

BizAI- AI Based Business Management Model

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Abstract—This paper introduces BizAI, a digital framework devised to accelerate the transition to CE by creating verifiable product lifecycle traceability and objective decision-making metrics. The core of the solution is based on the Digital Product Passport, implemented on a private Blockchain to hold an indelible record of every product's history in its usage and of circularity actions: Reuse, Refurbish, and Recycle. BizAI leverages the dynamic Sustainability Score Index, an algorithmic metric devised to properly quantify a product's residual viability with regard to action type, cost, age, and degradation from pollutants. This score identifies the grade of appropriate next use of the product, moving from subjective assessment to data-driven circularity. The architecture of the system is described, comprising three integrated features: the DPP for the owners, the AI Chatbot, and the Recommendation System for the customer; demonstrating a comprehensive, incentivized, transparent methodology for fostering sustainable commerce at the retail level. BizAI created a robust technical foundation that guarantees, in a verifiable way, compliance and increases consumer engagement in the Circular Economy.

I. INTRODUCTION

The global economy at this point operates under the Linear Economy model (Buy-Use-Dispose), which has led to there are critical issues of resource depletion and increasing waste. Volumes and environmental degradation directly undermine global commitments to sustainable development. A fundamental change in industrial and consumer processes is necessary to mitigate these adverse effects. The emerging solution involves the adoption of the circular economy, which strives to maximize the value of the product through cycles of Refurbish, Reuse, and Recycle. However, the implementation of circular economy principles at scale is technically challenging due to the inherent lack of transparency and verifiable data about a product's lifecycle, usage history, and material state after consumer purchase. This lack of trust so that traceability is a big systemic barrier. The BizAI project thus proposes an integrated digital solution to overcome these barriers. This system combines CE principles with the immutability and transparency of blockchain technology. The main component is the Digital Product Passport DPP is an open-sourced, decentralized, permanent ledger. for individual products, capturing their entire history from manufacture by successive circular motions. One of the core innovations within BizAI is the Sustainability Score Index (SSI). This dynamic, algorithmic score provides an ob-jective, quantifiable mea-

sure of a product's current ecological viability, factoring in variables such as action costs, pollutant degradation, and age. The SSI determines the product's appropriate reuse grade -for example, direct human contact use, limited use, and hence guide sustainable end-of-life decisions for both: Businesses and consumers. This paper describes the development and architecture of the BizAI system, showing how the integration of a blockchain backed DPP and dynamic SSI can provide a verifiable, efficient, incentivized mechanism for enabling a comprehensive transition from a linear to a functional circular economy model in retail.

II. PROBLEM STATEMENT

In the current world scenario, the dependency in the Linear economics, a 'Buy-Use-Dispose' economy, presents a huge threat environment sustainability. The idea of global developmental goals being effectively reached is greatly hampered by this. The lack of traceability and trust is the main reason the transition from linear economy to circular economy is failing. Therefore the current systems do not have an immutable record of product usage after purchase. This results in businesses finding it difficult to assess material reliability for both of the refurbish and recycle actions. Thus they do not have any choice but to discard the material.

Moreover, there is a severe deficiency in objective and data-driven decision-making. The absence of an algorithm driving the decision making process about the material sustainability after going through any process in its past affects the classification of material life. Thus, what is really needed is a verifiable, distributed platform that effectively integrates immutable tracking with dynamic scoring factors such as age, recycle cost, recycle count, emissions emitted during the process of recycle, etc., and robust consumer incentives for the promotion of sustainable development and operationalization of the circular economy at the retail level.

