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Artificial Intelligence as an Enabler of ESG and Circularity in E-Commerce: A Multi-Case Study of Amazon, HP, and Siemens

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Abstract **Original Research Article**

AI is introducing new changes to business operations in e-commerce, allowing companies to work more efficiently, smartly and speedily. Apart from supporting automation and tailored customer experiences, AI now makes it easier to make supply chains environmentally friendly and motivates the use of smart re-manufacturing. The study looks at the ways AI helps make online businesses operate sustainably and ethically. The use of AI in ESG helps to manage logistics so less fuel is used, checks the energy waste in warehouses, and tries to forecast better consumption of goods. Through AI, social issues in the workplace are addressed by improved safety, fair employment standards and fairness in hiring through absence of bias. AI-based systems assist in improving governance by helping to trace and verify the supply chain on blockchain. In addition, the study looks into smart re-manufacturing which uses advanced technology to bring used products back to nearly new status. With computer vision, predictive analytics and IoT sensors, companies can judge the wellness of things sent back, dismantle them in an automated way and cut back on wasting materials which helps with a circular economy. Reports from HP, Amazon and Siemens show how these technologies make a real difference and can be used in practice. Despite issues related to using AI in business and ethical concerns surrounding its decisions, the research indicates that mixing AI with ESG can help e-commerce become more sustainable. It helps to boost the company's brand, follow important rules and deal with long-term issues relating to society and nature. The authors point out that it is vital for companies to implement systems that support both profits and sustainability which leads to their continued success in an ever-responsible market.

Keywords: AI in E-commerce, ESG, Sustainable Business Operations, Smart Remanufacturing, Supply Chain Optimization.

I. INTRODUCTION

The 21st century has witnessed a paradigm shift in how global trade and commerce operate. E-commerce, once limited to simple online transactions, has evolved into a dynamic, AI-powered ecosystem capable of delivering hyper-personalized services, predictive decision-making, and highly efficient logistics. As digital commerce is expected to reach more than USD 7 trillion by 2025, using AI in e-commerce is required not just as an extra step but a key strategy to help businesses expand and operate more efficiently. AI is commonly used to improve the efficiency of supply chains, automate handling of goods, adjust prices based on the market, deliver support to customers through several channels and obtain prompt results from masses of data. Alternatively, the speedy progress made in e-commerce adds to the issues concerning nature, the workforce and politics. The usual setting of supply chains features simple, consecutive tasks which are not clear and require a lot of effort from both people and material, and this often causes waste, more carbon emissions, and labor standards that could be questioned. Dealing with these problems, world companies and officials depend on following ESG guidelines as the best practice. Firms try to make positive changes using these frameworks, focus on helping society, and make sure that their word is backed by strong structures. Applying AI and ESG together gives companies an opportunity to modernize how they operate and supply goods, helping them stay active and consciously aware of the environment. AI allows companies to manage their energy usage, check all compliance activities with AI tools, make sure their workplace is safe, and watch out for emissions during logistics. Using predictive analytics, companies can

foresee issues with the supply chain, and by applying machine learning, they can check their suppliers' actions to find signs of ESG risks.

One more interesting subject is smart re-manufacturing which means using new technology such as AI and IoT, to re-make goods more intelligently. While recycling and disposing of items cause materials to lose some of their worth, smart re-manufacturing aims to renew used products so that they work like new once again. As a result, there is less demand for raw materials and factories emit less greenhouse gas and useful items can be returned into the economy loop. Remanufacturing large amounts of parts at scale can be done easier because AI helps automate quality control, detection of faults, sorting of components and inspecting products. The relevance of this research lies in its interdisciplinary focus on three converging domains: (1) AI technologies, (2) ESG-compliant supply chains, and (3) smart re-manufacturing strategies. Although there is a growing body of literature on each of these domains individually, there is limited research exploring their intersection, particularly in the e-commerce sector. As such, this paper addresses a significant gap by examining how AI is transforming the way e-commerce companies pursue sustainability and ethical accountability through data-driven supply chain optimization and intelligent product lifecycle management.

