Stage-Gate Phase of Sustainable Product Development Process in Batik Fashion Industry: A Systematic Literature Review (SLR) and Future Research Agenda

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Abstract: The batik fashion industry in Indonesia faces challenges in adapting to the concept of sustainability, encompassing environmental, economic, and social dimensions. This issue has become increasingly critical due to consumer pressure and government regulations demanding environmentally friendly and socially responsible business practices. However, efforts to develop products in this industry often encounter a gap between sustainable innovation and efficient product management processes. Although the Stage-Gate model has been widely adopted in various industries to enhance process efficiency in product development, there remains limited research specifically integrating sustainability aspects into the Stage-Gate model within the batik fashion industry. Based on a systematic literature review (SLR), this study aims to demonstrate how a sustainable Stage-Gate model can be effectively implemented in developing batik fashion products by addressing environmental, economic, and social sustainability (Triple Bottom Line – TBL). The Triple Bottom Line (TBL) model can be categorized into three primary approaches that reflect the evolutionary stages of sustainability implementation: 1) Stage-Gate Traditional Product Development Process (SGTPDP), 2) Stage-Gate New Product Development Process (SGNPDP), and 3) Stage-Gate Sustainable Product Development Process (SGSPDP). The findings indicate that by adapting the Stage-Gate model to include sustainability elements at every stage of product development, the batik fashion industry can become more responsive to market demands and regulatory requirements while maintaining competitiveness and environmental preservation. This study contributes to the industry by showing that a sustainable Stage-Gate model not only enhances innovation processes but also supports the overall sustainability of the batik fashion industry.

Keywords: Batik Fashion Industry, Stage-Gate Model, Sustainable Product Development (SPD), Systematic Literature Review (SLR), Triple Bottom Line (TBL)

1. Introduction

The Indonesian batik fashion industry, as a vital component of the national creative economy, is increasingly under pressure to implement sustainability principles. This is driven by the global shift toward valuing environmental stewardship, economic responsibility, and social equity in business operations. International consumers are becoming more conscious of the origins of their purchases, often favouring products with ethical sourcing and minimal environmental impact (Eberling & Langkau, 2024). Batik production, blending traditional craftsmanship with modern techniques, poses several sustainability challenges, including excessive water usage and chemical-intensive dyeing methods. Moreover, the industry must address social dimensions, such as fair labour practices and cultural heritage preservation, making sustainable product development a complex but necessary pursuit in a tightly regulated global marketplace (Khoshnevisan, Fog, Baladi, Chan, & Birkved, 2023).

To tackle these multifaceted sustainability issues, the Stage-Gate model offers a promising framework for structuring the product development process within the batik fashion industry. This model divides the development process into distinct stages, each concluded with a "gate" to evaluate progress, especially concerning sustainability metrics. By embedding sustainability checkpoints throughout the development phases, companies can ensure that products align with environmental, social, and economic goals from ideation to commercialization. The model supports data-driven decision-making and encourages incorporating eco-conscious and socially responsible elements, helping firms meet market expectations while optimizing development efficiency (Goworek et al., 2020; Talay, Oxborrow, & Goworek, 2022).

Despite its success in manufacturing and high-tech industries, the Stage-Gate model's adaptation to sustainability-oriented fashion sectors, such as batik, remains limited. Its conventional application often prioritizes time-to-market and cost-efficiency over environmental and social considerations. This presents a significant challenge for the batik industry, where traditional production techniques are seldom aligned with

modern sustainability standards (Helo, Mayanti, Bejarano, & Sundman, 2024). Existing research has primarily emphasized the model's role in technological innovation, with few studies exploring how it can be reshaped to fit creative and culturally rooted industries like fashion, especially when sustainability is a central concern (Jafari, 2019).

