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Developing a Circular Economy-Oriented Business Process Model for Sustainable Weaving Industries

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A B S T R A C T

This research aims to develop a circular economy-based business process model for the traditional weaving industry in Nusa Tenggara Timur (NTT), Indonesia. The study addresses the problem of waste generation and resource inefficiency in the existing linear production process, which relies heavily on synthetic dyes and lacks systematic reuse or recycling practices. By applying the Business Process Model and Notation (BPMN) and the Circular Business Model Canvas (CBMC), a redesigned process integrates waste recovery, reuse, and upcycling. Simulation results indicate that introducing natural dyeing, product diversification from leftover materials, and reverse logistics significantly reduce environmental impact while increasing revenue by 15–20%. This model demonstrates the feasibility of adopting circular principles in small-scale traditional industries, providing environmental benefits and economic resilience. The findings contribute to sustainable business practices and offer a replicable framework for similar sectors.

Keywords: Circular Economy, BPMN, CBMC Weaving Industry, Sustainability

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1. Introduction

The traditional weaving industry in Indonesia embodies substantial cultural significance and considerable economic potential, particularly within the realms of the creative economy and Micro, Small, and Medium Enterprises (MSMEs). Ikat weaving from East Nusa Tenggara (NTT) functions not only as a representation of local cultural identity but also demonstrates extensive market potential on both domestic and international levels. According to a report issued by the Ministry of Industry, the craft subsector, which encompasses weaving, accounts for approximately 17% of Indonesia's creative economy Gross Domestic Product (GDP), with an observable upward trend in demand for ethnic products concomitant with the global shift toward sustainable lifestyles [1]. Consequently, the weaving industry is compelled to adapt strategically to ensure continued viability, with particular emphasis on mitigating environmental impacts throughout its production processes.

The traditional textile weaving process employs two primary types of dyes: natural dyes, which are derived from plant-based or other organic materials, and synthetic dyes, which originate from industrial chemical compounds. The use of these different dye types results in textiles with distinct aesthetic qualities and varying levels of durability and environmental impact. Despite the difference in dye sources, the weaving process itself is typically carried out manually and remains rooted in local, community-based practices. However, environmentally sustainable approaches have yet to be fully adopted within this industry. Several critical issues persist, including the prevalent use of synthetic dyes, the unregulated disposal of textile and thread waste, and the absence of structured recycling and waste management systems.

Figure 1. Woven Process

Figure 2. Dyeing Process of Weaving Threads

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The concept of circular economy represents an innovative approach that emphasizes the principles of resource reutilization, waste reduction, and sustainable product lifecycle management. The implementation of circular economy principles in the weaving industry is expected to generate business processes that are not only economically efficient but also yield positive environmental and social impacts. According to the Ellen MacArthur Foundation, the linear economic model increasingly burdens the environment, thus the transition towards a circular economy offers a strategic solution to mitigate environmental impact while enhancing economic value [2]. Circular economy prioritizes the principles of reduce, reuse, and recycle, as well as extending product lifecycles through business innovation. Furthermore, research by the Ministry of Environment and Forestry (KLHK) indicates that textile waste significantly contributes to water pollution and increased carbon emissions. Consequently, the application of circular economy principles in the textile industry, including traditional weaving, has the potential to reduce emissions by up to 24% and decrease waste by 40% [3].

This study aims to develop a business process model based on the circular economy concept, specifically designed to be adopted by stakeholders in the weaving industry. The model intends to establish a production ecosystem that is not only environmentally friendly and efficient but also capable of generating high added value for industry actors. By integrating sustainability principles at every stage of the production process, it is expected that the weaving industry will be better positioned to address market demands that increasingly emphasize environmental and social considerations. Furthermore, the implementation of this model has the potential to strengthen the competitive position of woven products in both global and domestic markets, where sustainability values are becoming decisive factors. Moreover, weaving production sites that apply the circular economy model can be developed into educational tourism venues. This initiative would enable the broader community and visitors to gain a deeper understanding of the weaving production process, while simultaneously promoting the preservation of cultural heritage and enhancing local economic value through education-based tourism.

