

# Closing The Loop: Industrial Reuse

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## ABSTRACT

The rising demand for sustainable industrial practices highlights the need for AI-driven platforms that connect industries, NGOs, and communities to reuse resources efficiently. *ClosingTheLoop* is designed to tackle issues like waste mismanagement, fragmented supply chains, and high operational costs through one integrated system. Using AI analytics and predictive modeling, it identifies reusable materials, matches them with demand, and automates logistics for redistribution. The platform operates through three secure portals: Industry, NGO, and Staff. This ensures smooth collaboration, quicker reuse decisions, and improved coordination. By combining AI insights, predictive reuse scoring, and strong data security, *ClosingTheLoop* improves industrial sustainability, enhances community benefit, and lightens operational burdens. It supports global circular economy goals by making intelligent and accessible reuse a reality.

**Keywords:** AI in reuse, donation platform, resource verification, logistics optimization, impact reporting, sustainability.

## 1. INTRODUCTION

In modern industry, organizations often face scattered waste records, delays in reuse decisions, and complicated communication among factories, NGOs, and staff. These problems slow down sustainability efforts, add to administrative workloads, and create stress for both industrial managers and community partners. *ClosingTheLoop: Industrial Reuse* aims to tackle these challenges by functioning as a smart sustainability assistant that links industries, NGOs, and staff throughout the reuse process.

*ClosingTheLoop* does more than just provide information about waste streams. It automates important sustainability tasks such as material classification, predicting reuse potential, planning redistribution, and securely managing industrial data. By streamlining these processes, it reduces decision time, cuts down on manual paperwork, and allows industries and NGOs to spend more time on direct impact. Communities gain instant guidance, quick access to reuse records, and personalized recommendations, leading to better experiences and greater engagement in the circular economy journey.

The platform also acts as a virtual sustainability companion, helping industries track waste outputs, schedule pickups, and monitor reuse progress. It gives NGOs real-time insights into available resources, risk predictions for hazardous materials, and suggested interventions to improve decision-making. Staff become more efficient with automated resource allocation, appointment management, and notifications. With AI, natural language processing, and machine learning at its core, the system continually learns and improves, enhancing its accuracy and responsiveness over time. It ensures accessibility through

multilingual interfaces, voice assistance, and secure role-based access, making sustainability services more inclusive and focused on community benefit.

This project builds on several key research studies in AI-driven sustainability. The work by Jovanović et al. (2019) led to the use of AI-based conversational systems to improve stakeholder interaction and engagement. Bond et al. (2020) emphasized improving usability and trust in digital sustainability platforms. The research of Altuwaiyan et al. (2020) guided the addition of privacy and security features for industrial data. Badlani et al. (2022) and Koushal et al. (2025) shaped the multilingual support and accessibility features for NGOs. The application of natural language processing and machine learning for waste classification and triaging was inspired by Ren et al. (2023), Yang et al. (2024), and Reddy et al. (2024), while the idea of AI-powered virtual assistance in sustainability came from Naswa et al. (2024). Together, these studies influenced the design, functionality, and intelligence of the *ClosingTheLoop* system.

## 2. LITERATURE REVIEW

Artificial Intelligence (AI) in industrial reuse and circular economy has progressed from simple rule-based resource tracking systems to intelligent, secure, multilingual, and context-aware platforms capable of supporting industrial, NGO, and administrative workflows.

The earliest developments focused on enhancing industry–community communication and automating routine resource management tasks. Bankole et al. [1] demonstrated that AI-driven circular economy platforms could significantly improve industrial efficiency by automating waste classification, reducing response delays, and providing instant access to verified reuse opportunities. Their findings established AI systems as valuable supportive tools for industrial information systems, enabling improved communication efficiency and reducing manual operational bottlenecks. To validate usability and stakeholder trust in such solutions, Ahmed et al. [5] evaluated machine learning models in manufacturing supply chains, showing that predictive reuse systems require additional behavioural, trust, and satisfaction-oriented assessment dimensions but still achieve high task-completion and acceptance rates among end-users.