III. OBJECTIVES

The primary objective of the BizAI project is to develop and validate a functional, decentralized system that operationalizes the Circular Economy within the retail sector. This is achieved through the following specific, measurable, and technical goals:

- 1) Develop a Blockchain-Enabled DPP: Develop a Blockchain-Enabled DPP: Create an immutable mechanism by implementing a custom private blockchain. It starts to log information from the manufactured block and appends a new block whenever a new circular action is taken such as Reuse, Recycle or Refurbish.
- 2) Establish a Dynamic SSI: To introduce an objective algorithmic metric quantifying a product's residual viability. The SSI is determined by calculating total degradation from the current score:

$$S_{\text{new}} = \max(0, S_{\text{current}} - \Sigma D_{\text{factors}}) \quad (1)$$

Where $\Sigma D_{\text{factors}}$ includes `base_degradation`, `cost_factor`, `pollutant_factor`, `age_factor`, and `count_factor`. The `base_degradation` is weighted by action priority: `Reuse(0.10) < Refurbish(0.20) < Recycle(0.30)`.

- 3) Implement Secure Retail Integration: Designing a User friendly interface for the business owner to easily identify products using product id etched on the product, view the DPP of the product, and approve in an authenticated manner actions initiated by the customer.
- 4) Incentivize Consumer Participation: Introduce an equitable reward mechanism in which every time a customer submits a product, they will receive points based on their return type. The submitted product needs to be verified and authenticated.
- 5) Enhance Customer Engagement: Develop an AI chatbot who will act like a store representative to help the customer in what they need along with a recommendation system to enhance customer experience.

IV. LITERATURE REVIEW

The BizAI project lies at the cross-section of three critical research domains, namely the Circular Economy, Blockchain Technology, and Digital Product Passports. Reviewing the literature provides insight into how integrated digital solutions must be developed to overcome systemic implementation barriers in the adoption of the Circular Economy.

A. The Transition to a Circular Economy (CE)

Speaking of the traditional linear economic model of Take-Make-Dispose we're all too familiar with, it's been shown that it's just not working. Leading to a general recognition of the need for the Circular Economy. The success of the CE is largely dependent on the ability to prolong the life of our products and use of circular loops like refurbishment, repair, and reuse, and yet, we're still faced with a massive challenge in our modern economic systems. A massive imbalance of information between the consumer, the retailer and the recycler, making it impossible to make responsible end-of-life decisions.

This has highlighted that we need a system of standardising and verifying the quality of products, something we don't have today.

B. Blockchain for Supply Chain Traceability and Trust

When it comes to creating trust and transparency in complex supply chains, blockchain technology has become a go-to solution, and in circular economy, the features of decentralization, immutability and encryption makes it very unique as they allow multiple, sometimes competing, users to share sensitive yet verified product data.

- **Immutability and Provenance:** Studies show that blockchain can wipe out any attempt to manipulate the data, so that the complete history of a product, something that's crucial for its sustainability score index, is fully dependable and can be used to verify that it's eligible for the high-value circular loops that have been discussed, like reuse.
- **Decentralized Access:** Well-known for facilitating collaborative access to product info, blockchain in CE makes it possible for the people who need it. Such as the BizAI business owner who gets to create blocks, and the customer who wants to view them, to interact with a common ledger without having to put all their faith in a single, fallible central authority. This is the foundation for the proposed custom private chain in BizAI.

C. The Emergence of the Digital Product Passport (DPP)

The interest in the Digital Product Passport is increasingly growing both at regulatory and industrial levels; a DPP is basically a container that collects and stores product-specific data for easier traceability and informs us about things like durability, composition, and how a product will be recycled or managed at the end of its life.

- **Integrating CE and Blockchain:** Fast coming into this picture is blockchain, literature says, the way to go to host and shield the DPP data in order to protect it from tampering, as regular databases cannot. BizAI jumps into line with this, proposing a DPP that is secured by a private blockchain.
- **The Gap Addressed by SSI:** Whereas all the current DPP proposals revolve around static information, such as initial material and the date of manufacture, there is a considerable lack in terms of the current value of the material after it undergoes any circular economy process, and how many times it has gone through a process. Sustainability Score Index within BizAI will serve to bridge this gap by being a quantitative post-action metric, taking the Digital Product Passport from just collecting data to actually being able to classify materials in an active and data-driven manner.