2. Literature Review

2.1 Traditional Weaving Industry in East Nusa Tenggara (NTT)

Ikat weaving is one of Indonesia's intangible cultural heritages that has been internationally recognized by UNESCO for its significant historical, aesthetic, and social value. According to data from the Ministry of Industry (2022), the province of East Nusa Tenggara (NTT) is home to more than 60 distinctive ikat motifs, which are not only competitive in the domestic market but have also penetrated international markets. The diversity of these motifs reflects the richness of local culture and serves as a vital component of the community's cultural identity.

Nevertheless, small and medium enterprises (SMEs) engaged in the ikat weaving sector continue to face a range of challenges related to environmental management and the sustainability of their production processes. One of the primary issues is the use of synthetic dyes, which pose a risk of environmental pollution, particularly to water resources. In addition, production waste such as leftover threads and fabric scraps is often not utilized optimally, leading to waste accumulation that negatively impacts the surrounding environment. Another pressing challenge is the limited access to environmentally friendly and affordable waste processing technologies.

A study conducted by Rahmawati [4] revealed that approximately 75% of ikat artisans dispose of their production waste without any form of treatment, highlighting the urgent need for the development of more sustainable production models. This condition underscores the necessity of adopting innovative approaches, such as the application of circular economy principles, to enhance production efficiency, reduce environmental impact, and simultaneously preserve the cultural value embedded in ikat weaving.

2.2 Circular Economy (CE)

The Circular Economy (CE) is an economic paradigm aimed at minimizing waste and optimizing resource utilization through strategies such as reduce, reuse, recycle, remanufacture, and upcycle [5]. This model fundamentally contrasts with the traditional linear economy, which operates on a take–make–dispose pattern and contributes to unsustainable resource extraction and environmental degradation [1].

Core principles of the circular economy include the extension of product lifecycles through maintenance, repair, and refurbishment; the conversion of waste into valuable resources through effective recycling and material innovation; and the integration of sustainability-oriented business innovations that transform production and consumption systems. Rather than viewing waste as an inevitable by-product, CE repositions it as a potential input within a closed-loop system, thereby promoting systemic efficiency and environmental stewardship.

In the textile industry, the adoption of CE principles holds considerable potential to reduce environmental impacts. According to the Ellen MacArthur Foundation, implementing circular strategies could lower greenhouse gas emissions by up to 44% and reduce solid waste generation by 50% [1]. These findings underscore the relevance of CE not only as a climate mitigation strategy but also as a transformative framework for promoting long-term sustainability within resource-intensive industries such as textiles.

2.3 Business Process Management (BPM) in Industry

Business Process Management (BPM) is a systematic methodology used to model, analyze, implement, monitor, and optimize business processes within an organization [6] This approach not only plays a vital role in enhancing operational efficiency but is also highly relevant in supporting the transition toward more sustainable business practices. In the context of the Circular Economy (CE), BPM serves as a strategic tool for identifying critical points in the production process that contribute to waste generation or resource inefficiencies.

Through comprehensive process analysis, BPM enables the redesign of workflows that support the principles of reuse and recycle, by creating closed-loop systems aimed at maximizing material reutilization. One of the key technical approaches within BPM is the development of Business Process Model and Notation (BPMN), a standardized graphical representation used to depict business processes in a structured, logical, and accessible manner for various stakeholders. The application of BPMN within the CE framework facilitates the visualization of efficient workflows, the integration of sustainability-driven process innovations, and the acceleration of data-informed decision-making.

Thus, the integration of BPM into circular economy initiatives not only allows for internal process optimization but also contributes systematically to the achievement of broader environmental and social objectives.