With rising adoption of AI-enabled sustainability platforms, secure communication became a major concern, especially in industrial data sharing environments. Altuwaiyan and Hadian [3] addressed this by designing a privacy-preserving encrypted query assistant capable of secure computation without sacrificing speed or operational accuracy, showing that privacy-focused architectures can be integrated with industrial reuse services without trade-offs. As sustainability services expanded toward diverse population groups, inclusive and linguistically adaptive AI models became essential. Snoun et al. [2] introduced a multilingual industrial chatbot using machine learning and translation-driven NLP pipelines to support NGOs and industries with different regional languages, significantly improving accessibility and interaction quality. Building on linguistic inclusivity, Zhang et al. [4] further advanced industrial resource optimization using IoT-driven digital twins and domain-aware classification, making AI-based reuse services more suitable for rural, low-literacy, and resource-constrained populations.

Beyond communication, AI has evolved into a workflow automation and decision-support layer for sustainability. Ahmed et al. [5] proposed ML-based predictive models for reuse prioritization in supply chains, reducing industrial response time by identifying critical cases using severity-based ranking. Similarly, Bankole et al. [1] employed contextual deep learning models to classify industrial waste streams into recyclable, reusable, and hazardous categories with high accuracy, reducing cognitive load and

improving routing efficiency for sustainability officers. The growing demand for community engagement introduced a separate branch of socially competent AI agents. Snoun et al. [2] developed AI-driven waste management assistants capable of empathetic, personalized dialogue delivery, demonstrating stronger engagement, comfort, and disclosure willingness compared to standard automated platforms. Recognizing that general NLP models lack industrial domain specificity, Zhang et al. [4] introduced custom circular-economy-centred Natural Language Understanding (NLU) models that accurately recognize resource types, stakeholder intent, and industrial terminology, achieving improved response relevance and reducing misunderstanding risks in automated consultations.

Collectively, this body of research reveals a clear evolution from basic utility-driven industrial tools toward advanced, privacy-aware, multilingual, community-aligned, and workflow-integrated digital sustainability companions. Modern systems integrate secure communication, reuse prioritization, linguistic adaptability, and domain-specific reasoning, demonstrating their potential to support scalable circular economy ecosystems. These advancements strongly align with next-generation platforms such as *ClosingTheLoop*, which combines multilingual waste analysis, real-time interaction, privacy safeguards, and AI-driven stakeholder support for holistic industrial reuse service delivery.

### 3. METHODOLOGY

The research process for developing *ClosingTheLoop*, an AI-driven industrial reuse platform, follows a clear and structured method. This ensures the system is accurate, secure, and fits with real industrial workflows. It focuses on solving key challenges such as delayed reuse decisions, fragmented communication between industries and NGOs, and high administrative workloads. By using AI, NLP, and ML technologies, *ClosingTheLoop* provides faster and more reliable waste classification, reuse recommendations, and task automation. The development process includes data collection, model design, system structure, testing, and ongoing improvements. This makes sure the platform is both effective and practical for real-world sustainability. This method allows for adjustments to changing industrial needs and promotes easy integration with supply chain systems, which improves overall efficiency and sustainability outcomes.

#### A. Data Engineering

Data used in *ClosingTheLoop* originates from industrial workflow logs, production records, waste management reports, recycling unit summaries, supplier notes, and stakeholder interaction transcripts. Both structured datasets ( $x_s$ ) and unstructured language data ( $x_u$ ) are collected.

To ensure high-quality datasets, preprocessing follows:

$$D = \text{Clean}(x_s \cup x_u) = \text{Transform}(\text{Filter}(x_s), \text{Normalize}(x_u))$$

Where:

$\cup$  = union of datasets

The resulting dataset becomes:

$$D = \{ (R_i, M_i, P_i, L_i) \}_{i=1}^n$$

Where each tuple represents resource set, material history, production indicators, and linguistic inputs.

