Integrating AI Smart Paper Waste Management into Epson L121 Printer for Educational and Office Use

A project Study

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In offices and schools, a lot of paper is consumed daily. Individuals frequently print worksheets, reports, and other papers. The paper is used once and discarded most of the time. This results in a very severe paper waste issue. At the same time, printing remains crucial for everyday activities in education and office settings. Due to this, there is a demand for intelligent and environmentally friendly printing options. This study centers on adapting an AI Smart Paper Waste system to the Epson L121 printer. The Epson L121 is an inexpensive and commonly used printer in most schools and small businesses. Adding smart features to this device makes it possible to minimize paper waste while enhancing printing behaviors without the need for expensive gear. The AI Smart Paper Waste system is programmed to identify clean, reusable paper. Where one side of a page is printed while the other side remains blank, the system will recognize this and allow for the reuse of the paper. It is wastepaper-free, saves paper, and reduces the cost of printing. The AI can also track the usage of paper and offer useful information about the habits of printing. Another key component of this project is the Smart Paper Usage Tracker. The system addresses routine issues in schools and offices where users tend to print without verifying their files, thus resulting in reprints. A few users even print a document multiple times due to errors or formatting problems. Others print everything in high-quality mode always, even when it is not required. These practices lead to a lot of waste paper and ink, particularly when printing on community printers such as the Epson L121.

Technology has made a great contribution to increased efficiency in many areas, including logistics such as In offices and schools, printers are employed on a daily basis to print worksheets, reports, forms, and other essential documents. Yet, this frequent use tends to produce a lot of waste paper. Excessive paper usage in offices, as cited by Shah, Amjed, and Alkathiri (2019), not only raises the cost of doing business but also causes environmental degradation, and therefore, more sustainable approaches are needed. Sometimes one side of the paper is utilized while the other side remains blank and is thrown away. All these trends justify the increasing issue of paper wastage and increased printing costs, especially when shared common printers like the Epson L121 are used. The Epson L121 is a favorite among inkjet printers because it is cheap and has a basic design and thus has widespread use in schools and small businesses. Nonetheless, the excessive use of such printers contributes to environmental pressure, so sustainable printing and paper recycling technologies are more critical (Ono et al., 2020).

Nonetheless, like other outdated printers, it lacks smart capabilities to control or reduce paper usage. It is difficult to track or restrict print activity that leads to wastage.With the emergence of artificial intelligence (AI), it is possible to create smart systems that can monitor user activities, identify reusable paper, and suggest better printing habits.AI can be programmed to identify unused or blank sides of printed sheets through scanned documents, enabling users to reuse paper more effectively and cut down waste. It can even track habitual printing errors such as misprints, low-ink warnings, or habitual jobs, and alert users prior to repetition of the same fault. The AI, in turn, can make real-time suggestions such as duplex printing on and off, adjusting margins, or merging documents to conserve paper as well as ink (Vasudevan, 2024). Such a product is not only inexpensive but also eco-friendly.

The study aims to integrate an AI-driven Smart Paper Waste system into the Epson L121 printer. Along with the AI system, a Smart Paper Usage Tracker will be created to track and analyze users' printing behavior over time. This tracker will gather metrics like the number of prints made per page, the number of one-sided vs. two-sided prints, and error patterns that are most frequent. The project, by combining the AI system with the usage tracker, hopes to have a dramatic decrease in wastage of paper and ink, encourage responsible and efficient usage of printing, and provide a smarter, environmentally friendly printing solution for schools and office settings (Schroth et al., 2022).

Innovative technologies like Artificial Intelligence (AI) and Machine Learning (ML) play a vital role in advancing the adoption and implementation of the circular economy in real-world applications . These technologies enhance the efficiency and effectiveness of various processes within circular models, including reverse logistics, waste management, resource optimization, and predictive maintenance . For instance, AI can automate the sorting of recyclable materials using computer vision, optimize collection routes to reduce fuel consumption, and predict when products or components are reaching end-of-life to facilitate timely recovery and reuse. Meanwhile, ML algorithms can analyze patterns in consumption, production, and disposal to support decision-making that minimizes waste and maximizes resource value (Noman et al., 2022). By integrating AI and ML into circular economy systems, organizations can better close the loop on materials, reduce environmental impact, and promote long-term sustainability.

The application is designed to serve both individual users and administrative stakeholders within an organization. Members of the lecturers and staff group are provided with personalized access to the system, enabling them to monitor and review their own printing and photocopying data. This includes detailed information such as the number of pages printed or copied, the types of documents processed, and the time and frequency of usage. By making this data accessible, the application encourages individual users to become more conscious of their paper consumption and adopt more environmentally responsible printing habits (Saetang et al., 2024). In contrast, executive or administrative users are granted broader access through a centralized dashboard interface. This dashboard aggregates data across all users within a department, office, or institution, offering a comprehensive view of overall printing and photocopying activity. Key metrics such as total paper usage, most active users, peak printing times, and usage trends over time are visualized through intuitive charts and graphs. This level of visibility empowers decision-makers to identify inefficiencies, set paper reduction goals, implement usage policies, and promote accountability among staff .

Paper has long been recognized as a material that can be reused to support the sustainable management of biomass resources, making it a promising option for environmentally friendly practices. However, while paper recycling is beneficial in reducing waste, it also presents significant environmental challenges. Traditional recycling methods often involve high energy consumption, particularly during the pulping and bleaching processes, as well as transportation inefficiencies associated with moving paper from collection points to large recycling facilities. These factors contribute to increased greenhouse gas emissions and resource use, somewhat offsetting the environmental benefits of recycling. To address these concerns, there is growing interest in the development and adoption of innovative recycling technologies that reduce these burdens. This study assessed a new paper recycling system, designed to be implemented directly within office environments, using a lifecycle assessment approach to evaluate its environmental impact. Unlike traditional methods, this technology does not require water-intensive pulping or chemical bleaching. In fact, it can reduce water consumption by over 90% compared to the conventional dry recycling process. Additionally, by eliminating the need for external transportation to recycling plants, the system significantly cuts CO_2 emissions related to logistics and handling (Ono et al., 2020).