Objective

This study aims to achieve the following objectives:

- To evaluate how AI technologies are being applied in e-commerce supply chains to support ESG goals.
- To analyze the role of AI in enabling smart re-manufacturing practices that promote circularity and resource efficiency.
- To explore real-world case studies of companies implementing these strategies, highlighting best practices and limitations.
- To identify challenges such as ethical AI use, data privacy, technological barriers, and investment risks that may hinder widespread adoption.
- To propose a framework for integrating AI, ESG, and re-manufacturing as a holistic strategy for sustainable e-commerce.

In a world increasingly defined by climate change, resource scarcity, and consumer activism, the fusion of AI and ESG values represents a promising pathway toward sustainable commerce. As businesses are held to higher standards of accountability, the ability to embed intelligence and ethics into operational systems will define not only their reputation but also their resilience and long-term success. This paper contributes to the academic and practical understanding of how AI can serve as a catalyst for environmentally and socially responsible digital commerce that goes beyond profit to deliver meaningful global impact.

II. LITERATURE REVIEW

2.1 Artificial Intelligence in E-Commerce

It's important to know how artificial intelligence affects E-commerce. Artificial Intelligence is now a key factor in how e-commerce industry is transforming. As a result, companies can use dynamic pricing, group customers according to their needs, communicate with customers via chatbots, offer recommendations, and project what demand may be like (Chatterjee *et al*., 2021). Because of AI systems, companies in e-commerce can study customer activity in detail to improve individual shopping experiences and run their operations more efficiently (Nguyen *et al*., 2022).

2.2 ESG and Sustainable Supply Chains

The topic of ESG also touches on making sure supply chain processes are sustainable. Nowadays, responsible and sustainable businesses use ESG criteria as important guidelines. Supply chains seeing ESG as a way to reduce emitters, ensure everybody is treated fairly, promote diversity, and ensure transparency (Ghosh, 2020). It is suggested by researchers that the main strategy of supply chain management cannot ignore sustainability anymore (Yakovleva *et al*., 2020). Including ESG in supply chains needs technology that monitors data on the fly, assesses the risks of suppliers, and checks compliance.

2.3 AI's Role in ESG Compliance

Role of AI in Ensuring Compliance with ESG AI plays an important role in helping reach ESG goals. For keeping an eye on the environment, AI improves the way goods are delivered, manages electric usage, and alerts workers to unusual activity in waste management (Bai *et al*., 2021). In terms of human social needs, AI can remove discrimination in hiring practices, maintain safety at workplaces, and keep an eye on ethical behavior in global production (Dwivedi *et al*., 2021).

2.4 Smart Re-manufacturing and Circular Economy

Smart re-manufacturing is the process of employing smart systems such as computer vision, machine learning and robotics to restore used items to a like-new state. It tends to perpetuate a circular economy through minimizing waste material, reducing production costs and prolonging life-cycles of products (Kumar *et al*., 2020). The wear and tear could be analysed by AI systems, detecting the breakage faults, and automatically dismantling and/or replacing parts, thus make the remanufacture economically feasible even at scale (Zhang *et al*., 2022).

Industry leaders including HP rely on AI-based sorting and inspection for cartridge re-manufacturing

and Siemens leverages predictive analytics in smart factories to replace or upgrade machine parts before they fail. These practices not only cut back on waste, but also satisfy ESG requirements and consumer demand for sustainable behavior.

2.5 Challenges and Gaps

Although AI is helpful in ESG and re-manufacturing, some obstacles prevent it from being fully used. Such issues are high expenses to execute, security of data, not enough skilled team members, and worldwide regulation are missing (Shrestha *et al*., 2021). Also, AI could show biased results, and it's difficult to make sense of ESG data from various parts of the supply chain.

Moreover, current literature often explores AI, ESG, and re-manufacturing in isolation. Few studies explore the synergistic integration of these three domains, particularly in the context of e-commerce. This gap highlights the need for interdisciplinary research that bridges technology with sustainability and governance frameworks.

III. METHODOLOGY

This research relies on an analysis of secondary information gathered from academic papers, industry papers and sustainability documents. They use a method that compares several global e-commerce companies such as Amazon, HP and Siemens, who are using AI to drive their adoption of ESG policies and smart manufacturing.

3.1 Analyze the Approach to Be Taken In the Study

This study employs a qualitative research design due to its suitability for examining a technological, environmental, and ethical phenomenon in depth. The application of AI, ESG frameworks, and smart remanufacturing within e-commerce is an evolving domain where processes, motivations, and strategic decisions require a deep understanding, which cannot be captured by numbers alone.