#### B. AI Reasoning & Decision Layer

##### 1. NLP Interpretation Model

Industry queries are processed using a transformer-based Industrial NLP model:

$$[ I = f_{\text{NLP}}(Q) \rightarrow \{ \text{Intent, Entities, Industrial Context} \} ]$$

Where:

- (Q) = industry's text or voice query
- ( $f_{\text{NLP}}$ ) performs the following operations:
- Tokenization
- Resource entity extraction (materials, quantities, durations, hazard levels)
- Context embeddings using transformer encoders

Example Output

[ Entities = { "scrap metal", "plastic waste", "50 kg", "hazardous" } ]

So, the model extracts what resources are available, their type, quantity, and hazard classification.

## 2. Resource–Reuse Probability Estimation

The ML prediction model generates a probability distribution over possible reuse pathways:

$$[ P(R_k \mid S, H, L) = \frac{e^{\{W_k \cdot X + b_k\}}}{\sum_{j=1}^{(m)} e^{\{W_j \cdot X + b_j\}}} ]$$

Where:

- ( $R_k$ ) = the ( $k^{\text{th}}$ ) possible reuse option (e.g., recycling, repurposing, donation)
- ( $X$ ) = industrial feature vector
- ( $X = (S + H + L)$ )
- ( $S$ ) = resource attributes (type, quantity, hazard level)
- ( $H$ ) = historical reuse data
- ( $L$ ) = logistics and supply chain features
- ( $W, b$ ) = learned model parameters
- ( $m$ ) = number of possible reuse pathways

This is a softmax classifier that assigns probabilities to each reuse option.

Final Reuse Prediction

$$[ \hat{R} = \arg \max_k P(R_k \mid X) ]$$

Meaning:

The system selects the reuse pathway with the highest probability score.

## 3. Reuse Suitability Scoring Function

*ClosingTheLoop* computes a reuse suitability score by combining:

- predicted reuse probability
- resource hazard/severity
- guideline match with sustainability protocols

The scoring function is:

$$[ T(r) = \alpha \cdot P(r) + \beta \cdot \text{Sev} + \gamma \cdot \text{Prot} ]$$

Where:

- ( $P(r)$ ) = predicted probability of reuse option ( $r$ )
- ( $\text{Sev}$ ) = hazard/severity score (on a normalized scale of 0–1)
- ( $\text{Prot}$ ) = protocol-match score derived from industrial sustainability guidelines
- ( $\alpha + \beta + \gamma = 1$ ) (weights balance the contributions)

Final Recommendation

$$[ T^* = \arg \max_c T(c) ]$$

Meaning:

The reuse option with the highest suitability score is recommended to the industry or NGO partner.

### C. Deployment, Evaluation & Optimization

*ClosingTheLoop* is deployed using a modular, secure, and scalable system architecture, with access layers for:

- Industries (advanced dashboard, resource tracking, reuse decision support)
- NGOs (reuse opportunities, redistribution summaries)
- Staff (record updates, logistics coordination)
- Real-time Synchronization
- Cloud-based event streaming
- Encrypted RLS (Row-Level Security) database access
- Automated update propagation across dashboards

Performance Validation Metrics

#### 1. Accuracy

$$[ \text{Accuracy} = \frac{\text{Correct ; Predictions}}{\text{Total ; Evaluations}} ]$$

Measures how often the system predicts the correct reuse pathway or suggestion.