The machine is designed to transform used paper into new, reusable sheets, effectively turning waste into a valuable resource. By implementing this technology in educational institutions such as schools, it can lead to significant cost savings by reducing the need to purchase new paper supplies. In addition to the financial benefits, the machine also contributes to environmental sustainability by minimizing paper waste and lowering the demand for new paper production. This process not only reduces pollution and carbon emissions associated with traditional recycling and manufacturing but also encourages a more circular and eco-conscious approach to resource use within the school system (Tumbagahan, 2025).

This demonstrates that Philippine small and medium-sized enterprises (SMEs) are already beginning to leverage artificial intelligence (AI) in their environmental sustainability practices, providing a credible and relevant local precedent for the adoption of similar technologies (Hernandez et al., 2023). Such examples validate the feasibility and impact of implementing AI-driven monitoring systems, like the proposed Smart Paper Usage Tracker integrated with the Epson L121 printer. By aligning with these emerging trends in the local business landscape, the project strengthens its relevance and supports the broader goal of promoting sustainable resource management through intelligent automation.

The commercial printing industry is undergoing a significant transformation with the integration of Artificial Intelligence (AI), yet there is limited literature on its specific applications and impact. This systematic review addresses two critical research questions: What are the key industrial domains where AI is applied in the printing industry, and what are the associated benefits and challenges? The study identifies the primary AI applications across Production Planning and Control (PPC), Quality Management (QM), Maintenance Management (MM), and Supply Chain Management (SCM). PPC employs optimization algorithms to optimize scheduling and resource allocation, improving production efficiency. In QM, Machine Learning and Computer Vision detect defects and optimize print quality. MM focuses on minimizing downtime by ensuring machines operate efficiently through predictive maintenance. Despite these advancements, challenges such as high-quality data requirements, algorithmic complexity, and integration difficulties persist (Muhammad & Zakaria, 2024).

We have identified a significant underutilization of data generated by paper machines, which represents a missed opportunity for improving operational efficiency and sustainability. To address this gap, we propose the implementation of a conceptual framework that leverages an operator assistance system, enhanced by state-of-the-art machine learning techniques. These techniques include classification algorithms to identify patterns and anomalies, forecasting models to predict operational trends, and alarm flood handling algorithms to manage and prioritize alerts effectively (Schroth et al., 2022). By integrating these intelligent tools into daily workflows, the system aims to provide real-time, data-driven support to machine operators. As a result, operators will be better equipped to adjust machine parameters with greater accuracy, leading to improved performance and a reduced environmental footprint of the paper production process. This approach aligns with ongoing efforts to digitalize industrial operations and supports the broader goal of sustainable manufacturing .

The study titled “Printing Defect Detection Based on Scale-Adaptive Template Matching and Image Alignment” introduces a novel approach for identifying defects in printed materials by combining Convolutional Neural Network (CNN) feature maps with image alignment techniques. CNNs are utilized to extract rich, hierarchical features from printing samples, which enables the system to detect subtle and complex defect patterns. The method incorporates scale-adaptive template matching, allowing it to effectively handle defects of varying sizes and shapes by dynamically adjusting the matching process based on the defect scale(Liu et al., 2023). Furthermore, image alignment is employed to accurately overlay templates onto the target images, reducing false positives caused by misalignments or distortions. The integration of these techniques results in a robust defect detection system that achieves an impressive accuracy rate of 93.6%, highlighting its reliability and effectiveness in real-world printing environments. This high level of precision can lead to significant improvements in quality assurance workflows by enabling early detection of defects, reducing waste, and minimizing manual inspection efforts. Overall, this approach exemplifies how advanced machine learning and computer vision methods can be harnessed to enhance automated inspection processes in the printing industry, supporting higher product quality and operational efficiency .

The integration of IoT-based smart waste management systems empowers municipalities to harness real-time data for a comprehensive understanding of waste generation and flow across urban areas. By deploying connected sensors within waste bins and on collection vehicles, cities gain the ability to continuously monitor fill levels, enabling dynamic scheduling of waste pickups based on actual need rather than fixed timetables. This approach optimizes collection routes, significantly reducing unnecessary trips, which in turn cuts operational costs and decreases fuel consumption. Beyond cost savings, this data-driven system contributes to environmental sustainability by minimizing carbon emissions associated with waste collection vehicles. It also improves service quality by preventing bin overflow, thereby helping to maintain cleaner, healthier urban environments and enhancing residents' quality of life. Moreover, IoT platforms often incorporate predictive analytics, allowing city planners to anticipate fluctuations in waste generation caused by factors such as population growth, seasonal events, or commercial activity.

These insights enable more strategic allocation of resources and infrastructure planning, ensuring the waste management system remains efficient and scalable (Dr Thangavel, 2024).