This study conducts a systematic literature review (SLR) to explore how the sustainable Stage-Gate model can be adapted for the batik fashion industry, emphasizing its potential to address pressing environmental, social, and economic demands. The review investigates best practices and sustainability elements applicable to each stage of the model, aiming to guide batik producers in developing products that minimize environmental impact and respond to evolving consumer expectations and regulatory frameworks (Idrees, Xu, Haider, & Tehseen, 2023; Xu, Mei, Liang, & Sun, 2023). By mapping relevant strategies and identifying knowledge gaps, this research seeks to build a practical and holistic framework to assist stakeholders in the sustainable transformation of the batik fashion value chain.

2. Literature Review

This study employed the Systematic Literature Review (SLR) methodology to explore sustainability in the batik fashion industry, aiming to identify trends, gaps, and driving factors behind sustainability integration. The research formulated specific questions, keywords, and criteria to assess how sustainability practices are implemented, measured, and disclosed within the industry. Despite growing environmental concerns, the review found limited academic attention on sustainability approaches in batik fashion. The investigation, as shown in Figure 1, based on secondary data from articles published between 2020 and 2024, and further exploration from 2010, highlights the need for more comprehensive research on sustainable innovation and product development using a structured, deductive approach.

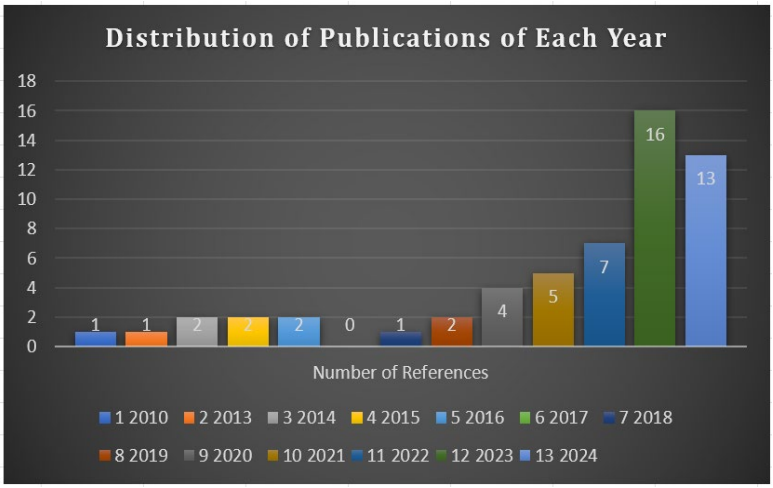

Figure 1: Distribution of Publication of Each Year, 2010 – 2024

The inclusion criteria focused on full-text, peer-reviewed studies in English from the ScienceDirect database, using specific keywords such as "sustainable batik fashion industry" and "batik sustainability" to capture relevant literature from 2010 to 2024. Broader terms like "Sustainability" and "Innovation" were later combined to refine the search. Studies published before 2010 or not in English were excluded, as no relevant research on sustainable batik fashion was found before that year, ensuring the review encompassed the most relevant and recent developments in the field.

The initial step, illustrated in Figure 2 on ScienceDirect, involved employing precise keywords such as "sustainable batik fashion industry," "batik sustainability," "Sustainability," and "Measurement," which yielded 3,967 results. Phase Two: 3,459 studies were excluded after reviewing titles, abstracts, and keywords, as they were unrelated to the concepts of the batik fashion industry, sustainability, measurement, or sustainability reporting. Phase Three in Table 1.: Mapping of 56 Selected Research Publications were subjected to a more detailed review by examining titles, abstracts, keywords, and conclusions related to the topic. Phase Four: The authors meticulously assessed the 56 selected articles for their relevance to the research scope. As a result, 43 studies were eliminated.

