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Implementation of Inclusive Closed Loop in Improving Production Efficiency and Sustainability

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Abstract

Amidst increasing external pressures related to sustainability, such as international regulations, stakeholder expectations, and global consumer demands, the rubber industry is required to develop internal strategies that are not only operationally efficient but also adaptive to the transformation towards environmentally friendly production and supply chain practices. This study aims to analyze the implementation of an inclusive closed-loop supply chain as a strategic approach for companies to integrate production efficiency, waste reduction, and respond to institutional pressures for sustainability. The novelty of this study lies in the integration of an inclusive closed-loop approach that goes beyond the traditional concept of recycling, prioritizing the active participation of all internal actors (production, procurement, sustainability) and strengthening cross-functional relationships within the organization as the basis for the transition to a green supply chain. This research is built on a combined theoretical framework: the Natural Resource-Based View (NRBV) to explain internal capabilities in creating a competitive advantage based on sustainable resources; Institutional Theory to identify the influence of external pressures on organizational behavior; and Stakeholder Theory to explore the dynamics of expectations and the involvement of key actors in the value chain. The method used is a quantitative explanatory approach, with data collection through a survey of managers at rubber processing companies in Indonesia. Data were analyzed using Structural Equation Modeling - Partial Least Squares (SEM-PLS) to examine the relationships between inclusive closed-loop dimensions, operational efficiency, green supply chains, and companies' strategic adaptation to sustainability pressures. The expected results indicate that inclusive closed-loop supply chains contribute significantly to achieving operational efficiency and waste reduction, while strengthening companies' capabilities in building environmentally friendly supply chains and production processes. These findings are expected to provide theoretical contributions to the development of resource- and institutional-based sustainability strategies, as well as practical implications for companies responding to global challenges through inclusive and sustainable business model transformations.

Keywords: Inclusive closed-loop supply chain, green supply chain, NRBV, institutional pressure, stakeholder engagement, operational efficiency, corporate sustainability, SEM-PLS

1. Introduction

The current global manufacturing production model is still dominated by a linear "take-make-dispose" approach, which leads to high resource consumption, waste accumulation, and greenhouse gas emissions. As global pressures on climate change, resource scarcity, and sustainability demands increase, this approach is becoming increasingly obsolete. The alternative offered by the circular economy (CE) concept offers promise, with its core principles emphasizing reuse, recycling, and waste reduction through a closed-loop system. However, global adoption of the circular economy remains relatively low. The Circularity Gap Report (2024) states that only around 7.2% of the world's total materials are recycled back into the production system. This indicates a significant gap between sustainability principles and their implementation in manufacturing practices (Circle Economy, 2024).

Current manufacturing production generally follows a linear “take–make–dispose” model, leading to high resource consumption and waste accumulation. The concept of a circular economy with closed-loop production is a strategic solution because it can extend the lifespan of materials and reduce emissions. However, its practical implementation remains limited. For example, an article by reviews quantitative models of sustainability in the supply chain and states that most deterministic models do not incorporate life cycle analysis, highlighting a significant gap in effective closed-loop design [1].

Quantitative studies explicitly examining closed-loop supply chain design have also emerged. [2], for example, developed an integrative SEM framework in the petrochemical industry based on a questionnaire with 230 respondents. Their findings confirmed a significant relationship between economic motivation, customer awareness, environmental regulations, and sustainability. This model can be downloaded in full as the journal is open access.

In addition, robust supply chain design with closed-loop optimization in the tire industry has been investigated. A study by proposed a robust multi-objective model (a combination of deterministic and fuzzy) in a CLSC network, addressing uncertainty in demand, return rates, and production costs. The results show that optimal capacity management and distribution/collecting center networks can reduce pollution while maintaining company profitability [3].

Closed-loop supply chain (CLSC) is a strategic technical approach to supporting the circular economy, particularly in the context of sustainable production. Govindan, Jha, and Garg (2016), using multi-objective mixed-integer programming modeling, demonstrated that effectively integrated product recovery within the supply chain can reduce the environmental footprint while simultaneously increasing company profitability. This research emphasizes that a quantitative approach can precisely measure the balance between economic efficiency and environmental sustainability [4]

In addition to RBV theory, the concept of "circular operations" also serves as an important foundation for integrating lean, green, and circular practices into a company's operational processes. A study by stated that circular operations can improve operational efficiency while strengthening a company's long-term competitiveness. Circular operations encourage the transformation of production processes to be more adaptive to material recovery, lower energy consumption, and the use of alternative, recycled-based raw materials [5].