Printing is a fundamental component of numerous industries, including manufacturing, banking, commercial enterprises, public education, and government administration. It supports critical business operations by enabling the production of contracts, reports, marketing materials, instructional documents, and official records. Despite its importance, the printing industry faces significant environmental challenges primarily due to the substantial volume of solid and liquid waste it generates during routine operations. Solid waste from printing processes typically includes excess paper, used cartridges, packaging materials, and defective printouts, while liquid waste comprises chemical solvents, inks, toners, and wastewater containing harmful pollutants. Many of these substances contain hazardous components such as heavy metals and volatile organic compounds (VOCs), which, if not properly managed, can contaminate soil and water bodies, posing risks to ecosystems and human health. Moreover, the energy-intensive nature of printing processes contributes indirectly to environmental degradation through greenhouse gas emissions. As printing demands continue to grow with expanding business and administrative needs, the cumulative environmental footprint becomes increasingly significant. These issues underscore the urgent need for the industry to adopt sustainable printing technologies, waste minimization strategies, and effective recycling programs (Garcia, Datta, & Pili, 2016).

Significance of the Study

The integration of AI-powered smart paper waste management into the Epson L121 printer presents a timely and practical solution for promoting sustainability and efficiency in both educational and office environments. This study is significant for several key stakeholders:

1. Student

- Promotes **environmentally responsible behavior** by providing real-time notifications on paper usage, highlighting excessive or duplicate printing.
- Encourages **awareness and mindfulness** in printing practices, helping users develop sustainable habits.

Reduces printing errors and waste by identifying problematic documents before reprinting.

2. Educators

- Functions as a complementary tool to traditional teaching methods, especially in coding and technical disciplines.
- Minimizes repetitive tasks such as code review or document checking, enabling educators to concentrate on deeper instructional engagement.

Delivers data-driven insights and adaptive feedback, supporting personalized student learning and performance tracking.

3. Educational Institutions

- Aligns with the increasing integration of AI technologies in academic environments, enhancing the institution's image as an innovator in education.
- Helps address the growing demand for efficient digital and coding education by supplementing limited teaching resources.
- Contributes to improved learning outcomes by increasing student engagement and reducing resource waste.
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4. Researchers and Developers

- Serves as a foundational framework for future research in the use of AI—particularly transformer-based language models—in educational applications.
- Highlights challenges and opportunities in AI-assisted learning, offering direction for the evolution of intelligent tutoring systems.

As environmental sustainability and resource efficiency become increasingly important in both academic and professional settings, this study proposes the integration of an AI-powered Smart Paper Waste Management system into the Epson L121 printer. The aim is to address the persistent issue of paper waste due to redundant printing, user error, and inefficient document handling by leveraging artificial intelligence to monitor, analyze, and optimize printing behavior.

Despite the rise of digital tools, printed materials remain essential in classrooms, administrative offices, and workplace environments. However, uncontrolled printing often leads to excessive paper use, misprints, and resource inefficiencies. Students and office personnel frequently print duplicate files, unoptimized layouts, or incomplete documents, contributing to unnecessary waste and higher operational costs. Existing printers, particularly entry-level models like the Epson L121, lack the intelligence needed to prevent such waste or to guide users in making eco-conscious printing decisions.

Moreover, institutions and businesses face growing pressure to adopt greener practices and align with sustainability goals. Yet, many lack affordable and scalable solutions that promote responsible printing without compromising functionality or user convenience. Educators and administrators, in particular, struggle with balancing the need for physical materials while minimizing environmental impact and managing limited budgets.

This study addresses these gaps by developing a cost-effective and AI-integrated solution that enhances the Epson L121 printer with smart paper waste management capabilities. The system will deliver real-time feedback on print jobs, detect errors or duplicate submissions, and encourage sustainable habits through intelligent notifications and data-driven insights. By transforming a widely used budget printer into a smart, eco-friendly device, the study seeks to improve operational efficiency, promote sustainability, and support responsible printing behavior in both educational and office environments.

To guide the development and evaluation of the AI Smart Paper Waste Management system for the Epson L121 printer, this study aims to answer the following research questions:

1. How can artificial intelligence be effectively integrated into the Epson L121 printer to monitor, analyze, and reduce paper waste in real-time?
2. What methods can be used to provide users with actionable feedback on their printing behavior to encourage more sustainable and efficient practices?
3. How does the implementation of AI-powered paper waste management impact overall paper consumption and user awareness in educational and office environments?
4. What are the technical and practical challenges in integrating AI features into a basic printer model like the Epson L121, and how can these be addressed?
5. How can the system adapt to different user types (e.g., students, educators, office staff) to ensure personalized and effective waste reduction strategies?

This study aims to develop an AI-integrated software system for the Epson L121 printer that intelligently monitors and analyzes printing activities to minimize paper waste in both academic and professional environments. By leveraging artificial intelligence and real-time data tracking, the system seeks to encourage users to adopt more efficient and sustainable printing habits.

1. To design a PC-based application using Python that logs all print jobs from the Epson L121 printer.
2. To analyze user print behavior using basic AI models (e.g., rule-based logic or clustering).
3. To provide real-time notifications and suggestions for improving printing efficiency (e.g., reminders to use “Print Preview” or “Draft Mode”).
4. To evaluate the effectiveness of the system in reducing paper waste among student users.
5. To integrate additional monitoring features such as alerts for low paper supply and detection of paper jams (optional).

The conceptual framework for this study illustrates how an AI-powered smart paper waste management system can be integrated into the Epson L121 printer to promote sustainable and efficient printing practices in educational and office environments. The framework is organized into three core components: Input, Process, and Output—each representing a critical stage in the system’s functionality.Input refers to the collection of printing data, including document type, page count, user behavior, and frequency of print jobs.

Process involves the application of AI models—such as rule-based logic or lightweight machine learning algorithms—to analyze print patterns, detect redundancies, and generate real-time recommendations. Output consists of actionable feedback for users, such as alerts about duplicate printing, suggestions for draft mode, and paper-saving reminders.The framework also incorporates a feedback loop, allowing the system to continuously adapt based on user interactions and behavioral changes. This iterative refinement ensures that the system remains effective over time, supporting institutions and individuals in building long-term sustainable printing habits.