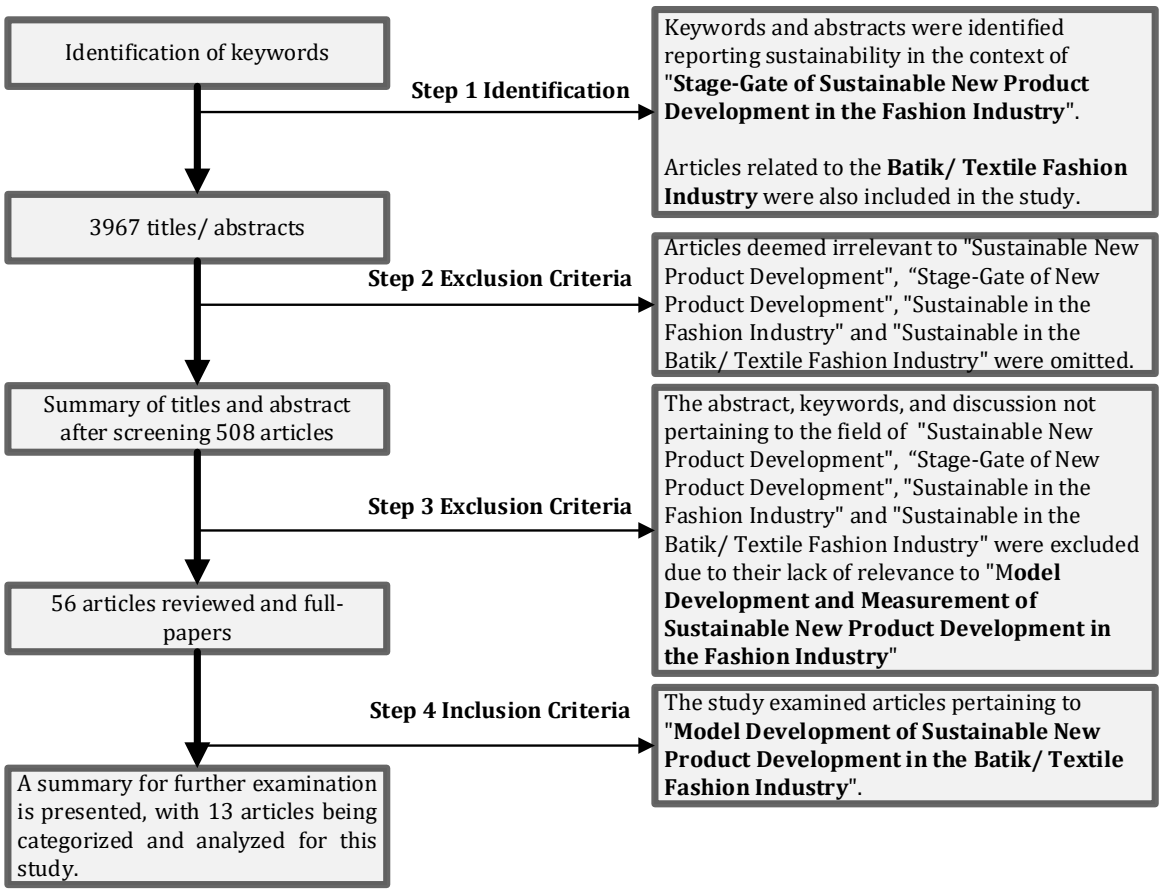

Figure 2: Flow chart of the Research Process

The 56 selected articles in Table 1 reflect a strong alignment with the Triple Bottom Line (TBL) integration—environmental, social, and economic sustainability has become central in sustainable product development (SPD), especially in the fashion and textile sectors. Research often highlights environmental priorities such as lifecycle thinking and sustainable materials (Appolloni, Centi, & Yang, 2023; Watz & Hallstedt, 2022), while others stress the importance of ethical labour and social engagement (Thorisdottir & Johannsdottir, 2019). Economic aspects, like cost-effectiveness and competitive advantage, are also vital (Ma, Adam, Teo, & Wong, 2024). However, balancing all three pillars remains challenging, requiring integrated sustainability indicators to support comprehensive SPD decisions (Rehman et al., 2024).