D. AI Tools for Customer Engagement

Literature on retail technology supports the effectiveness of AI Chatbots for instant customer service and Recommendation Systems for influencing purchasing decisions. In the BizAI model, these modules operate as independent, customer-facing interfaces. AI Chatbot serves as a general store representative, and the Recommendation System provides standardized product recommendations. Their role is to enhance overall

usability and consumer interaction, indirectly Supporting the business environment where the DPP system operates operates.

V. REQUIREMENTS

This section outlines the functional and non-functional requirements necessary to develop and deploy the independent BizAI modules, with a specific focus on the core Digital Product Passport system that enables the Circular Economy loop.

A. Functional Requirements

These define the specific functions the system must perform.

- 1) DPP Chain Initialization: The system shall enable the business owner to initiate a new product's Digital Product Passport by creating the first block Manufactured Block on the private chain that includes initial block which would include data like a product ID, initial score, age, recycle cost, recycle count, etc.
- 2) Blockchain Security and Integrity: The system shall secure the DPP using a custom private blockchain architecture, ensuring immutability and adding a new block every time one of the circular economy process are carried out on the material.
- 3) Customer Return Input: The system should allow for the customer to input the product ID and select a desired circular action:(Refurbish, Reuse, or Recycle) upon product submission by the customer using the customer interface.
- 4) Owner Authentication and Approval: The system must require the business owner to authenticate and approve a customer's requested action after physical product assessment. This step is mandatory and crucial to maintain the integrity of material composition and efficient grading of the material after process action.
- 5) SSI Calculation and Grading: The system must Automatically calculate the Sustainability Score Index post-action using the defined degradation formula. This computation should apply the particular action weight: 0.10, 0.20, or 0.30 to Reuse, Refurbish and Recycle respectively and subsequently assign the product to one of the five designated classification grades ranging from Grade A to Grade E, where Grade A is best suitable for direct human contact uses and Grade E being "Dispose".
- 6) Incentivization Mechanism: The system must automatically reward a calculated amount of reward points to the customer's account upon the business owner's successful Approval and block creation, ensuring participation and promotion in circular economy.
- 7) Independent AI Chatbot Functionality: The system

must provide an independent, Natural Language Processing AI Chatbot that serves as a general store representative, addressing standard Product and service queries of the customer for a seamless user experience.

- 8) Independent Recommendation System Functionality: The system shall provide an independent Recommendation System that suggests products to customers according to historical purchase data or predetermined criteria.

B. Non-Functional Requirements

These define the criteria used to judge the operation of the system.

- 9) Security and Cryptography: The custom private blockchain must employ robust cryptographic hashing and a strong consensus mechanism to prevent unauthorized block addition, data alteration, and protect user data.
- 10) Performance and Latency: The SSI calculation and new block generation must be executed rapidly (target < 5 seconds) to ensure near real-time transaction processing at the point of return.
- 11) Usability: The business owner's interface for block creation and approval must be intuitive and optimized for minimal clicks, focusing on the ease of entry for the alphanumeric product ID, requiring minimal training.
- 12) Data Integrity: All data written to the blockchain must be verified against predefined schema rules before inclusion to maintain consistency across the distributed ledger.
- 13) Viewability and Transparency: The system must allow the customer to securely view the DPP history of their returned product. All block creations and SSI calculations, while secured, must be auditable by authorized participants.
- 14) Scalability: The system must be scalable to accommodate a growing inventory of products and an increasing transaction volume on the private chain without performance degradation.

VI. METHODOLOGY

The BizAI system is implemented by following a modular architecture consisting of a core Circular Economy layer— Based on a custom private Blockchain and the Sustainability Score Index and two independent customer-facing AI modules. The methodology describes technical steps and underlying logic for each component.

A. System Architecture

Overall system architecture consists of three distinct and independent layers :

- 1) Core Circular Economy Layer (Private Blockchain): The decentralised blockchain responsible

for the DPP’s immutable record and the SSI calculation logic.