3. Research Implementation

This study employs a qualitative descriptive approach using a case study method focused on small and medium-sized weaving enterprises (SMEs) in the province of East Nusa Tenggara, Indonesia. This approach was selected to gain an in-depth understanding of the production dynamics within traditional weaving practices, as well as the sustainability challenges faced by these enterprises. The main objectives of this research are to map the existing business processes, identify key sources of waste generated throughout the production cycle, and to design a circular economy model integrated with Business Process Management (BPM) principles.

The research process was conducted systematically and began with a literature review to establish the theoretical foundation regarding circular economy concepts, business process management frameworks, and sustainable practices within traditional textile industries. This was followed by primary data collection, carried out through field observations at production sites and in-depth interviews with weaving artisans and business owners. These methods were used to gather empirical insights into production practices, workflow patterns, raw material usage, and current waste management strategies. The collected data were analysed to develop a BPM-based business process model that supports circular economy principles and is contextually appropriate for weaving SMEs in East Nusa Tenggara.

3.1 Existing BPM Notation

The existing BPMN model of the traditional weaving process illustrates a linear production flow that begins with thread preparation and ends with fabric finishing, without incorporating any circular practices. The process starts with the preparation of threads, followed by synthetic dyeing a stage that generates significant chemical wastewater. After dyeing, waste is immediately disposed of without treatment or reuse, indicating a lack of waste recovery mechanisms. The subsequent steps include weaving and finishing, which complete the process flow.

This linear approach reveals two major issues: environmental impact and resource inefficiency. The use of synthetic dyes introduces harmful substances into the ecosystem, and the absence of any feedback loops means valuable materials such as leftover threads and fabric scraps are wasted. Moreover, the process does not integrate opportunities for value creation through recycling or upcycling.

To address these shortcomings, the process must transition toward a circular model that introduces stages for waste recovery, reuse, and product diversification, reducing environmental harm while enhancing economic value.

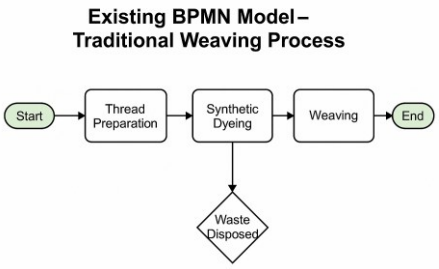

Figure 3. Existing BPMN Model

3.2 Circular BPMN Model

The process begins with Thread Preparation followed by Natural Dyeing, replacing synthetic dyes to reduce environmental impact. After dyeing, waste streams are managed through multiple circular paths:

1. Reuse – Excess threads and fabric scraps are directly repurposed into accessories.
2. Upcycling – Damaged or irregular fabrics are transformed into derivative products like bags or wallets, creating added value.
3. Recovered Waste – Remaining materials are collected for recycling, ensuring minimal landfill contribution.

A Recovered Waste Gateway indicates that recyclable waste loops back into the system rather than being discarded. The Finishing stage occurs before distribution, with leftover material again directed into reuse or recycling channels.

This model shifts from a linear flow to a closed-loop system, aiming to:

- Reduce resource waste and environmental harm.
- Enhance economic value through product diversification.
- Support sustainability in local weaving industries.

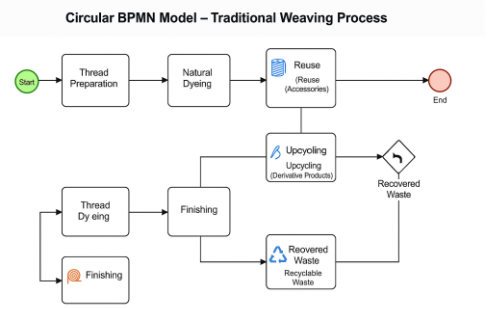

Figure 4. Circular BPMN Model

3.3 Circular Business Model Canvas

The Circular Business Model Canvas (CBMC) for the traditional weaving industry in NTT focuses on embedding sustainability and circularity principles within the value chain. The canvas consists of nine core elements adapted for circular economy:

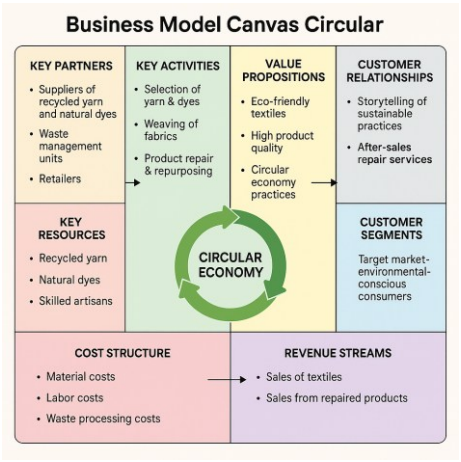

Figure 5. Circular Business Model Canvas

4. Results

Field observations conducted on weaving MSMEs (Micro, Small, and Medium Enterprises) in East Nusa Tenggara (NTT) revealed that the production process remains predominantly traditional, with minimal data recording or documentation practices. Synthetic dyes are still extensively utilized due to their affordability and accessibility, despite their detrimental impact on the environment. Textile and yarn waste is typically discarded or incinerated. There is an absence of systematic reuse or recycling practices among the observed artisans.

Through the application of Business Process Model and Notation (BPMN), it was identified that the primary stages contributing to waste generation are the dyeing and weaving processes. The main sources of waste include, residual dye effluent (liquid waste), unused or excess yarn, fabric remnants resulting from defective production.

A pilot intervention applying the circular economy model was conducted on a small scale involving three selected artisans. The outcomes demonstrated the following:

- The substitution of synthetic dyes with natural alternatives led to a reduction of liquid waste volume by approximately 60%
- Leftover yarn was repurposed into accessory products, which were successfully commercialized as secondary product lines
- Fabric off-cuts were transformed into value-added products such as small bags and wallets, yielding higher market value

The integration of reuse and recycling activities within the production workflow generated new entrepreneurial opportunities. Production efficiency improved, as previously discarded materials were revalued into economically viable inputs. Revenue derived from recycled products increased by an estimated 15–20%. Moreover, there was a favorable market response toward eco-friendly products, particularly among the tourism segment.

The proposed model demonstrates strong potential for replication, contingent upon the provision of training programs, technical assistance, and initial incentives. However, key challenges remain, particularly the absence of centralized waste collection infrastructure and the generally low initial awareness among artisans regarding sustainability and environmental stewardship.

5. Conclusions

This study demonstrates that a circular economy-based business process model is applicable and adaptable to the traditional weaving industry, particularly in the context of East Nusa Tenggara (NTT), Indonesia. By strategically utilizing production waste as a secondary raw material, micro, small, and medium enterprises (MSMEs) are able to transition toward more sustainable production practices. This approach yields several tangible benefits, including:

- Environmental impact reduction through the minimization of textile waste and the substitution of synthetic dyes with eco-friendly alternatives;
- Enhanced operational efficiency and product diversification, as previously discarded materials are reprocessed into value-added goods such as accessories and handicrafts;
- Improved market competitiveness by appealing to environmentally conscious consumer segments, particularly among tourists and niche markets that prioritize sustainable products.

The findings underscore the potential of circular economy principles to not only address ecological concerns but also to drive innovation and resilience within traditional craft-based industries.

6. Acknowledgements

This study proposes the following recommendations to support the implementation of circular economy practices in the traditional weaving sector:

1. Local governments and MSME support institutions should offer training on reuse and recycling techniques tailored to local contexts, integrating traditional knowledge with practical applications.
2. Community-based recycling centers should be developed to support efficient waste collection and processing while encouraging local participation and employment.
3. Eco-certification of environmentally friendly products should be promoted to enhance market competitiveness and attract environmentally conscious consumers.
4. The business model can be adapted to other traditional textile sectors, with necessary adjustments based on local materials, techniques, and cultural conditions.

These steps are key to scaling sustainable practices in traditional industries through collaborative efforts.

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