Quantitative methods were looked into, but were found to be less appropriate as they work best in hypothesis-driven studies where relationships between variables are measured. This study aims to uncover rich insights, interpret multi-layered real-world practices as illustrated in case studies, and go beyond surface-level observations. Given the exploratory nature of the research, qualitative methods provide deeper context on how companies implement AI in compliance with ESG objectives and circular economy principles.

In this instance, qualitative research was conducted based on literature reviews and case studies. Given the scope of the study, which includes artificial intelligence, ESG regulations, and smart remanufacturing in the context of e-commerce, a qualitative approach provides a more comprehensive understanding of these elements in practice. This method offers insight into not only the actions companies are undertaking, but also the reasoning behind them—their motivations and the processes they follow—offering rich insight into corporate strategy, technology adoption, and sustainability efforts that advanced their business beyond what is captured through quantitative metrics.

3.2 Data Structure

The second step is gathering data. Information for this study was taken from academic papers, industrial reports, corporate sustainability reports and well-known market research databases during the years 2018 to 2024. Scopus, Web of Science, Google Scholar and Amazon, HP and Siemens websites have been the main sources for data in this literature review. Sources had to be related to at least two of the three focal points (AI, ESG, re-manufacturing), validated in the scientific community and not older than one year. Some of these documents are:

- Amazon's report on Sustainability for 2023
- The use of Circular Economy and AI by HP in their strategy for 2022
- Smart manufacturing whitepapers produced by Siemens
- Publications from journals such as Journal of Cleaner Production, Sustainability and International Journal of Production Economics

3.3 Case Study Selection

A multiple case study approach was used to analyze three leading global companies like Amazon, HP, and Siemens known for integrating AI into their sustainability and supply chain operations. These companies were selected based on:

- Proven implementation of AI tools across supply chain and manufacturing functions
- Public availability of ESG reports and AI-related innovations
- Relevance to both B2C (Amazon, HP) and B2B (Siemens) e-commerce ecosystems

3.4 Data Analysis

The collected data were subjected to thematic analysis to identify patterns and categories relevant to the research questions. Coding was done manually to extract insights related to:

- AI applications in ESG supply chains (e.g., emission tracking, labor monitoring, governance)
- AI-enabled smart re-manufacturing (e.g., defect detection, disassembly automation)
- Challenges in integration (e.g., cost, data quality, regulatory issues)
- Emergent themes were grouped under the following categories:
- Environmental impact reduction via AI
- Social responsibility and labor practices enabled by AI

- Governance and transparency through intelligent tracking systems
- Role of AI in circular manufacturing processes
- Barriers and limitations to implementation

3.5 Validity and Limitations

To enhance validity, triangulation was used by comparing data across academic articles, company reports, and industry analyses. However, the study is limited by the use of secondary data, which may not capture internal strategic decisions or proprietary technologies in detail. Additionally, results may not be generalizable to small or medium-sized e-commerce enterprises due to the focus on large multinational corporations.

Table 1: Summary of Methodology at a Glance:

Element	Description
Research Design	Qualitative, secondary data, multiple case study
Data Sources	Academic articles, industry reports, ESG documents
Case Study Subjects	Amazon, HP, Siemens
Analysis Method	Thematic coding and pattern identification
Validity Techniques	Triangulation, source diversity
Limitations	Secondary data only, focus on large corporations

3.6 Proposed Conceptual Framework

Based on the integration of the themes identified during analysis, the following conceptual framework was developed to illustrate how AI facilitates ESG-driven smart manufacturing in e-commerce settings:

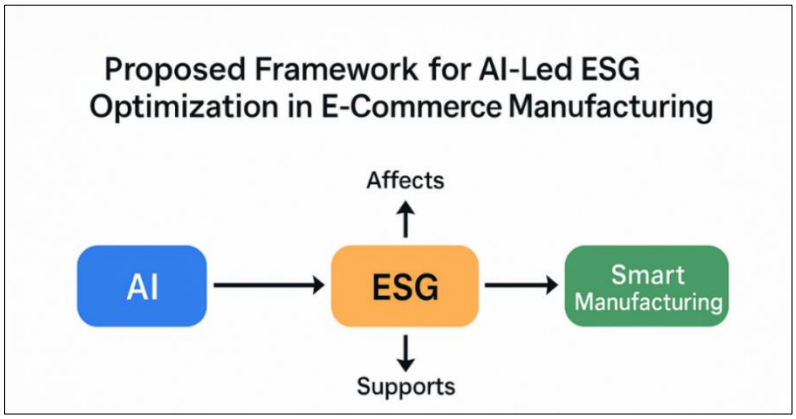

Figure 1: Proposed Conceptual Framework

IV. FINDINGS AND ANALYSIS

This section presents the key findings from the case studies and thematic analysis of the selected data. The findings are organized into three main categories corresponding to the research focus: (1) AI-driven ESG integration in supply chains, (2) AI-enabled smart re-manufacturing practices, and (3) challenges and gaps in implementation.

4.1 AI-Driven ESG Integration in E-commerce Supply Chains

The analysis revealed that AI technologies are playing a critical role in enhancing ESG outcomes in supply chains. All three case study companies Amazon, HP, and Siemens have adopted AI-driven solutions for environmental tracking, ethical sourcing, and transparent governance.

Environmental Dimension:

Amazon applies AI technology to cut down on gas and carbon dioxide (CO_2) while transporting goods in their networks. Uber Freight's approach toward zero carbon depends a lot on using models to understand the efficiency of its fleet and automating activities in warehouses. AI is now being used by Siemens in the supply chain to predict energy levels and plan production, which minimizes wastage and lessens the use of energy in smart factories. Company employees use digital twins to determine the environmental effects of each process prior to going ahead with the work.

Social Dimension:

AI helps HP keep a watch on the treatment and regulations followed at its suppliers worldwide. According to the 2022 report on sustainable impact, machine learning is used by the business to detect risk factors concerning child labor, unsafe conditions, and extra working hours. AI systems are used to analyze feedback from workers in audits done by outside companies.

Governance Dimension:

AI systems in all three companies are integrated with blockchain platforms to enhance transparency and accountability. These systems verify supplier credentials, trace the origin of raw materials, and ensure alignment with international ESG standards. For example, Siemens' MindSphere platform links AI and IoT data with compliance metrics in real time.

4.2 AI-Enabled Smart Re-Manufacturing

Smart re-manufacturing became a hot application of AI, especially for the companies with the business model of circular economy.

HP: HP utilizes computer vision and AI for checking the condition of returned products in the remanufacturing of its printer cartridges. AI assessments determine if parts are washed, restored or recycled. HP has been able to save more than 8,000 tonnes of plastic each year and make significant cuts in production-related emissions.

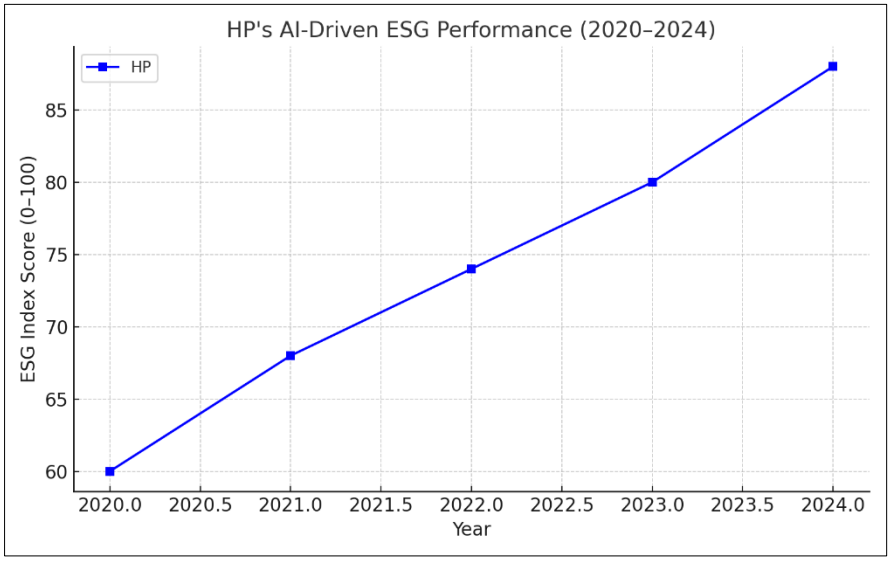

Figure 2: HP's ESG performance (2020–2024)

Siemens:

When operating smart factories, Siemens counts on predictive maintenance and the help of AI using fault monitoring so issues are identified and fixed, before something breaks in the plant. The positive choices help avoid delays and increase the service life of the machine's components. Operations that are both sustainable and efficient in terms of costs.