- 2) Business Owner Interface: A secure web application for authenticated block creation, transaction approval, and product assessment by the owner only.
- 3) Customer Interface: A public-facing application host ing the independent AI Chatbot and Recommendation System, and providing read-only access to the DPP. History, a feautre to submit their product along with the option to choose which Circular Action should be taken.



Fig. 1. High level Diagram

B. Digital Product Passport (DPP) Implementation

The DPP utilizes a custom private blockchain that ensures Traceability and immutability.

- Blockchain Selection: a custom private blockchain is used per product to ensure controlled participation (Business Owner node only) and high transaction speed, retaining the immutability property of Distributed Ledger Technology.
- Block Structure: Every product chain’s foundation is a Manufactured Block - static data, initial SSI. Subsequent blocks are created upon owner approval of circular actions including Action Type, product ID, Calculated new Sustainability Score Index , and resulting Reuse Grade.

C. Sustainability Score Index (SSI) Algorithm

Sustainability Score Index is a dynamic metric calculated during the block generation phase to quantify the environmental cost and degradation of the chosen action.

- 1) Total Degradation Formula: The new score (S_{new}) is derived from the current score ($S_{current}$) by subtracting the total calculated degradation ($\Sigma D_{factors}$):

$$S_{new} = \max(0, S_{current} - \Sigma D_{factors}) \quad (2)$$

- 2) Degradation Factor Components: The total degradation is composed of five weighted factors:

- base degradation = initial score \times action weights
- cost factor = $(\frac{\text{action cost}}{\max(P_{price}-1)}) \times S_{initial} \times 0.15$
- pollutant factor = $(\frac{\text{pollutants}}{100}) \times S_{initial} \times 0.10$
- age factor = $(\frac{\text{product age}}{10}) \times S_{initial} \times 0.05$
- count factor = $(\frac{\text{action count}}{20}) \times S_{initial} \times 0.10$

- 3) Action Weighting: The action weights reflect the environmental priority of the circular action, ensuring that least preferred action (Recycle) yields the highest base degradation.

TABLE I
ACTION WEIGHTING FOR SSI DEGRADATION

Action Type	Weight	Priority
Reuse	0.10	Highest
Refurbish	0.20	Moderate
Recycle	0.30	Lowest

D. Independent AI Module Implementation

The AI Chatbot and Recommendation System operate independently from the core DPP blockchain logic, utilizing standard centralized databases for efficiency.

- AI Chatbot: Implemented using Natural Language The NLP engine is trained on store-specific FAQs. It answers general questions and acts like a store representative.
- Recommendation System: Uses a collaborative filtering or content-based filtering algorithm on centralized transaction history to provide personalized product suggestions.

VII. FUTURE RESEARCH SCOPE

Technology and Dynamic Scoring Sustainability Score Index for various aspects in the future. The result of this is academic research and technical exploration work:

A. Optimization of the Sustainability Score Index (SSI)

It is suggested that future studies should focus more on refining the current model and generalizing it to cover a wider spectrum of issues.

- 1) Dynamic Weighting through Machine Learning: The current weights are fixed for Reuse Refurbish and Recycle, respectively, as 0.10, 0.20, and 0.30 for the rent action. One important field of study is the integration of Machine Learn- train ML models to dynamically change action weights. via real-time factors including regional energy consumption rates, current prices of commodity materials, it also reduces the rate of local pollution.
- 2) Externalized Cost Integration: Research may focus on the precise modeling and integration of complex environmental factors such as carbon cost, water footprint in the pollutant factor and in the cost factor components, thereby changing the Sustainability Score Index from a decline by Index to a comprehensive Total Environmental Cost TEC metric.
- 3) Material-Specific Degradation Profiles: Development of highly specific SSI parameters that provide for particular degradation pathways depending on material classes e.g., polymers versus metals versus organic materials to ensure that the Sustainability Score Index calculation is material specific

B. Scalability and Interoperability of the DPP Blockchain

Since the current chain is private, further research is needed to study the transition and integration process with wider supply chain networks.:

- 4) Cross-Chain Communication Protocols: Exploring interoperability protocols that will facilitate BizAI Private DPP chain for safe data exchange: example final SSI score, reuse grade with industries having expertise about recycling for continuation of the flow of the end goal. That way, the integrity of a private ledger is not compromised.
- 5) Decentralized Autonomous Organization (DAO) Governance: Feasibility study of transitioning to the owner-centric Proof-of-Authority, PoA consensus mechanism to a more decentralized multi-stakeholder model (e.g., including third-party certified refurbishers) or the regulators in the scheme that is a DAO.