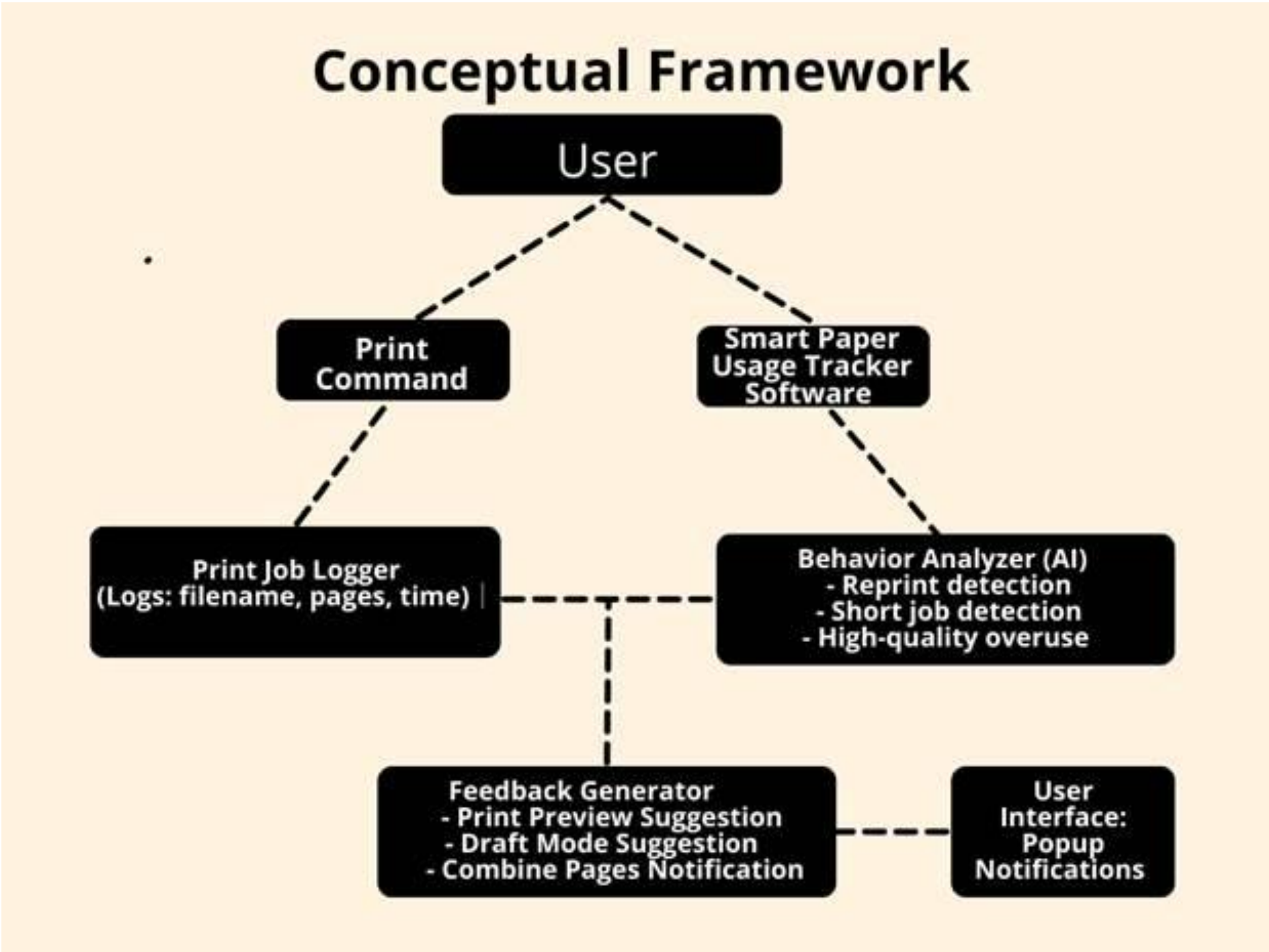


Figure 1(Conceptual Framework)

Figure 1 presents the conceptual framework for the integration of an AI Smart Paper Waste Management system into the Epson L121 printer. It outlines the system's development and implementation process across three key stages: Input, Process, and Output.The Input stage includes essential data such as print job details (e.g., document type, number of pages, frequency of printing), user printing behaviors, and system status indicators (e.g., low paper warnings or paper jams). It also includes the integration of AI components such as rule-based logic or machine learning models, which enable the system to analyze and interpret user habits.The Process stage focuses on the core functionality of the system: analyzing printing behavior using AI, identifying inefficient or redundant print patterns, and generating real-time suggestions for improved efficiency—such as reminders to use print preview or avoid reprinting similar documents. The system also monitors performance metrics and evaluates changes in user behavior over time.The Output stage highlights the expected outcomes of the system, including reduced paper consumption, increased user awareness of sustainable practices, and improved operational efficiency in educational and office environments. Additionally, the system provides support to administrators and educators through usage data and sustainability reports.A feedback loop is integrated into the framework to ensure continuous refinement of the AI system. This loop allows the system to evolve based on user responses, performance results, and environmental factors, enhancing its effectiveness over time.