The Stage-Gate model offers a structured approach to incorporating sustainability across six product development phases: ideation, concept, business case, development, testing, and market launch. Early-phase integration ensures long-term viability (Pedroso et al., 2023), while feasibility analyses during the business case phase support strategic planning (Garcia-Ortega, Galan-Cubillo, Llorens-Montes, & de-Miguel-Molina, 2023). In development and testing, Set-Based Engineering and circular economy methods enhance design efficiency (Miranda, Ponce, Molina, & Molina, 2019). Launch strategies focused on sustainable branding foster stakeholder alignment and market acceptance (Ikram, 2022). These phase-specific tools reinforce sustainability-driven innovation.

Indonesia's batik fashion industry, rich in cultural heritage, offers unique potential for adopting TBL and Stage-Gate models. Yet, challenges such as low awareness and limited resources hinder progress (Demyanova, Colucci, Silva, & Vecchi, 2023). By drawing from global textile insights (Gornostaeva, 2023), the industry can innovate in design and local enterprise while honouring its cultural roots. A context-sensitive SPD roadmap is essential for ensuring environmental, economic, and social sustainability in Batik's future.

Table 1: Mapping of 56 Selected Research Publications

No.	Article	Triple Bottom Line			Stage-Gate NPD						Industry
		Environment	Social	Economic	Ideation	Concept	Business Case	Development	Testing	Market Launch	Fashion/ Textile
1.	(Achaw & Danso-Boateng, 2021)	✓									
2.	(Adamkiewicz, Kochańska, Adamkiewicz, & Łukasik, 2022)	✓									
3.	(Appolloni et al., 2023)	✓	✓	✓							
4.	(Battesini Teixeira, de Medeiros, Kolling, Duarte Ribeiro, & Morea, 2023)	✓			✓	✓	✓		✓	✓	✓
5.	(Carvalho Garcia, 2023)	✓	✓								
6.	(Chopra, Dong, Kaur, Len, & Ki Lin, 2023)	✓	✓	✓							✓
7.	(Claxton & Kent, 2020)	✓			✓	✓	✓	✓	✓	✓	✓
8.	(Delaney & Liu, 2024)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
9.	(Demyanova et al., 2023)	✓	✓	✓							
10	(Dissanayake & Sinha, 2015)	✓			✓	✓					
11.	(Efrata & Radianto, 2022)				✓	✓		✓	✓	✓	✓
12.	(Elamri, Zdiri, & Hamdaoui, 2023)	✓								✓	
13.	(Fung, Chan, Choi, & Liu, 2021)	✓	✓	✓	✓	✓			✓		✓
14.	(Fuxman, Mohr, Mahmoud, & Grigoriou, 2022)	✓	✓								
15.	(Garcia-Ortega et al., 2023)	✓									
16.	(Gmelin & Seuring, 2014a)	✓	✓	✓							
17.	(Gmelin & Seuring, 2014b)	✓	✓	✓							
18.	(Gornostaeva, 2023)	✓									
19.	(Goworek et al., 2020)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
20.	(Harsanto & Permana, 2021)	✓	✓	✓							
21.	(Helo et al., 2024)	✓									