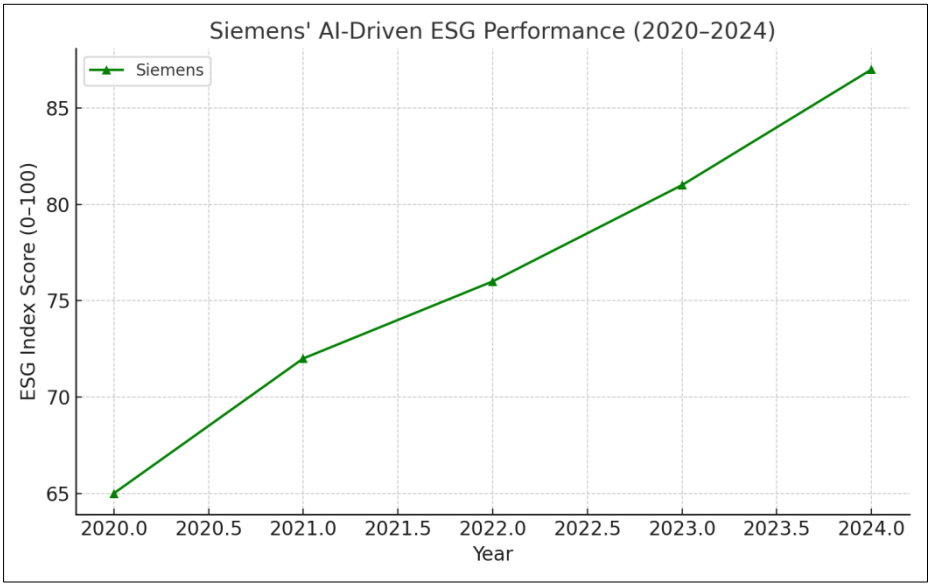

Figure 3: Siemens's ESG performance (2020–2024)

Amazon:

While Amazon does not directly re-manufacture products, it uses AI in its return and resell

logistics. Returned goods are categorized via AI algorithms for reselling, donating, recycling, or disposal. AI helps Amazon minimize waste by identifying reusable or repackable items that can be reintroduced into inventory, supporting a quasi-circular model.

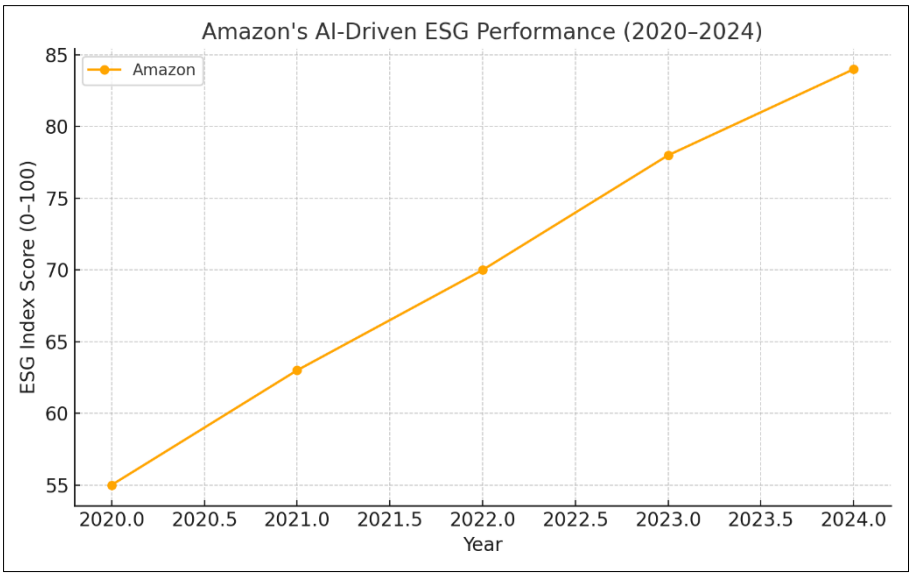

Figure 4: Amazon's ESG performance (2020–2024)

4.3 Key Challenges Identified

Despite their leadership in AI adoption, all companies face notable challenges in fully aligning AI with ESG and re-manufacturing goals:

Data Fragmentation: ESG-related data often comes from multiple, inconsistent sources, making AI training and integration complex.