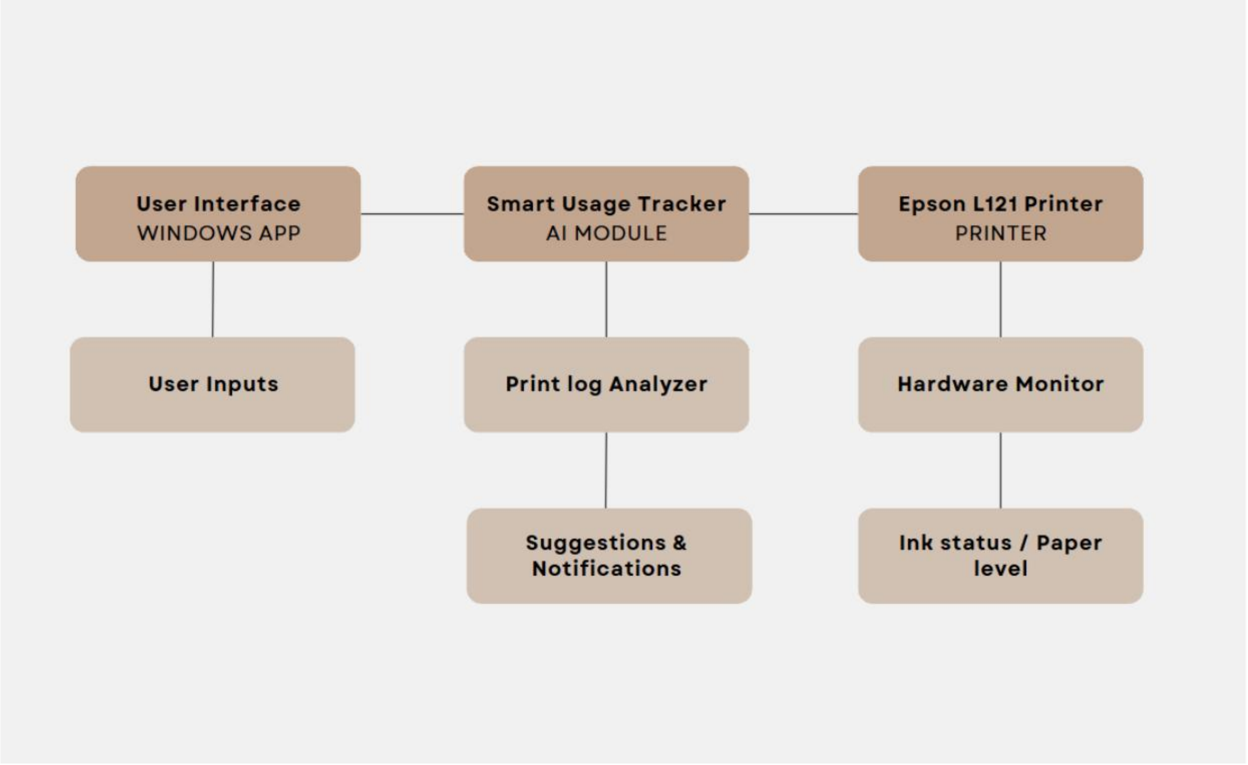
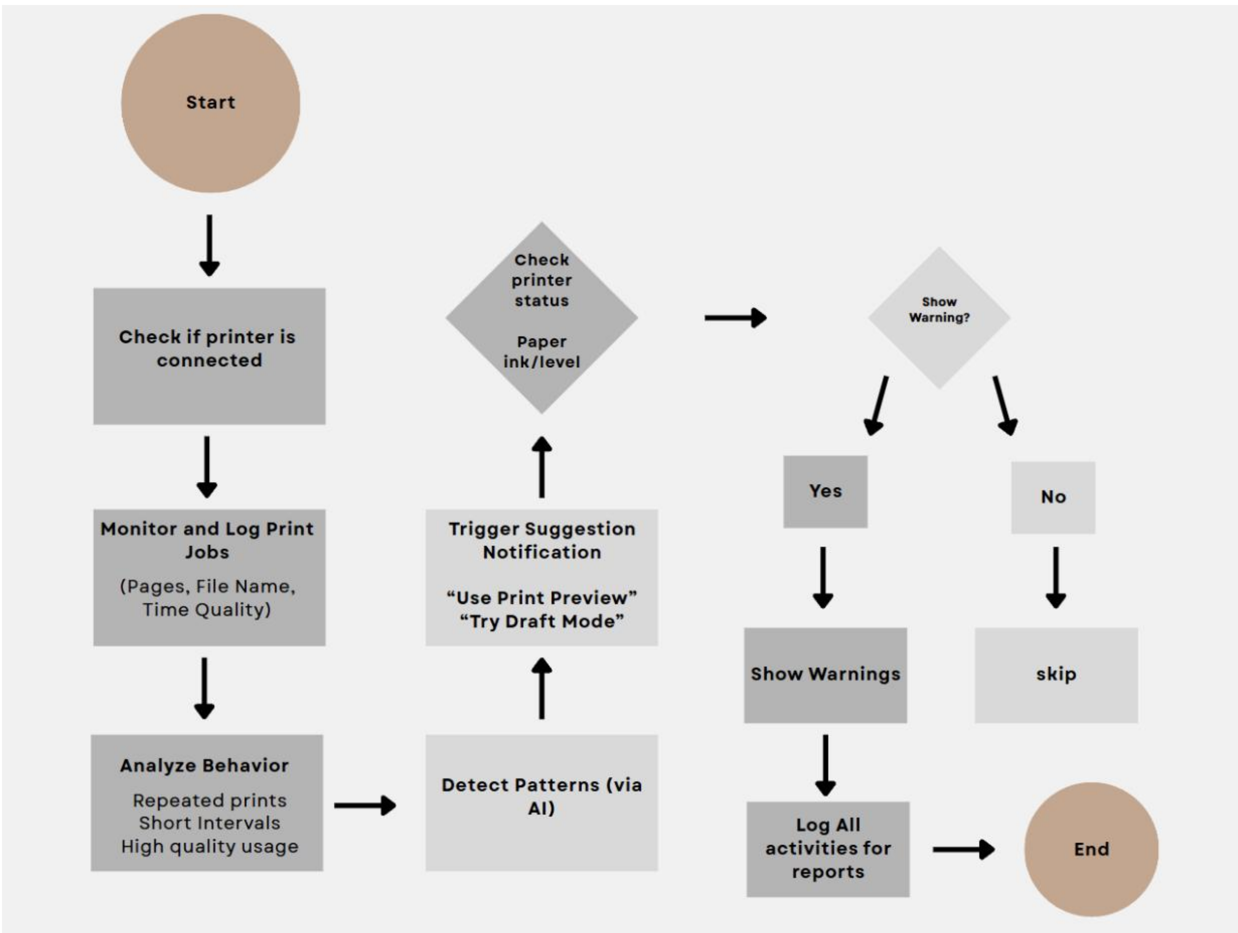