C. Behavioral Economics of Incentivization

The current rewarding system is point-based. Future research could, for example, explore the behavioral science behind consumer engaging in circular models:

- 6) Gamification and Tokenomics: The study of how the which utility tokens or Non-Fungible tokens, in general, as part of circular actions, can further gamification of the return process may encourage to higher participation rates than for simple reward points.
- 7) Comparative Incentive Modeling: Performing a comparative review of incentive models, such as instant cashback, discounts on green products, by considering all other options available for obtaining relief, such as philanthropic gifts. Strategy for various demographics and product categories by promoting sustainable practices.

VIII. IMPROVING EXISTING SYSTEM

The current architecture of BizAI allows to create a traceable and immutable foundation for circular economy. Still there are a few assumptions being followed that are not always true in real time scenario. In this section we will focus on the aspects which can be enhanced on the current system which could not be addressed due to complex modern retail and manufacturing.

A. Dynamic Cost Modeling

The existing technology relies on a fixed cost of Circular actions for each category of products for calculating the cost factor in the SSI algorithm. This is impractical in real life, as the actual cost of circular actions (refurbishment, reuse preparation, or recycling) is highly dependent on external and operational factors.

- Improvement: Dynamic Cost API Integration. The system should integrate with external APIs or internal databases that provide real-time pricing for labor, transportation, and energy depending on the local rates. The

action cost variable should consists of various external factors which keep changing by time:

$$\text{action_cost} = f(\text{labor_rate}, \text{energy_price}, \text{transport_distance}) \quad (3)$$

This enhancement ensures the SSI reflects the true, up-to-the-minute economic viability of a circular action.

B. Composite Product Complexity and Granular Tracking

The current DPP assumes a product is a single, homogeneous entity with a single SSI. This fails to address complex products that consist of multiple composite parts with varying lifespans, material compositions, and independent recycle counts.

- Improvement: Nested DPPs and Component-Level SSI. The system must allow the initial Manufactured Block (FR1.0) to register a hierarchical structure. The main product's DPP would function as a parent record, containing nested, independent DPPs for key sub-components. This allows the SSI to be calculated *per-component* upon disassembly, ensuring that high-value parts can be tracked and reused multiple times. The parent SSI would then be a weighted average of its components' residual scores.

C. Enhanced Material Degradation and Certification

The pollutant_factor is currently a simple degradation metric. In reality, material safety for reuse requires complex testing, especially for sensitive applications like food contact or medical use.

- Improvement: Digital Certification and Sensor Data Integration. For products designated for high-value reuse (e.g., Direct Human Contact Use), the system should require an authenticated block from a Third-Party Certification Authority (TPCA). This block would confirm laboratory-verified pollutant levels and material integrity, allowing the system to override the base pollutant_factor with certified data, thereby enhancing trust and safety.

D. Offline Transaction Management

A core practical concern for small retail operations is network reliability. The current NFR2.0 assumes constant connectivity for near real-time block generation.

- Improvement: Delayed Consensus Queue (DCQ) Protocol. The business owner's interface should allow returns to be logged temporarily in a secure, encrypted local queue when the private blockchain network is inaccessible. The local system would issue a temporary receipt and reward points, but the actual block creation and final SSI calculation (FR1.3) would be executed and timestamped only when connectivity is restored and the Proof-of-Authority (PoA) consensus is achieved. This ensures transaction continuity and data integrity even during network outages.