No.	Article	Triple Bottom Line			Stage-Gate NPD						Industry
		Environment	Social	Economic	Ideation	Concept	Business Case	Development	Testing	Market Launch	Fashion/ Textile
22.	(Ikram, 2022)	✓		✓							
23.	(Jestratijevic, Uanhoro, & Rana, 2024)										
24.	(Karadayi-Usta, 2024)										
25.	(Ki, Wang, Chong, Chenn, & Ha-Brookshire, 2023)	✓	✓	✓							
26.	(Kim, Kang, & Lee, 2020)	✓	✓								
27.	(Klemm & Kaufman, 2024)		✓								✓
28.	(Kozlowski, Searcy, & Bardecki, 2018)	✓	✓		✓	✓		✓			
29.	(Lang, Armstrong, & Liu, 2016)	✓									✓
30.	(J. Li, Li, & Fan, 2024)	✓									
31.	(Z. Li, Zhou, Zhao, Guan, & Yang, 2024)	✓									
32.	(Ma et al., 2024)										
33.	(Mazzi, 2023)	✓									
34.	(Miranda de Souza & Borsato, 2016)	✓			✓	✓	✓	✓	✓	✓	
35.	(Miranda et al., 2019)	✓	✓	✓	✓	✓		✓			
36.	(Moon, Youn, Chang, & Yeung, 2013)				✓	✓					
37.	(Muenchinger, 2023)	✓			✓	✓					
38.	(Nayak, Jajpura, & Khandual, 2023)	✓									
39.	(Pedroso et al., 2023)	✓	✓	✓	✓	✓					
40.	(Petala, Wever, Dutilh, & Brezet, 2010)				✓	✓	✓	✓			
41.	(Peter John & Mishra, 2023)	✓									
42.	(Ramos et al., 2024)	✓									
43.	(Rehman et al., 2024)	✓									

No.	Article	Triple Bottom Line			Stage-Gate NPD						Industry
		Environment	Social	Economic	Ideation	Concept	Business Case	Development	Testing	Market Launch	Fashion/ Textile
44.	(Rese, Baier, & Rausch, 2022)	✓									
45.	(Riazi & Saraeian, 2023)	✓									
46.	(Spindler, Schunk, & Könecke, 2023)	✓	✓								
47.	(Stella, Fraterrigo Garofalo, Cavallini, Fino, & Deorsola, 2024)	✓		✓							
48.	(Talay, Oxborrow, & Brindley, 2020)			✓							
49.	(Talay et al., 2022)	✓	✓	✓							✓
50.	(Tavernaro et al., 2021)					✓		✓		✓	
51.	(Thorisdottir & Johannsdottir, 2019)	✓	✓	✓							✓
52.	(Thorisdottir, Johannsdottir, Pedersen, & Niinimäki, 2024)	✓	✓	✓							✓
53.	(Watz & Hallstedt, 2022)										
54.	(Wilson, 2015)				✓	✓					✓
55.	(Yang, Al Mamun, Reza, Yang, & Aziz, 2024)	✓									
56.	(Zhao et al., 2021)	✓	✓	✓							

A systematic literature review on sustainable new product development (NPD) in the fashion industry identified 13 full-text studies for in-depth analysis, highlighted with boxed indicators in Table 1. These studies emphasize the urgent need for a structured framework integrating traditional craftsmanship with modern sustainability practices in the batik fashion industry. Although sustainability has gained attention in mainstream fashion (Thorisdottir & Johannsdottir, 2019; Wilson, 2015), its implementation in the batik sector remains limited. This study explores key concepts, tools, and gaps in the Stage-Gate framework, as batik SMEs lack formalized development processes (Battesini Teixeira et al., 2023; Efrata & Radianto, 2022).

Key phases of the Stage-Gate process, such as idea generation, concept design, prototyping, and commercialization, are analysed through the sustainability lens. Previous studies emphasize the importance of embedding sustainability at the initial design stage (Claxton & Kent, 2020; Delaney & Liu, 2024) and managing supply chain complexities in later stages (Fung et al., 2021; Talay et al., 2022). Moreover, incorporating stakeholder collaboration and frugal innovation approaches is seen as vital in resource-constrained traditional industries (Goworek et al., 2020; Pedroso et al., 2023). The taxonomy of smart and sustainable products (Miranda et al., 2019) also reinforces the need for integrated tools to support decision-making in batik product development.

This study proposes a conceptual Stage-Gate model tailored to the SPD process in the batik fashion industry. The model synthesizes sustainability strategies from existing literature (Thorisdottir et al., 2024) and offers a

foundation for empirical validation and policy recommendation. Future research should focus on testing the model in real-world batik production to align local heritage with global sustainability goals.