Figure 2 (System's Block Diagram)

The system block diagram illustrates the interaction between three major components: the User Interface (Windows App), the Smart Usage Tracker (AI Module), and the Epson L121 Printer. The User Interface allows users to provide inputs or commands through a Windows application. These inputs are then sent to the Smart Usage Tracker, which acts as the brain of the system. The AI module processes these inputs and monitors print behavior through a Print Log Analyzer, enabling it to offer meaningful suggestions and notifications to reduce waste. On the hardware side, the Epson L121 Printer is monitored via a Hardware Monitor that collects data such as ink levels and paper usage. This data is sent back to the AI module for analysis. The Smart Usage Tracker connects the software inputs and hardware feedback,



allowing it to offer smart interventions like print behavior tracking and predictive maintenance suggestions. This ensures efficient resource usage and minimizes paper and ink waste.

Figure 3 (System’s Flow Chart)

The flow chart outlines the sequential operations of the smart print management system. It starts by checking if the Epson L121 printer is connected. Once confirmed, the system begins to monitor and log print jobs—recording important data such as file name, number of pages, print quality, and time of printing. This data is then used to analyze user behavior, identifying patterns like repeated prints, unnecessary high-quality usage, and frequent short interval print jobs. The system's AI module detects patterns from the logged data and triggers smart suggestions such as "Use Print Preview" or "Try Draft Mode." Simultaneously, it checks printer status. If anomalies or inefficient usage are detected, it decides whether to show warnings to the user. If warnings are shown, all activities are logged for reporting and analysis purposes. If not, the user may skip, and the process ends. This structured approach enables proactive guidance and waste reduction, fitting perfectly for school and office environments where excessive printing is common.

The Smart Paper Usage Tracker supports the Sustainable Development Goals by promoting responsible consumption (SDG 12), fostering innovation in basic infrastructure (SDG 9), and enhancing educational efficiency (SDG 4). Through AI-powered monitoring and real-time suggestions, it minimizes printing waste, integrates smart technology into office routines, and encourages sustainable habits in schools and workplaces—ultimately contributing to a more efficient, informed, and environmentally conscious community.

1. SDG 12: Responsible Consumption and ProductionThe Smart Paper Usage Tracker directly contributes to SDG 12 by promoting more efficient and mindful consumption of paper and ink—resources commonly overused in academic and office settings. By monitoring user behavior and delivering real-time suggestions, the system helps reduce unnecessary reprints, low-efficiency printing practices, and wasteful habits. It also encourages users to adopt sustainable alternatives such as draft mode, double-sided printing, and document previewing. Over time, this behavior change leads to a culture of environmental responsibility and contributes to minimizing the ecological impact of printing activities across institutions.
2. SDG 9: Industry, Innovation, and InfrastructureThis system integrates modern artificial intelligence into a traditionally manual process, transforming ordinary printing into a smart and adaptive activity. By using

rule-based AI or machine learning to analyze print behavior and optimize user performance, the project demonstrates how technology can enhance everyday infrastructure. The system serves as an example of accessible innovation that can be implemented even with basic office printers like the Epson L121, bridging the gap between legacy hardware and smart technology. Its low-cost, software-driven approach supports scalable and inclusive digital transformation for both educational and office environments.

3. SDG 4: Quality Education By minimizing printing errors and material waste, the system allows students, teachers, and staff to focus more on meaningful academic tasks rather than printer-related issues. It reinforces digital literacy and responsible usage habits among students, which are essential competencies in modern educational and professional contexts. Furthermore, the system provides schools with opportunities to allocate saved resources toward improving learning materials, facilities, or digital tools. In this way, the project not only enhances operational efficiency but also supports the broader goal of inclusive and equitable quality education.

Methods

This study adopts a developmental research design focused on the creation, implementation, and assessment of an AI-powered Smart Paper Usage Tracker integrated into the Epson L121 printer. The goal of this research is to address the growing issue of paper and ink waste in educational and office settings by developing a system that encourages responsible and sustainable printing habits through intelligent monitoring and behavior-based suggestions.The research begins with a planning phase that includes understanding the needs of the target users—primarily students and office staff—through observations and informal conversations. These preliminary activities help identify common issues such as excessive reprints, inefficient printer settings, and lack of user awareness about waste.

Alongside this, a review of related systems and sustainable practices in printing provides additional insight into effective solution design.Once the groundwork is laid, the development phase focuses on building the actual system. The software is programmed using Python, leveraging Windows-based tools such as print spooler logs and print job monitoring APIs. The system records key data including the number of pages printed, the file name, print quality settings, and timestamps. A rule-based AI or simple logic-based model is used to detect repetitive or inefficient behaviors—such as frequent reprinting of the same document or always printing in high-quality mode—and respond with intelligent suggestions. These may include prompts like “Try draft mode” or “Preview before printing.” To support printer reliability, a sensor is added to monitor paper levels and alert users when paper is running low, reducing the chances of failed or incomplete print jobs.

