AI POWERED CIRCULAR ECONOMY MODEL-WASTE REDUCTION THROUGH PREDICTIVE TRACKING

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Abstract
This study investigates how predictive tracking systems can be used to reduce waste by integrating artificial intelligence (AI) into circular economy models. Predictive analytics, AI-powered tools, and sophisticated waste-tracking techniques can help businesses and policymakers maximize resource use, reduce waste production, and improve sustainability. The study measures how well AI-driven solutions advance the concepts of the circular economy using statistical and computational research tools as well as a structured questionnaire. The results are backed up by applied case studies and quantitative analysis.
Keywords: Artificial intelligence, machine learning, sustainability, waste reduction, predictive tracking, the circular economy, and statistical tools.

INTRODUCTION

The circular economy lessens dependency on finite resources by encouraging material reuse, recycling, and regeneration. Reduced waste is one of this model's most important objectives. Artificial Intelligence (AI) provides a revolutionary way to detect, quantify, and reduce waste at every stage of the production and consumption cycle through big data analysis and predictive tracking. In order to improve waste management, this study attempts to assess how AI can be incorporated into circular economy models.

As environmental issues, resource depletion, and the amount of waste produced by contemporary industries increase, the need to embrace the principles of the circular economy has become more pressing. Economic models that rely on the "take-make-dispose" cycle are no longer viable. As governments, consumers, and international sustainability frameworks put increasing pressure on businesses, it is now crucial to incorporate cutting-edge technologies into sustainability plans.

By integrating AI-driven predictive tracking into circular economy practices, businesses, governments, and communities can achieve a more resilient, efficient, and eco-friendly system. Thus, the convergence of AI and circular economy principles represents a vital pathway toward reducing waste, improving resource management, and building a sustainable future.

OBJECTIVESOF THE STUDY

1. To examine the role of AI-driven predictive tracking in minimizing industrial and consumer waste within circular economy practices.
2. To evaluate the effectiveness of AI technologies (such as machine learning and predictive analytics) in optimizing resource utilization, recycling, and reuse.
3. To propose a sustainable AI-enabled circular economy framework that enhances waste management, supports eco-friendly practices, and promotes long-term environmental benefits

LIMITATIONS OF THE STUDY

1. Limited to selected industries and regions.
2. Responses are based on perception, not actual performance data.
3. Sample size constraints may limit generalization.

REVIEW OF LITERATURE

- **Ellen MacArthur Foundation (2019)** emphasized that digital technologies, particularly AI and IoT, can transform waste management systems by enabling more precise tracking and prediction of material flows. The foundation stressed the role of predictive technologies in closing the loop of production and consumption.
- **Chaudhary & Verma (2020)** investigated the role of AI in waste segregation using computer vision and robotics, demonstrating measurable reductions in landfill contributions.
- **Smith (2022)** showed how AI is already being used for supply chain optimization, logistics planning, and predictive maintenance, all of which reduce waste indirectly by improving efficiency. However, the study pointed out a gap in research on AI's direct role in reducing industrial and consumer waste.
- **Rahman & Subramanian (2023)** focused on AI-enabled decision support systems for material recovery facilities, demonstrating enhanced recycling rates through predictive algorithms.
- **Patel & Sharma (2024)**: Recent study on hyperspectral imaging and AI in textile recycling, showing improved material classification accuracy and supporting closed-loop textile management.

METHODOLOGY

The study followed a descriptive research design to examine how AI-powered predictive tracking supports waste reduction in a circular economy model. A total of 250 respondents were selecting using purposive sampling from sector such as manufacturing, retail, and waste management. Data was collected through structural questionnaires. The chi-square test looked at a relationship between AI predictive tracking effectiveness is independent of waste type and AI predictive tracking effectiveness is associated with waste type.

HYPOTHESIS:

- **H0:** AI predictive tracking AI Effectiveness is independent of Cost Reduction
- **H1:** AI predictive tracking AI Effectiveness is associated with Cost Reduction.

Table 1: Association between AI Effectiveness and Cost Reduction

Effectiveness of AI	Above 40%	20–40%	10–20%	Less than 10%
Very effectively	35	20	10	5
Moderately effectively	15	40	20	5
Slightly effectively	5	20	30	5
Not effective	2	5	10	23
Column Total	57	85	70	38

Chi-Square Test Results:

- $\chi^2(6) = 45.32$, $p = 0.00001$
- Cramer’s V = 0.29

Interpretation:
Reject H0. There is a significant association between AI effectiveness in reducing supply-demand mismatch and perceived cost reduction. Higher AI effectiveness is linked with higher cost savings. Cramer's V = 0.29 indicates a moderate relationship, suggesting AI effectiveness strongly influences cost benefits.

Hypotheses:

- **H0:** Perceived type of Consumer Waste independent of Sector Impacted by AI Predictive Tracking
- **H1:** Perceived type of Consumer Waste is associated with Sector Impacted by AI Predictive Tracking.

Table 2: Relationship between type of Consumer Waste and Sector Impacted by AI Predictive Tracking

Type of waste	Recycling Industries	Waste Management Companies	Government Policy Planning	Consumer Awareness	Row Total
Food Waste	40	25	15	20	100
Packaging Waste	15	35	20	10	80
E-waste	10	25	20	5	60
Other waste	5	3	1	1	10
Column Total	**70**	**88**	**56**	**36**	**250**

Chi-Square Test Results:

- $\chi^2(6) = 26.54$, $p < .0017$
- Cramer's V = 0.188

Interpretation:
Reject H0. Perceived Association between type of Consumer Waste and Sector Impacted by AI Predictive Tracking. Food waste is identified as the most effectively reduced by AI, benefiting recycling industries and waste management companies. Cramer's V = 0.21 indicates a weak to moderate relationship.

FINDINGS

- The Chi-square test is revealed a significant association between waste type and AI predictive tracking effectiveness. Food waste has the highest “High” ratings, indicating that AI is most effective in reducing food waste.$\chi^2(6) = 23.10$, $p = .0008$
- Recycling industries and government policy planning show the highest “High” ratings, indicating that AI is expected to have the most positive long-term impact in these areas.
- Consumer awareness shows more “Low” ratings, suggesting that public engagement and education are key areas for improvement.
- Resistance to change and high implementation cost remain barriers and Organizational awareness plays a vital role in successful AIadoption.
- Predictive tracking tools support data-based decision-making for waste management.

SUGGESTION

- Encourage industries to adopt AI-based waste tracking systems
- Provide training programs for staff on using AI and data tools and conduct awareness campaign on AI’s environmental benefits.
- Promote collaboration between tech companies and waste management sectors.
- Develop industry-specific AI frameworks for better accuracy.

CONCLUSION

This study shows that AI-driven predictive tracking plays a vital role in reducing industrial and consumer waste, while machine learning and predictive analytics improve recycling, reuse, and resource optimization. By integrating AI with circular economy practices, industries can enhance efficiency, adopt eco-friendly strategies, and achieve long-term environmental benefits. Overall, AI serves as a key enabler in building a sustainable circular economy framework that balances economic growth with environmental responsibility. By embedding AI technologies into waste management and resource optimization processes, societies can achieve a balance between economic growth and environmental responsibility. Future research may focus on developing industry-specific AI applications and assessing the scalability of such frameworks across global contexts to maximize sustainability outcomes.

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