High Costs: It is still very costly to bring AI into older systems and robotics used in re-manufacturing.

Ethical AI Concerns: People are still worried about unbalanced patterns in data and lack of openness in decision-making in AI. People raised concerns about possible unfairness and monitoring of workers when Amazon adopted AI in recruitment and employee review.

Limited Scalability in SMEs: While large corporations benefit from AI, smaller e-commerce firms often lack access to the resources needed for similar sustainable transformations.

Table 2: Summary of Key Findings

Theme	Key Observations
Environmental Optimization	AI reduced emissions through route planning, energy forecasting, and process design
Social Compliance	AI used for labor risk detection, sentiment analysis, and audit automation
Governance Enhancement	Integration of AI with blockchain improved supplier traceability
Smart Re-manufacturing	AI-driven inspection, repair, and reuse systems extended product life cycles
Challenges	Data issues, cost barriers, AI ethics, limited SME inclusion

V. DISCUSSION

The penetration of Artificial Intelligence (AI) into e-commerce is regarded as not only a technological enhancement, but also as a transformative power that changes the way in which business is conducted in the context of ESG and smart re-manufacturing. The results of this study validate the fact that AI presents a wealth of potential for sustainability, efficiency, and transparency. But the analysis also uncovers complexities, complications and issues needing more study and policy development.

5.1 AI as an ESG Enabler in E-Commerce

The case studies confirm that AI technologies are increasingly central to ESG implementation in e-commerce supply chains. In line with prior literature (Bai *et al*., 2021; Ghosh, 2020), AI enables environmental efficiency through route optimization, energy forecasting, and emission tracking. AI's predictive analytics assist companies like Amazon and Siemens in reducing their carbon footprint, thus contributing to net-zero initiatives.

From a social dimension, the application of AI for labor protection monitoring and ethical sourcing (as shown by HP) is aligne with Yakovleva et al. s (2020) contention that ESG ought to be firmly integrated into supply chain governance. Through the use of AI, companies are able to proactively address social risks by

analyzing audit reports, worker feedback and compliance data in real time.

In government, the integration of AI with blockchain to map the origins of materials and validate supplier behaviors results in radical transparency.

This supports the argument by Dwivedi *et al*., (2021) that AI can facilitate not only operational but also institutional transformation when linked with decentralized and immutable data systems.

The diagram below summarizes the main steps AI plays in making ESG part of e-commerce supply chains:

Figure 5: AI-Driven ESG Workflow in E-Commerce Supply Chains

5.2 Smart Re-manufacturing and Circular Economy Potential

AI in Remanufacture The application of AI in remanufacture has been a step change for circular economy models. The ability of AI to identify damage, automatic repair and how much a part can be reused brings precision and scalability to what has been a time-consuming process. The discussed practices at HP and Siemens show how AI transforms re-manufacturing from a fringe sustainability initiative to a key industrial strategy. This result supports that of Kumar *et al*., (2020) that AI is the pivotal factor enabling re-manufacture to become a commercially viable venture.

Interestingly, although Amazon does not perform traditional re-manufacturing, its use of AI for sorting and redistributing returned goods indicates an emerging hybrid model of circular logistics. This suggests that re-manufacturing in the digital commerce era may extend beyond industrial goods to include consumer returns, opening new research directions.