IX. PROPOSED DESIGN

The proposed design for BizAI is a three-tier, modular architecture centered on a custom private Distributed Ledger Technology (DLT). This design ensures the separation of the core traceability logic (DPP) from the independent customer-facing features.

A. Architectural Overview

The system is structured into three main layers: Presentation, Application Logic, and Data/Ledger.

System Architecture Layers:

- 1. Presentation Layer: Contains the Customer and Owner UIs (web/mobile interfaces). The Owner UI includes secure block creation; the Customer UI includes independent AI tools and read-only DPP viewing.
- 2. Application Logic Layer: Hosts the Transaction Handler, SSI Engine, Incentivization Service, and AI Services. This layer is responsible for executing business logic and authority validation.
- 3. Data/Ledger Layer: The core repository. The Private Blockchain stores immutable DPPs; the Centralized DB (CDB) stores customer data, rewards, and transaction history.

B. Digital Product Passport (DPP) Workflow

The core function is to create a DPP and update it by adding blocks whenever a circular action is taken on the product.

- 1) Product Onboarding (Manufactured Block): The owner registers product ID and initial data ($S_{initial}$). The Transaction Handler packages the data into the first block, which the owner’s node signs .
- 2) Circular Action Process (New Block Creation):
 - Initiation: Customer inputs product ID and selects $Action_{type}$ (Reuse, Refurbish, or Recycle) from the drop down menu.
 - Calculation: The SSI Engine fetches $S_{current}$ and variables affecting the degradation rate for computing S_{new} and Classification Grade .
 - Approval: A new block is created after the owner’s approval.
 - Incentivization: Incentivization Service credits (Reward Points) are added to customer’s account with reward points depending upon the product submitted by the customer.

C. SSI Engine Design

The SSI Engine is the critical component responsible for calculating the Sustainability Score Index which is in turn used to grade the material based on the range in which the SSI lies in.

Core SSI Calculation Logic:

- Input Data: $Action_{type}$, $S_{initial}$, P_{price} , Pollutants, Age, Count, and $S_{current}$ (from last block).
- Calculation: The engine computes $\Sigma D_{factors}$ and the core equation:

$$S_{new} = \max(0, S_{current} - \Sigma D_{factors}) \quad (4)$$

- Output: The final S_{new} is mapped to the final Reuse Grade (e.g., Direct Human Contact Use, Restricted Use).

D. Independent Module Integration

The AI Chatbot and Recommendation System services interface directly with the Centralized Data Base for customer history and store data to answer customer queries and suggest products based on historical purchases.

X. RESULTS

The BizAI project successfully implemented a proof-of-concept showing that the core functionalities of the Digital Product Passport (DPP), the immutability of the private blockchain, and the calculation of the Sustainability Score Index (SSI) depends on multiple factors responsible for degradation of materials. The results validate the feasibility of the proposed methodology for transition from Linear Economy to Circular Economy.

A. Proof of Concept: SSI Algorithm Validation

To validate the SSI Engine , a product lifecycle simulation was executed. The simulation begins with a single product and tracks three sequential circular actions.

TABLE II
INITIAL SIMULATION PARAMETERS

Parameter	Value/Source	Unit
Initial Score ($S_{initial}$)	100.0	Grade
Initial Product Price (P_{price})	100.00	INR
SSI Grade Threshold ($S_{new} \geq 80$)	Direct Contact Use	Grade

1) Scenario 1: First Action - Reuse (Lowest Degradation): The score degradation is calculated using $S_{current} = 100.0$ and action weight = 0.10.

TABLE III
SCENARIO 1: REUSE ACTION DEGRADATION

Factor	Value/Calculation	Degradation (D_f)
Base Deg. (Action Weight 0.10)	100×0.10	10.00
Cost Factor (5.00 INR)	$(5/100) \times 100 \times 0.15$	0.75
Pollutant Factor (10 g of CO ₂ eq)	$(10/100) \times 100 \times 0.10$	1.00
Age Factor (1 month)	$(1/10) \times 100 \times 0.05$	0.50
Count Factor (1 Action)	$(1/20) \times 100 \times 0.10$	0.50
Total Degradation ($\Sigma D_{factors}$):		12.75

The resulting New Sustainability Score is $S_{new} = 100.0 - 12.75 = 87.25$, assigning the Reuse Grade: Direct Contact Use.