3. Sustainable Product Development Process in the Batik Fashion Industry

This study critically examines the integration of sustainability into the New Product Development (NPD) process within the fashion (textile/batik) industry by proposing a Stage-Gate model. It emphasizes the urgent need to align product innovation with environmental stewardship, social equity, and economic viability.

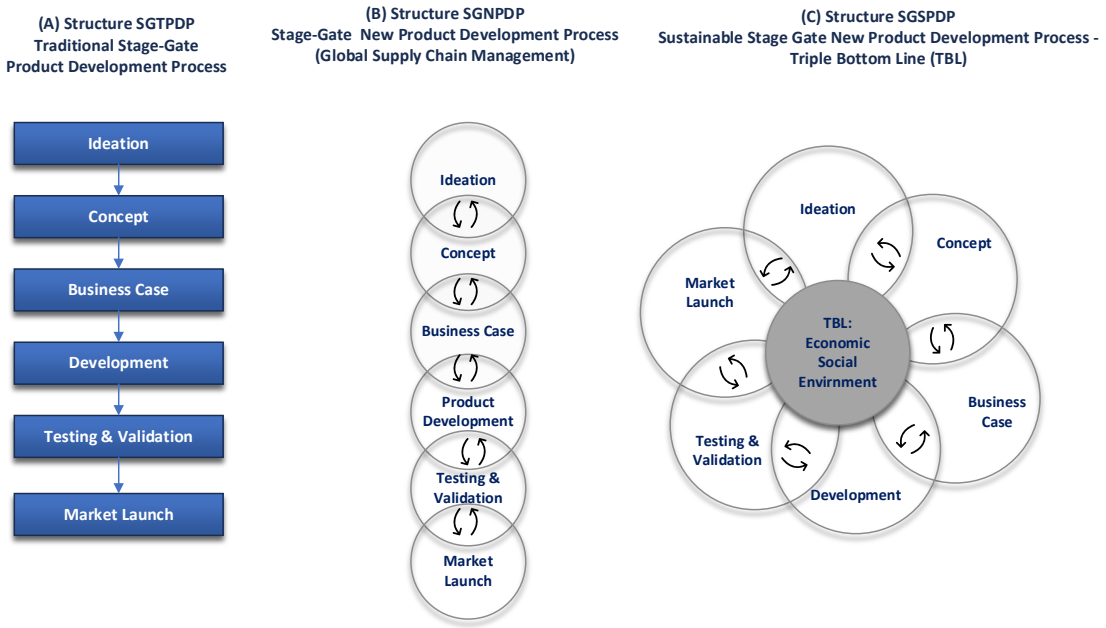

Figure 4: The evolution of fashion product development process (A,B and C Structures) – Integrated Sustainable Stage-Gate: Sustainable Fashion Industry : (Fung et al., 2021) and (Cooper & Sommer, 2016).

By embedding sustainability criteria from the earliest development stages, the model aims to strengthen industry performance while safeguarding Indonesia's cultural heritage. The findings offer strategic guidance for industry stakeholders and policymakers to drive transformative, sustainability-oriented innovation in the batik and textile sectors.

The integration of two primary sources, namely Fung et al. (2021) and Cooper & Sommer (2016), is reflected in Figure 4, which presents an evolutionary structure in three stages: Structure A, B, and C, within the context of the Integrated Sustainable Stage-Gate. These structures demonstrate a gradual transformation toward a more sustainable approach in the fashion industry.

The Stage-Gate Traditional Product Development Process (SGTPDP) represents a conventional, linear approach to fashion product development, emphasizing speed and production efficiency. In this model, decisions related to design, development, and production occur sequentially, often without significant consideration of environmental and social impacts. Sustainability is not a core component; the primary objective is efficiently delivering a market-ready product. In contrast, Structure B, the Stage-Gate New Product Development Process (SGNPDP), begins incorporating sustainability as a criterion evaluated at each development stage. Structure C, the Stage-Gate Sustainable Product Development Process (SGSPDP), advances this approach further by promoting cross-functional collaboration and stakeholder engagement. It ensures that decisions throughout the product development cycle consider not only economic viability but also environmental and social responsibility. This shift from SGTPDP to SGSPDP demonstrates a growing dedication within the fashion industry to adopt innovative processes aligned with global sustainability standards and ethical accountability.