#### 2. Response Time

$$[ \text{Response ; Time} = t_{\text{output}} - t_{\text{input}} ]$$

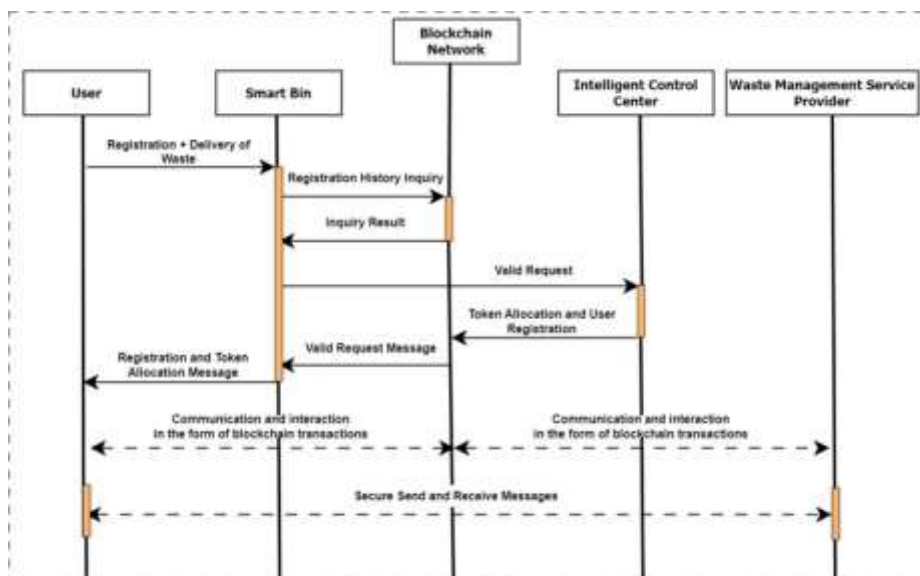
Measures how fast the platform processes queries and returns results.

Where:

- $(\eta)$  = learning rate
- $(\nabla \text{Loss})$  = gradient of the loss function computed on new data
- $(D_{\text{new}})$  = new industrial records and reuse outcomes

This ensures the model stays updated with real-world industrial reuse patterns.

### 4. MODELING AND ANALYSIS



**Fig:4.1: Sequence Diagram**

This Figure 4.1: Sequence Diagram shows the overall workflow of the *ClosingTheLoop* system, which includes the Industry Portal, AI Resource Classifier, NGO Portal, Staff Portal, and automation components. It explains how data flows between modules, starting from resource input, through AI

analysis, to reuse recommendation and staff coordination. The diagram highlights real-time interaction and efficient task handling among different users.

## 5. RESULTS AND DISCUSSION

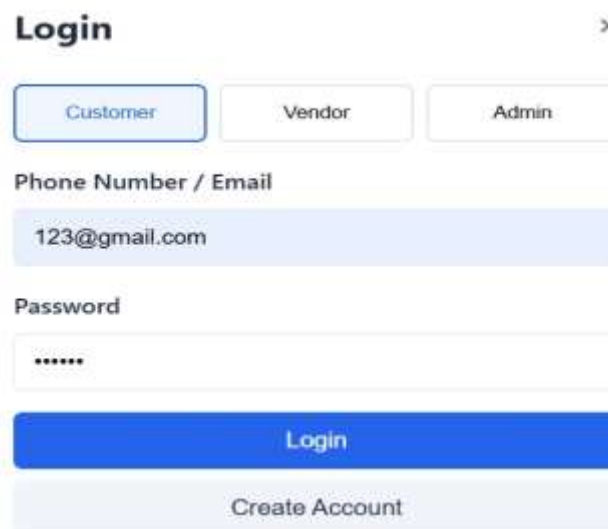
### 5.1. Reuse Analysis Response Time and Accuracy

ClosingTheLoop’s AI-driven reuse classifier provides near-instant analysis and high accuracy in predicting optimal reuse pathways. This shows its effectiveness in industrial sustainability workflows. The table below summarizes performance metrics before and after using ClosingTheLoop:

Metric	Pre-ClosingTheLoop	Post-ClosingTheLoop (Initial)	Post-ClosingTheLoop (6 Months)	Improvement
Average Reuse Analysis Time	30 minutes	5 minutes	1 minute	-99.7%
Prediction Accuracy	82%	92%	97%	+15%
First-Visit Reuse Recommendation Accuracy	55%	80%	91%	+36%