2) Scenario 2: Second Action - Recycle (Highest Degradation): The score degradation is calculated using $S_{current} = 87.25$ and action weight = 0.30.

The resulting New Sustainability Score is $S_{new} = 87.25 - 33.38 = 53.87$, assigning the Reuse Grade: Limited Use.

TABLE IV
SCENARIO 2: RECYCLE ACTION DEGRADATION

Factor	Value/Calculation	Degradation (D _i)
Base Deg. (Action Weight 0.30)	87.25×0.30	26.18
Cost Factor (25.00 INR)	$(25/100) \times 87.25 \times 0.15$	3.27
Pollutant Factor (5 g of CO ₂ eq)	$(5/100) \times 87.25 \times 0.10$	0.44
Age Factor (6 months)	$(6/10) \times 87.25 \times 0.05$	2.62
Count Factor (2 Actions)	$(2/20) \times 87.25 \times 0.10$	0.87
Total Degradation ($\Sigma D_{factors}$):		33.38



Fig. 2. Enter Caption

B. Blockchain Functionality and Traceability

The private blockchain implementation successfully met the key requirements for immutability and verifiable traceability of product history .

- **Immutable History:** Any effort made at altering the SSI score or any other informatin regarding the product is prohibited by the use of hashing algorithm.
- **DPP Verification:** The customer interface successfully retrieved and displayed the history of the product DPP, making the whole application more accessible and transparent.
- **Performance:** Block generation and SSI calculation occurred in an average of 2.8 seconds, well below the target of 5 seconds, ensuring capability to handle real-time application in a retail setting.

C. Incentivization and Customer Modules

User testing confirmed that the owner interface was user friendly and easy to adapt . The independent modules functioned as required:

- **Incentivization:** The Incentivization Service successfully credited the customer’s centralized account with reward points immediately following the block addition in both scenarios, after the request has been approved by the owner.
- **Architectural Separation:** The AI Chatbot and Recommendation System provided their respective services independently.

XI. DISCUSSION

The successful proof of concept implementation of BizAI now validates the potential of BizAI to act as a robust and necessary framework to accelerate the shift from a linear to a Circular Economy. This discussion interprets the results in light of the initial problem statement and the established literature.

A. Addressing the Problem of Traceability and Trust

The root issue detected was related to traceability not being verifiable and trusted within the lifecycles of products. Through the implementation of the Digital Product Passport using a custom, private blockchain deployed by BizAI, this very inadequacy has been precisely addressed. From the outcomes obtained, it becomes clear that the history regarding the product is irrecoverable after the owner’s authenticated consent—a very important factor offering an added advantage over conventional centralized databases in terms of auditability and thereby assurance from a compliance perspective and even consumer trust. This follows from acquired literature with regard to the role of Distributed Ledger Technology in enabling supply chain transparency.

B. Validation of the Dynamic Sustainability Score Index (SSI)

The SSI algorithm was effective in providing an objective, dynamic metric quantifying residual sustainability (FR1.4). Simulation results clearly convey the intended behavioral incentive built into the system:

- **Prioritization:** The much higher degradation weight applied to "Recycle" had the effect of causing a far steeper drop of the SSI score (from 87.25 to 53.87), relative to the preferred action, "Reuse", whose (score fell from 100.0 to 87.25)" This result successfully converts the project’s CE priorities into a quantifiable economic signal.
- **Decision Support:** Final scores directly determined the next certified use grade of the product, such as Limited Use for the recycled product. This removes subjective judgment of the business owner and directly addresses the core problem of arbitrary material classification, to maximize the value of returned inventory sustainably.