After development, the system is introduced to a real-world environment for testing. A group of student participants will use the system in a computer laboratory or shared printing area. Their experiences, along with system logs and generated reports, are used to assess the tool’s usability, effectiveness in reducing waste, and influence on user behavior. Observations and feedback from participants provide additional data for evaluation.Following testing, the results are carefully analyzed. This includes reviewing user feedback, system performance, and any challenges that arose during deployment. Based on the findings, refinements will be made to improve both functionality and user experience. The research design ensures that the final system not only functions technically but also aligns with the goals of sustainability, efficiency, and educational enhancement.

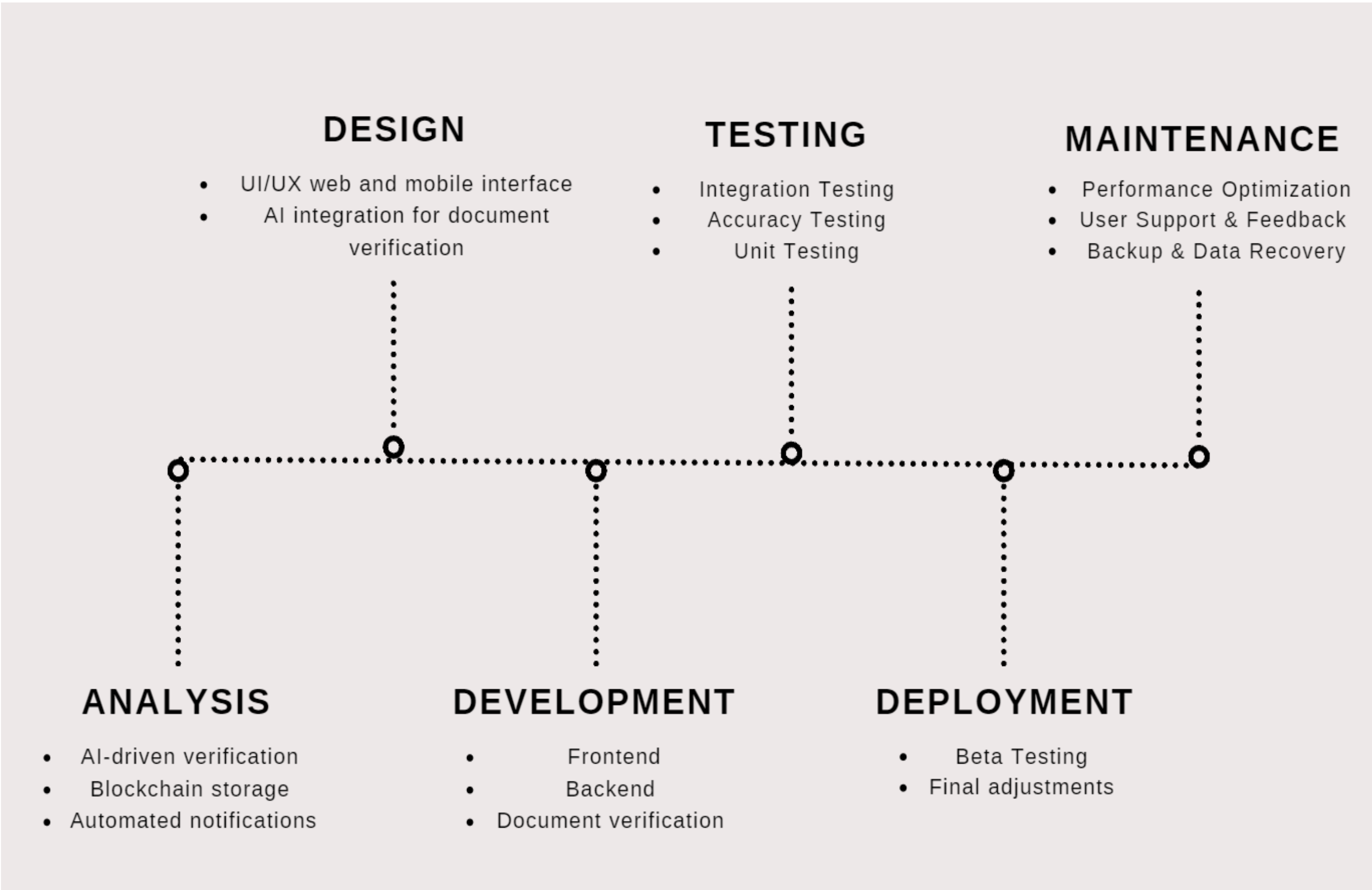


Figure 4 (Software Design and Development)

Primary sources in this research include empirical data gathered from real-time monitoring of printing behavior, user interaction logs, and system-generated reports from the AI Smart Paper Waste Management prototype. Data collected through direct observations, usage analytics, and user feedback from educators, office staff, and IT personnel serve as firsthand evidence of the system's effectiveness in reducing paper waste and optimizing printer usage. The development, implementation, and evaluation phases of the AI-integrated Epson L121 system also provide primary insights into its functionality, accuracy, and practical application in real-world educational and office settings.Secondary sources consist of previously published research, journal articles, and case studies that discuss AI integration in office systems, sustainable printing practices, and environmental impact reduction technologies. These include studies on AI-driven resource optimization, smart printing solutions, and behavior-based waste management systems. Notable references include works on AI for sustainability, digital transformation in educational institutions, and energy-efficient technologies in workplace settings. These secondary sources help frame the study within a broader academic context, support the methodology, and reinforce the system's relevance to Sustainable Development Goals and modern infrastructure innovation.