The integration of Industry 4.0 technologies such as the Internet of Things (IoT), blockchain, and big data analytics also plays a crucial role in supporting the implementation of closed-loop production. found that digital technology can increase visibility and transparency in reverse logistics flows and help optimize remanufacturing processes. This approach not only improves process efficiency but also strengthens real-time operational sustainability monitoring and tracking systems [6].

A review of the existing literature reveals several significant research gaps. First, most studies still focus on closed-loop supply chain and logistics aspects, with few truly evaluating implementation at the inclusive internal production level. Second, quantitative approaches that measure the simultaneous contribution of green capabilities, technology, and company policies to efficiency and sustainability are still limited. Third, there is little recent empirical research based on primary data that examines the impact of an inclusive closed-loop approach on production output, energy efficiency, waste reduction, and socio-economic impacts holistically.

Based on these gaps, this study aims to analyze the implementation of inclusive closed-loop production as a strategy to improve efficiency and sustainability in the manufacturing sector. This research will evaluate the role of green technology integration, organizational capabilities, and internal coordination on production efficiency and sustainability outcomes through quantitative approaches, such as multiple regression or structural modeling (PLS-SEM). The focus on the production level (rather than just the supply chain) provides both theoretical and practical contributions that can enrich the circular economy literature from the perspective of inclusive internal production.

Thus, this research is expected to contribute to the development of RBV and circular operations theory in the context of sustainable manufacturing, as well as generate practical implications in the form of policies for strengthening human resources, environmentally friendly production technologies, and managerial coordination that can be adopted by manufacturing companies. This is crucial in addressing global challenges related to energy efficiency, industrial waste reduction, and achieving the Sustainability Development Goals (SDGs) targets.

2. Research Methodology

This study uses a quantitative approach with the Structural Equation Modeling (SEM) method, which is suitable for testing the relationship between latent variables simultaneously [7]. The nature of this study is explanatory because it aims to explain the effect of the implementation of an inclusive closed loop on production efficiency and sustainability. The research location was chosen at the company PT Kirana Megantara, which has implemented the closed loop concept since 2021. The study population was production supervisors, directly involved staff, and rubber farmers, totaling approximately 1,000 people. The sample was selected purposively, namely only those who worked for at least one year and were involved in the closed loop process, while outsourced employees or those who refused to participate were excluded from the sample. The data collection technique used a Likert scale questionnaire 1–5. The research instrument was tested for validity through content testing by experts and construct testing with CFA, and its reliability through Cronbach's Alpha of at least 0.7 [7]. Data analysis was carried out using SEM-PLS with SmartPLS 4 software, starting with the outer model test to ensure validity and reliability, then the inner model test to test the hypothesis and see the influence between variables, as recommended [7]. The research stages include literature study, questionnaire preparation and validation, data collection, analysis, and reporting. The operational definition of variables includes inclusive closed loop as a production system with internal recycling and related party involvement, measured through employee participation, supplier cooperation, and raw material reuse [8]; production efficiency as the ability to produce optimal output at minimal cost, measured through output/input ratio, waste reduction, and production speed [9]; and sustainability as the ability to maintain environmentally and socially friendly operations, measured through emission reduction, energy efficiency, and stakeholder satisfaction [10]..

3. Results and Discussion

3.1. Respondent Characteristics

The study involved a total of 117 respondents selected based on the following inclusion criteria: having worked for at least one year and being involved in an inclusive, closed-loop process. The following table describes the respondent profile based on gender, age, highest education, position, and work experience.

Table 1. Respondent Characteristics

Characteristic	Category	Frequency	(%)
Gender	Male	79	67.5%
	Female	38	32.5%
Age (years)	≤ 20	1	0.9%
	21–30	45	38.5%
	31–40	51	43.6%
	41–50	14	12%
	> 51	6	5.1%
Education	High School/Vocational (SMA/SMK)	5	4.3%
	Diploma	6	5.1%
	Bachelor	92	78.6%
	Postgraduate	14	12%

Most respondents were aged 31–40 years, university graduates, and/or equivalent, reflecting experience and direct involvement in closed loop implementation.

3.2. Outer Model

Validity Test

Convergent validity is assessed using the Average Variance Extracted (AVE). An AVE value > 0.50 indicates good validity.

Table 2. Convergent validity

Variable	AVE	Description
Inclusive Closed Loop	0.606	Valid
Production Efficiency	0.721	Valid
Sustainability	0.561	Valid

The test results show that the instrument meets the validity requirements.

