer data, if available).

B. Database Structure

- User Table: UserID (PK), Name, Email, RegistrationDate.
  Device Table: DeviceID (PK), UserID (FK), Category, Model, PurchaseDate, InitialEcoScore, CurrentStatus (Active/Disposed).
- Lifecycle_Event Table: EventID (PK), DeviceID (FK), EventType (Repair/Upgrade/Disposal), EventDate, Details_JSON, ImpactScoreChange.
- Green_Product_Catalog Table: ProductID (PK), Name, Manufacturer, EcoRating, Recyclability, Link_to_Purchase.

C. Tools and Technologies for Development

a. Version Control: Git and GitHub
b. Deployment/Hosting: Cloud platform (MongoDB Atlas), Netlify and render for web application deployment.
c. Green Shopping Advisor Logic: Custom Rule-Based System (e.g., implemented in Python) that suggests products based on a user's need, prioritizing products with high Eco-Scores and documented long lifecycles.

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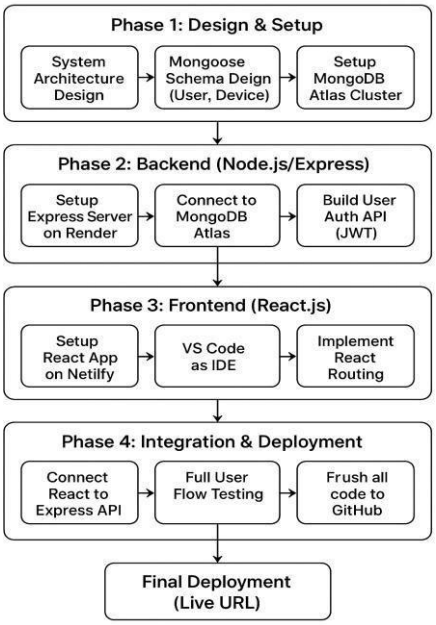

Fig. 3. Application Development

9. Conclusion

EcoNova is an AI-powered online platform that combines lifecycle tracking, repair advice, and green shopping tips to encourage the use of sustainable electronics. EcoNova empowers environmentally conscious choices by involving users throughout the entire product lifecycle, from repair decision- making to final responsible disposal, in contrast to traditional e- waste solutions that only concentrate on recycling. The system's diverse effects include fostering social responsibility, assisting neighborhood repair companies, and lowering greenhouse gas emissions through prolonged product use. EcoNova serves as a model for utilizing

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