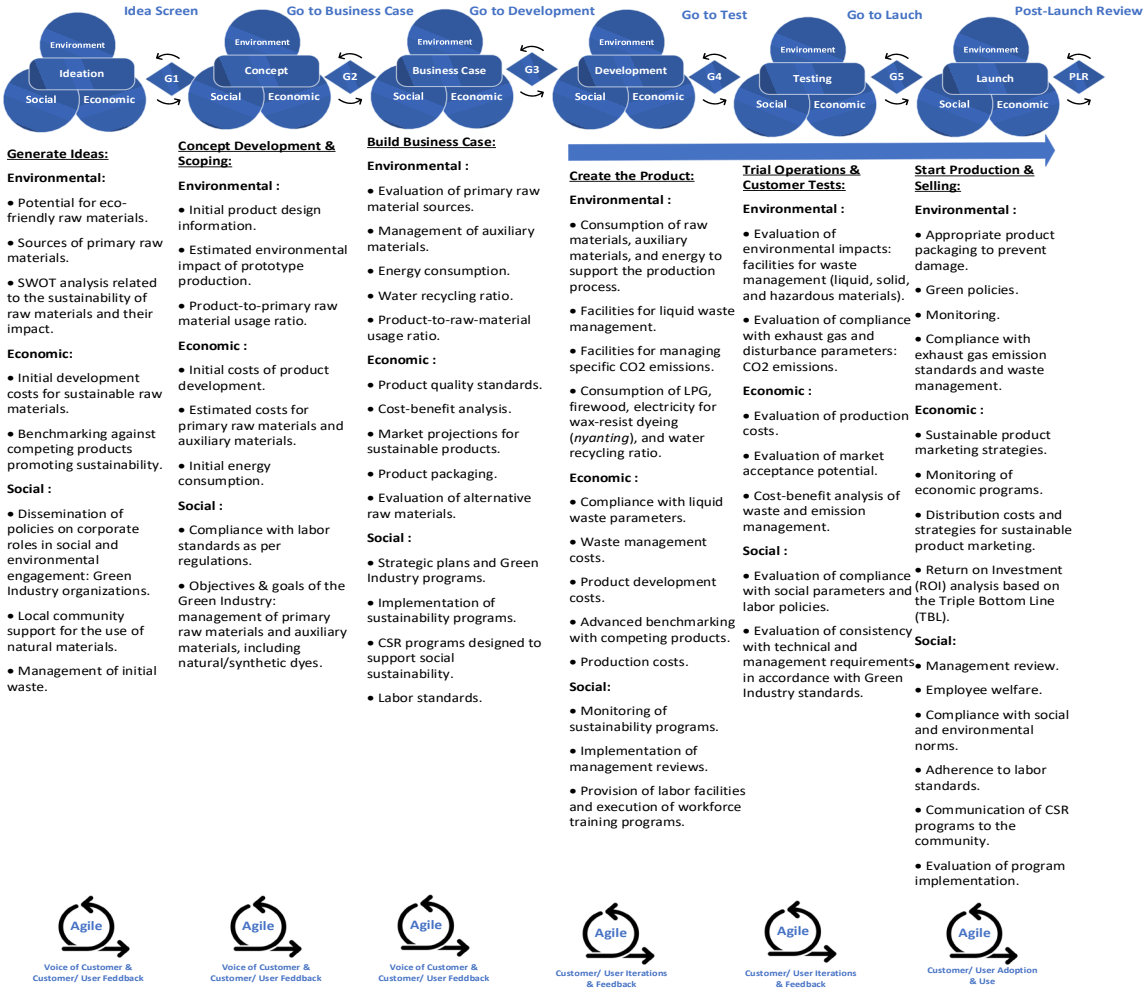

Figure 5: Conceptual Model of the Stage-Gate Phase for Sustainable Product Development Process in the Batik Fashion Industry