Reliability Test

Reliability was measured using Cronbach's Alpha (CA) and Composite Reliability (CR). CA and CR values >0.70 indicate good reliability. [7].

Table 3. Reliability

Variabel	Cronbach's Alpha	Composite Reliability	Description
Inclusive Closed Loop	0.807	0.816	Relible
Production Efficiency	0.782	0.785	Relible
Sustainability	0.738	0.743	Relible

3.3. Inner Model

R-Square Coefficient of Determination

Table 4. Coefficient of Determination

Variable Dependent	R^2	Category [7]
Production Efficiency	0.551	Moderat
Sustainability	0.585	Moderat

The R^2 value (coefficient of determination) indicates the variation explained by the model.

Hypothesis Testing

Hypothesis analysis was conducted to examine the effect of inclusive closed-loop systems on production efficiency and sustainability**.**

Table 5. Presents a summary of the results of the hypothesis testing

Hypothesis	Path Coefficient	t-statistic	p-value	Description
Inclusive Closed Loop → Production Efficiency	0.449	3.575	0.000	Significant (+)
Inclusive Closed Loop → Sustainability	0.767	15.189	0.000	Significant (+)
Suistanbility → Production Efficiency	0.345	2.848	0.004	Significant (+)

These results indicate that the implementation of inclusive closed loop has a positive and significant effect on production efficiency and sustainability.

3.4. Discussion

The results of this study reinforce the findings of the hybrid SEM ANN model and confirm that a closed-loop manufacturing system incorporating product development (eco-design, LCA), production processes (lean, green techniques), people (staff training & participation), and policies (environmental policies) significantly improves sustainable manufacturing performance[11]. The inclusive closed-loop variable, which emphasizes employee participation and supply chain collaboration, is consistent with the "people" and "policies" dimensions in that study.

Furthermore, critical reviews of closed-loop supply chain models focus on the economic and environmental dimensions and often neglect social aspects (social sustainability), even though all three should be synergistic in implementing a sustainable closed-loop supply chain (SCLSC) [12]. The findings demonstrate the significant influence of an inclusive closed-loop system on sustainability and efficiency, supporting the need to integrate the social dimension through employee and supplier engagement as an integral part of a mature circular economy model.

In the context of closed-loop network design, we introduce a multi-objective optimization model for a resilient and sustainable post-pandemic supply chain that considers demand and emission uncertainty, using metaheuristic approaches such as the Whale Optimization Algorithm and Simulated Annealing[13]. Their emphasis on system flexibility and operational resilience is relevant to the research findings, namely that an inclusive closed-loop structure, established since 2021 and featuring cross-functional collaboration, improves operational stability under various conditions.

On the other hand, the paper's description of robust supply chain optimization related to capacity flexibility and government subsidies shows that flexible strategies (e.g., facility capacity that can adjust recycling volumes) result in lower costs and minimal CO_2 emissions compared to a rigid capacity model[14]. This intersects with the value of production efficiency in your findings: companies that adopt an inclusive closed-loop approach involve capacity realignment and long-term partnerships with suppliers.

4. Conclussion

Based on the quantitative analysis, this study concludes that the implementation of Inclusive Closed Loop practices has a significant and positive influence on both Production Efficiency and Sustainability. The strongest effect was observed on Sustainability, supporting the theoretical view that inclusive circular systems are essential in strengthening environmental and social responsibility beyond economic gains. Additionally, Sustainability itself was found to positively affect Production Efficiency, in line with previous studies highlighting that sustainable operational strategies—such as waste reduction and resource optimization—can enhance efficiency and competitiveness. These findings confirm that integrating inclusive circular approaches not only improves sustainability performance but also contributes to production efficiency, thereby achieving the objectives set in this research and aligning with the theoretical framework.

Drawing from these results, it is recommended that companies actively embed inclusive closed-loop principles in their operational strategies by involving various stakeholders—suppliers, consumers, and communities—to strengthen sustainability outcomes and realize efficiency improvements. Businesses are also encouraged to integrate sustainability into daily operations through investments in green technologies, training, and environmentally friendly process innovations. For future research, scholars could extend this study by applying similar models to different industries or using longitudinal approaches to explore long-term impacts. Policymakers may also consider designing regulations and incentives that facilitate the adoption of inclusive and sustainable production systems. These recommendations, derived from empirically tested and statistically significant results, are expected to provide practical insights for industry and enrich academic discourse in the field of sustainable production and circular economy.

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