C. Architectural Efficiency and User Adoption

the architectural decision to keep both the AI Chatbot and Recommendation System as independent modules decoupled from the core DLT (FR2.0, FR3.0). This prevented the high-performance demands of real-time customer service to impact the computationally heavier blockchain node, thereby contributing to a strong performance result of 2.8 seconds block time (NFR2.0). Furthermore, positive usability feedback given for NFR3.0 and a workable incentivization mechanism as in FR1.6 is indicative of high potential for owner and customer adoption, which is usually left out in purely technical implementations of DLTs.

To summarize, BizAI shows how a blockchain-backed DPP with a robust, algorithmic SSI could provide a feasible, transparent and performance-driven solution that can execute the Circular Economy, effectively, right at the point of sale.

XII. FUTURE SCOPE

The immediate future scope is devoted to translating the limitations identified in the methodology, added to the valuable feedback from potential end-users, into concrete development phases. It encompasses addressing real-world operational challenges and enhancing the system's external connectivity.

A. Phase I: Operational and Resilience Enhancements

These features focus on stability, usability in practice, and the reduction of real-world burdens, including network reliability and ease of use for the business owner.

- 1) **Offline Transaction Management Integration:** Integrate the Delayed Consensus Queue (DCQ) Protocol, as proposed in Section VIII. Customer returns and initial data logging can be processed efficiently through a secure local cache, even in the absence of a private blockchain network. Actual block generation and PoA consensus would be automatically handled once the network becomes available.
- 2) **Optimized Material Prediction for Owner:** Implement a feature which will cross-reference the SSI-assigned Reuse Grade e.g. "Limited Use" with a centralized database of material conversion recipes. This gives the owner immediate, profitable suggestions on what kind of new items can be created from the collected materials.
- 3) **Simplified Customer Engagement:** Enhance the customer-facing AI Chatbot to include only highly accessible information related to rewards and product return processes for maximum user engagement and system throughput based on general user feedback.

B. Phase II: External Connectivity and Supply Chain Expansion

These expansions have focused on scaling the system beyond the single-retailer environment, increasingly integrating with upstream and downstream partners.

- 4) **Third-Party Integration API:** Create a secure, authorized Application Programming Interface API that would enable the integration of external third-party recyclers or refurbishers to be able to work with BizAI's private chain. This then can send product transfer blocks to certified partners in addition to adding further blocks post-action stating the SSI score after said action and completion.
- 5) **Supplier and Manufacturer Data Integration:** Establish partnerships to integrate initial product data ($S_{initial}$, detailed material lists) directly from manufacturer systems via an authorized data bridge. This automation reduces manual owner input requirements FR1.0 and greatly enhances data accuracy as well as system ease of use.
- 6) **Regulatory Compliance Layer:** Add functionality such that the system can produce regularized reports on regulatory matters, e.g., proposed DPP compliance documents, based on immutable data recorded on the blockchain. The purpose of this is to ready the system

for integration into future binding regulatory frameworks.

XIII. CONCLUSION

The BizAI project successfully designed and demonstrated a decentralized digital framework essential for the effective implementation of CE within retail operations. By addressing the critical systemic limitations of the linear model, BizAI provides a verifiable and objective pathway toward sustainable commerce.

This is achieved by seamlessly integrating a Digital Product Passport secured through a custom private Blockchain into the dynamic Sustainability Score Index. Simulated SSI calculation demonstrated the ability to translate environmental priority, or Reuse → Refurbish → Recycle, into a quantifiable economic signal via score degradation-no subjective decision-making with respect to product status at end of life. The modular architecture maintains high performance (average block time of 2.8 s) and keeps the core DLT logic separate from independent customer facing AI tools.

In this way, BizAI achieves not only its two key objectives of an immutable traceability system and objective scoring metric but also provides a test case for the technical feasibility of scaling such a model in a retail context. The system lays down a solid foundation for further research, especially on dynamic cost modeling and external supply chain integrations, making it a key and important tool to achieve verifiable compliance and ensure widespread consumer participation in the next generation of sustainable economic practices.

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