TOOLS AND EQUIPMENTS

Category	Tools/Materials
Hardware	- Epson L121 Printer
	- Laptop or Desktop (Windows OS)
	- Paper sensor module (optional for jam/paper feed)
	- Ink level checker (manual or sensor-based)
Software	- Python Programming Language
	- win32print or Windows Print Spooler Logs
	- SQLite or CSV for logging print data
	- Tkinter / PyQt (for GUI)
	- Scikit-learn (for AI model, optional)
	- Notification System (Toast/Popup alerts)
Participants	- Students (for user feedback and behavior analysis)

Sources of Data

Primary source of data

1. **User Activity logs**

- Data on number of print jobs, pages printed, file names, and print quality.
- Logs of user interactions with the system (e.g., when suggestions are shown, warnings accepted or skipped).

2. **Printer Hardware Data**

- Real-time data from the Epson L121 printer, including ink levels, paper usage, and device status.

3. **Surveys and Questionnaires**

- Responses from students, educators, and office staff about their printing habits, awareness of waste, and feedback on the AI system.

4. **Structured Interviews**

- Feedback from IT personnel, teachers, and administrative staff regarding the system's effectiveness, usability, and relevance to institutional needs.

5. **Observational Data**

- Recorded behaviors of users before and after system deployment (e.g., frequency of unnecessary print jobs, changes in print settings).

6. **Prototype Testing Results**

- Data collected during alpha and beta testing phases, including system performance, response times, and detection accuracy of the AI module.

Secondary Source of Data

1. **Academic Journals & Conference Papers**

- Studies on AI in resource management, printer monitoring systems, and sustainable office technologies.

2. **Manufacturer Documentation**

- Technical specifications and manuals for Epson L121 printers (e.g., ink usage, paper handling, software interface).

3. **Government & Institutional Reports**

- Data on paper consumption in schools/offices from environmental agencies or educational departments.
- Example: Philippine Department of Education guidelines on sustainability.

4. **Environmental Research Databases**

- Statistics on paper waste, carbon footprint of printing, and case studies on green office initiatives.

5. **Industry Case Studies**

- Real-world applications of smart printing systems or AI-based monitoring in enterprise settings.

The study involves the following groups of participants:

Students and Office Staff: High school students, college students, and office personnel who regularly engage in printing tasks. Participants are selected through purposive sampling to ensure they represent a range of printing habits, from casual to frequent users. A target sample size of 50 to 100 participants ensures reliable data for both behavioral analysis and user experience evaluation.

Educators and Administrators: School teachers, academic coordinators, and office managers who provide valuable insights into printing policies, resource usage, and institutional practices. Their feedback is essential in evaluating how the system impacts overall paper consumption, budget allocation, and operational efficiency.

Technical Experts: IT personnel and AI developers who assess the technical performance of the smart tracking system. Their role is to ensure proper system integration, monitor the AI's behavior detection accuracy, and provide recommendations for software refinement.

AI Smart Paper Usage Tracker: A custom-built system integrated with the Epson L121 printer, capable of logging print behavior, monitoring hardware status (ink and paper levels), and providing intelligent suggestions to minimize waste. The system features a Windows-based interface and an AI module that analyzes printing patterns.

Testing Environment: Classrooms, computer labs, and office workstations where the printer system is actively used. The study includes both on-site and simulated usage to reflect real-world scenarios.

Evaluation Tools: Usage logs, print job analytics, and automated reports to measure efficiency improvements. Surveys, feedback forms, and interview guides are used to assess user satisfaction, system usability, and behavioral changes related to responsible printing practices.

Data Analysis Plan

1. Quantitative Analysis

Descriptive Statistics

Analyze print frequency, pages printed, ink usage, and instances of user suggestions before and after system implementation (mean, median, standard deviation).

Pre- and Post-Implementation Comparison

Use **paired t-tests** or **ANOVA** to compare user behavior and waste levels before and after using the AI system.

Trend analysis

Identify patterns over time (e.g., reduction in unnecessary prints, increase in usage of draft mode or print preview).

User Feedback Scores

Likert-scale responses from surveys (e.g., satisfaction, perceived usefulness) will be summarized and visualized using bar charts and pie graphs.

2. Qualitative Analysis

Thematic Coding

Interview transcripts and open-ended survey responses will be analyzed using thematic coding to identify recurring themes (e.g., ease of use, sustainability awareness).

User Sentiment Classification

Categorize responses into positive, neutral, or negative sentiments to understand user perception.

Standard Set

Sustainability Benchmarks

United Nations SDG 12: Focus on reducing paper and ink waste, promoting responsible consumption.

DepEd Green Schools Program (if applicable): For aligning with institutional efforts on sustainability in the Philippines.

Usability Standards

ISO 9241-210 (Human-centered design for interactive systems): Ensures the system meets user needs and is easy to interact with.

System Usability Scale (SUS): A 10-item scale to quantify user satisfaction.

AI and Software Standards

IEEE 7000-2021: Standards for ethically aligned AI system design.

Software Performance Metrics: Uptime, response time, accuracy of detection (e.g., correct suggestions or alerts), and logging reliability.

Prior Art Search

1. Existing Smart Printing Solutions

HP Smart App and Canon PRINT App offer mobile integration and limited monitoring but lack intelligent waste feedback mechanisms.

PaperCut MF: A commercial solution for print management in institutions, focused on tracking and reporting but not AI-driven behavior feedback.

2. AI in Resource Management

Studies on AI-based energy optimization or smart grid monitoring provide insight into how behavioral tracking improves efficiency—similar principles applied to printing.

Research on smart metering systems in utilities (e.g., water or electricity) shows parallels to monitoring paper usage and providing corrective suggestions.

3. Research Papers & Academic Work

“Smart Print Management System for Office Networks” – outlines basic tracking without AI suggestions.

“AI-Based Monitoring System for Green Offices” – discusses broader frameworks but not printer-specific.

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