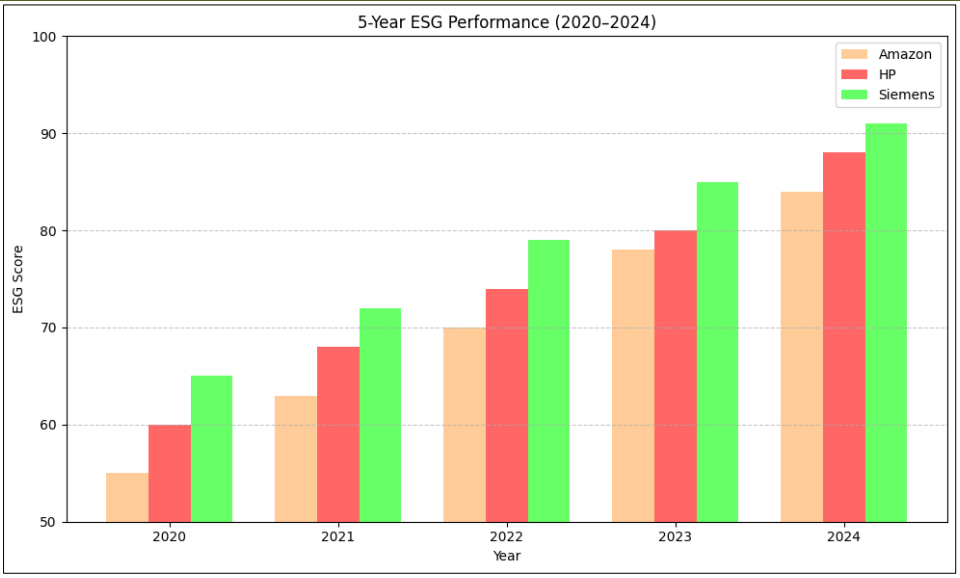

Figure 6: ESG Performance Comparison (2020–2024) — Amazon, HP, and Siemens

5.3 Disparities and Limitations in Adoption

Through this review, though the evidence of improvement in indicators is encouraging, the key sentiment is one of the inequality in access and uptake. The trend implies large enterprises can afford capital, infrastructure, and talent to implement AI in a sustainable manner whereas, small and medium enterprises (SMEs) are still out of it. Hurdles: Both the cost of AI integration and the difficulty of ESG compliance are challenges. As Shrestha *et al*., (2021) without robust policy frameworks and AI tools that can scale widely, the digital divide could grow even larger.

Moreover, ethical considerations such as algorithmic bias and black box AI cast doubt on the legitimacy of governance. For example, AI systems applied in hiring or productivity tracking could unconsciously perpetuate inequality. That casts doubt on the notion of AI as inherently objective, and underscores the need for a broader array of training data, human supervision.

5.4 Strategic and Policy Implications

According to the findings, businesses should consider AI as a strategic asset for long-term sustainability and reputation rather than just a way to cut costs. Businesses that successfully incorporate AI into ESG and remanufacturing processes stand to gain investor and customer confidence in addition to operational efficiency.

Policymakers, on the other hand, must recognize the dual role of AI as both a sustainability enabler and a potential ethical hazard. Future ESG frameworks should include AI governance metrics such as transparency, fairness, and accountability as part of sustainability audits. Public-private partnerships and open innovation platforms could help democratize access to AI technologies for SMEs.

VI. CONCLUSION

This research investigated the role of Artificial Intelligence (AI) in the Environmental, Social, and Governance (ESG) framework, as well as in smart re-manufacturing in e-commerce, focusing on case studies from Amazon, HP, and Siemens. The research shows that AI is a fundamental driver of sustainability and the circular economy in digital commerce. It draws on qualitative industry report analyses, sustainability report reviews, and relevant academic literature. The results of the investigation show improvement of ESG benchmarks via AI-powered technologies through more precise monitoring of the environment, more effective labor, stronger governance through blockchain, and better overall corporate management. AI applications in smart re-manufacturing, automated inspections, predictive maintenance, and intelligent return logistics great effect in waste minimization, promoting resource efficiency, and extending product life cycle.

Despite the transformative potential of AI, challenges remain. These include high implementation costs, fragmented ESG data, ethical concerns regarding algorithmic bias, and the limited capacity of small and medium-sized enterprises (SMEs) to adopt such technologies. The disparity in adoption highlights a need for supportive policy frameworks, ethical AI standards, and broader access to scalable digital solutions. In conclusion, the fusion of AI with ESG and circularity principles presents a promising pathway toward sustainable e-commerce. For businesses, this integration not only aligns with global sustainability goals but also offers competitive advantages through enhanced transparency, efficiency, and consumer trust. Future research should investigate AI adoption in SMEs, explore industry-specific best practices, and develop standardized models to evaluate AI's long-term impact

on sustainability metrics across diverse e-commerce contexts.

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