The Conceptual Model of the Stage-Gate Phase for the Sustainable Product Development Process in the Batik fashion industry, as illustrated in Figure 5., integrates the core dimensions of sustainability – economic, environmental, and social – into the earliest stages of ideation and evaluation. These pillars form the basis for developing product concepts that balance cost-efficiency, environmental stewardship, and social responsibility. Environmental aspects involve selecting sustainable raw materials and evaluating lifecycle impacts. Economic evaluation includes benchmarking and cost analysis. Social considerations emphasize engaging local communities and strengthening internal sustainability roles to ensure alignment with broader social responsibility objectives.

This model adopts a structured Stage-Gate framework, with critical checkpoints such as “Go to Concept,” “Go to Business Case,” “Go to Development,” “Go to Test,” and “Go to Launch.” Between gates, development is driven by Agile principles, embedding iterative loops and ongoing feedback collection. This responsiveness to stakeholder input ensures that products evolve continuously and remain aligned with sustainability objectives. Integrating customer feedback mechanisms at every stage signifies a commitment to sustainable production, and sustainable value creation that adapts to real-world user needs and expectations.

Crucially, elements like “Voice of Customer,” “Customer Adoption,” and “Post-Launch Review (PLR)” highlight a user-centred, market-oriented approach to sustainability. The model does not treat sustainability as a fixed checklist but as a dynamic and evolving framework. Through Agile integration and a sustainability lens applied across the entire product lifecycle, the model enables the development of Batik products that are not only market-relevant but also ethically and environmentally accountable.

4. Future Research Agenda

This study opens avenues for further research into the application of the Sustainable Stage-Gate Model in the batik fashion industry and beyond. Future research directions may include the following:

1. Empirical Validation: Conduct in-depth field studies to test the SGSPDP framework's practical application, identifying real-world challenges and opportunities across varied batik production settings.
2. Development of Evaluation Tools: Create targeted, data-driven sustainability metrics to measure the Triple Bottom Line impacts at each stage of the Stage-Gate process.
3. Application of New Technologies: Explore the integration of artificial intelligence (AI), big data, or digital platforms to enhance sustainability assessments and inform smarter decision-making.
4. Adaptation for Other Creative Industries: Conduct cross-sectoral research to assess the model's adaptability to other cultural and creative fields such as textiles, crafts, and design industries.
5. Skill Development and Training: Assess the need for capacity building among artisans and SMEs to implement sustainability-focused product development effectively.

5. Conclusion

This study presents a sustainable Stage-Gate model as a vital framework for guiding environmentally, economically, and socially responsible product development in the batik fashion industry. By systematically integrating sustainability principles into each product development phase, the industry can better meet market demands and regulatory standards. Through a systematic literature review, we classified three key approaches—traditional (SGTPDP), new (SGNPDP), and sustainable (SGSPDP) product development—and demonstrated that adopting the sustainable model enhances innovation while aligning with Triple Bottom Line (TBL) goals. The main contribution of this research is the development of a Conceptual Model Stage-Gate Phase of the Sustainable Product Development Process in the Batik Fashion Industry, which not only strengthens measurable sustainability efforts but also lays a foundation for future studies across fashion sectors rooted in cultural heritage.

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Ethics Declaration

The writing of this paper was conducted independently by the authors without the assistance of artificial intelligence (AI) in the creation of the main content, data analysis, or result interpretation.

AI Declaration

AI tools were used in a limited capacity for literature search, language editing, and grammar checking to enhance clarity and readability. All ideas, arguments, and conclusions presented in this paper are entirely the work of the authors.

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