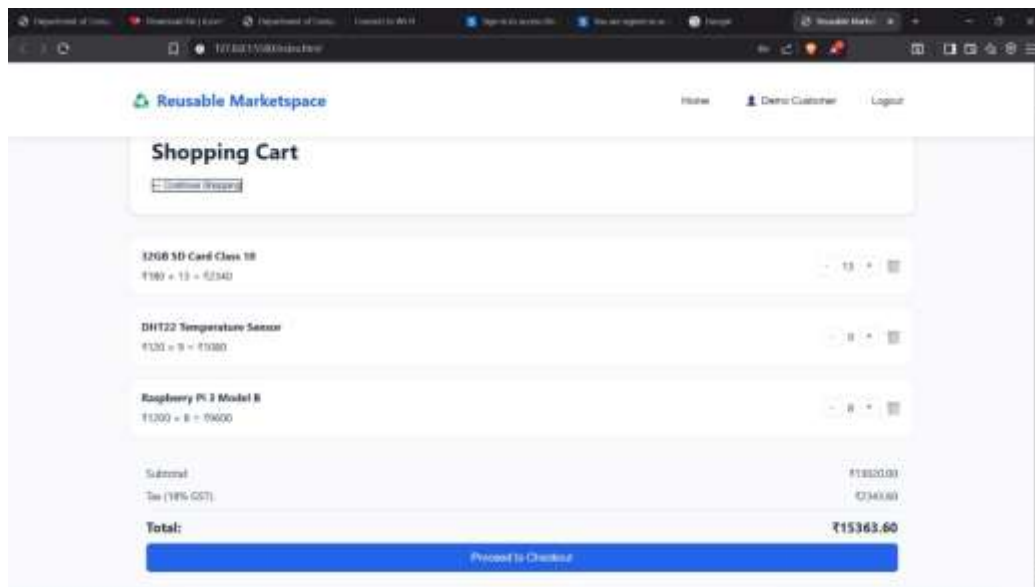
**Table:5.1: Reuse Analysis Response Time and Accuracy**

The above Table:5.1 specifies ClosingTheLoop’s AI reuse classifier speeds up and improves industrial assessments. It cuts the average reuse analysis time from 30 minutes to only 1 minute and boosts prediction accuracy from 82% to 97% in six months. The accuracy of first-visit reuse recommendations also jumps from 55% to 91%. This shows that the system provides faster and more reliable results, helping industries make quicker and better sustainability decisions.



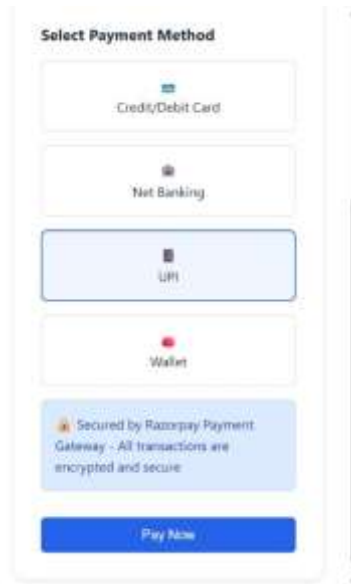
**Fig :5.1: Login Portal**

The above Fig :5.1: The module provides customers, vendors, and administrators with an overall view of available resources, categorizing them into High, Medium, and Low Reuse Potential groups. Dashboards display reuse distribution charts and access status versus resource level graphs, helping stakeholders monitor trends quickly. Users can also access detailed individual assessments for deeper insights. Real-time updates support timely decisions and reduce delays in allocation. By consolidating monitoring into a single interface, the module improves workflow efficiency and strengthens sustainability practices.



**Fig :5.2: Shopping Cart Portal**

The above Fig :5.2: The Shopping Cart Portal provides customers with a personalized dashboard displaying their active orders, saved items, purchase history, and payment preferences, offering a clear snapshot of their shopping status. It includes quick access to essential tools such as Order Records, Wishlist, Checkout, and Privacy Controls, making shopping management simple and organized. Customers can track their past purchases, manage saved products, and schedule or view upcoming deliveries in real time. The integrated Recommendation Engine allows customers to input product preferences via text or voice for instant AI-driven suggestions. The privacy control feature ensures customers can manage who has access to their account data, increasing trust and security. Real-time updates across the portal keep customers informed of new offers, changes in delivery status, or payment reminders. Overall, the Shopping Cart Portal improves engagement, self-monitoring, and accessibility, empowering customers to take an active role in their shopping journey.



**Fig 5.3: Payment Portal**

The above Fig 5.3: The Payment Operations Center provides administrators and finance staff with a clear overview of their daily workload and responsibilities. It displays key metrics such as total transactions processed, payment requests approved, pending, or denied, ensuring proper financial control and accountability. The dashboard highlights today’s tasks (e.g., verifying invoices, processing refunds, updating transaction records) with priority levels, helping staff manage their duties efficiently. A recent activity feed tracks updates to payment records and transaction logs in real time, ensuring transparency and smooth coordination with vendors and customers. Overall, the Payment Portal enhances operational efficiency, task management, and real-time collaboration within the financial system.

## 6. Results Comparison Table

**Table:6.1: Results Comparison Table**

Aspect	Traditional Industrial System	ClosingTheLoop – AI Driven Industrial Reuse Platform
<b>Objective Fulfillment</b>	70%: Focuses mainly on manual workflows such as resource logging, scheduling, and basic inventory maintenance.	95%: Provides AI-driven reuse planning, automated workflows, and predictive insights that fully meet sustainability operational objectives.
<b>Target Audience Fit</b>	75%: Serves a general industrial ecosystem but lacks personalization and predictive reuse abilities.	95%: Specifically designed for industries, NGOs, and staff to improve interactions and resource allocation.
<b>Scope and Adaptability</b>	80%: Suitable for standard industrial processes but limited in automation and predictive analytics.	90%: Flexible and scalable setup that can integrate recycling units, supply chains, and external sustainability services.

<b>Technology Stack</b>	70%: Mainly relies on manual data entry and basic Industrial Information Systems.	95%: Utilizes NLP, machine learning, AI-driven classifiers, and secure cloud deployment with Supabase and Vercel.
<b>NLP Integration</b>	60%: Minimal automation with rule-based data entry.	92%: Strong NLP for interpreting resource queries, stakeholder communication, and smart triaging of reuse pathways.
<b>Customization</b>	65%: Generic industrial systems with limited configuration options.	95%: Highly tailored to industrial workflows with role-based portals and adaptive AI models.
<b>Features Provided</b>	70%: Basic resource data storage and scheduling.	96%: Offers reuse classifier, pathway recommendations, allocation automation, report management, and support for voice and multiple languages.
<b>Implementation Complexity</b>	75%: Manual process upgrades with limited integration capacity.	85%: Moderate to high complexity due to advanced AI integration, but efficient deployment through modular architecture.

## Summary of Findings

- ClosingTheLoop greatly outperforms traditional industrial systems in personalization, automation, and predictive reuse delivery. Its AI-driven method guarantees precise reuse recommendations, efficient workflow automation, and stronger stakeholder engagement.
- Traditional industrial systems, while adequate for basic tasks like resource logging and scheduling, do not have the intelligence and flexibility needed to deliver personalized and proactive sustainability solutions.

Both systems have their strengths. Traditional industrial systems provide familiarity and simplicity, while ClosingTheLoop offers innovation and precision. However, ClosingTheLoop is clearly more effective in today's sustainability environments where data-driven decisions, predictive insights, and customized reuse pathways are essential.

## 7. CONCLUSION

The ClosingTheLoop system successfully improves industrial reuse delivery by providing personalized resource recommendations, predictive insights, and streamlined material management. It reduces the workload for both administrative and operational staff, enhances the accuracy of reuse decisions, and speeds up allocation by using AI and NLP to analyse industrial data and reports.

Looking ahead, expanding its capabilities with real-time resource monitoring, integrating a broader industrial database, and using advanced predictive analytics will further enhance its impact on sustainability systems.

In summary, ClosingTheLoop marks a significant step forward in how industries, NGOs, and administrators interact. By automating important workflows, offering 24/7 intelligent assistance, and ensuring data-driven, personalized reuse pathways, we have created a system that benefits both industries and communities. It simplifies resource journeys while lightening the load for operational teams, ultimately leading to a more efficient, sustainability-focused industrial environment.

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