Integrating Wabi-Sabi and Mottainai into Sustainable Screen Printing: A Practice-Led Study

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ABSTRACT

The textile and apparel industry faces significant sustainability challenges due to resource-intensive production processes and material waste generation, particularly in screen-printing operations. While existing solutions largely focus on technological optimization, the potential of cultural-aesthetic frameworks as drivers of sustainable industrial practice remains underexplored. This study investigates the integration of the Japanese aesthetic philosophies of Wabi-sabi (embracing imperfection) and Mottainai (respect for materials and waste minimization) into contemporary screen-printing processes. Adopting a qualitative, practice-led research design, the study combines field observations within an industrial textile printing facility, semi-structured interviews with 15 practitioners, and a series of controlled studio-based experiments. The findings identify five key intervention points within the production workflow, including technique manipulation, ink reuse, repurposing of defective outputs, and screen reuse. Empirical observations indicate that a substantial proportion of production waste, particularly unused inks and rejected samples, can be reintegrated into the design process, with experimental applications demonstrating the potential to reduce material discard levels by an estimated 20–35% at the sampling and post-production stages. The study further demonstrates that controlled irregularity and material reuse can generate distinctive, value-added textile outcomes while improving resource efficiency. By reframing defects and waste as aesthetic and material assets, the research proposes a shift from linear production toward a more circular, design-driven model. The findings contribute a novel framework that operationalizes Wabi-sabi and Mottainai within industrial textile contexts, offering practical implications for sustainable innovation. The study also highlights key challenges related to scalability, quality control, and market acceptance, providing directions for future research and pilot-level industrial implementation.

Keywords: Wabi-Sabi and Mottainai, Sustainable Screen-Printing Led Study

INTRODUCTION

The global textile and apparel industry is widely recognized as one of the most resource intensive and environmentally impactful sectors, contributing significantly to water pollution, chemical discharge, and solid waste generation. Textile production processes, particularly dyeing and printing, are among the most environmentally damaging stages of the value chain due to their extensive use of water, energy, and chemical inputs. As a result, the industry generates substantial volumes of waste, including defective materials, excess dyes, and postproduction residues, much of which is disposed of in landfills or incinerators, leading to the loss of valuable resources and an increased environmental burden (Sandin & Peters, 2018; Catarino, 2025).

Within this broader context, screen printing remains one of the most widely used textile surface design techniques due to its versatility, durability, and suitability for mass production. However, conventional screen-printing processes are associated with significant environmental challenges, including high water consumption, energy-intensive curing processes, and the generation of chemical waste and rejected print materials. The multi-stage nature of the process, comprising screen preparation, ink formulation, printing, and washing, further contributes to inefficiencies and waste accumulation (Hoque, 2024). Leftover inks, damaged print samples, and obsolete screens represent underutilized resources that are often discarded rather than reintegrated into the production cycle.

In response to these challenges, there has been a growing emphasis on developing sustainable textile processing methods, including the adoption of digital printing technologies, eco-friendly inks, and cleaner production strategies. Such innovations have demonstrated potential in reducing environmental impacts compared to conventional methods by minimizing water usage and chemical discharge (Catarino, 2025). Additionally, recent studies highlight the potential of integrating recycled textile materials into production processes, emphasizing material efficiency and circularity within the textile value chain (Yildiz et al., 2024). These developments align with broader circular economy principles, which advocate for reducing waste, extending material lifecycles, and promoting reuse and recycling as key strategies for sustainable industrial transformation (Sandin & Peters, 2018).

Despite these technological advancements, current approaches to sustainability in textile printing remain largely techno-centric, focusing primarily on process optimization and material substitution. Limited attention has been given to the role of cultural, aesthetic, and philosophical frameworks in shaping sustainable design practices. Emerging perspectives in sustainable design research suggest that addressing environmental challenges requires not only technological innovation but also a rethinking of underlying values that define quality, beauty, and material use in production systems.

In this regard, traditional Japanese aesthetic philosophies offer a valuable alternative framework for reimagining sustainability in textile design. The concept of Wabi-sabi emphasizes the appreciation of imperfection, irregularity, and transience, challenging dominant industrial ideals of uniformity and flawlessness. Complementing this perspective, the philosophy of Mottainai reflects an ethical attitude toward material use, advocating respect for resources and discouraging waste through reuse, repair, and full material utilization. These principles resonate strongly with contemporary sustainability paradigms; particularly circular economy approaches that emphasize resource efficiency and waste minimization.

However, despite growing scholarly interest in sustainable textile practices and the influence of cultural aesthetics on design, existing research has predominantly focused on either technological solution (Singh & Bridgens, 2021), small-scale, craft-based applications (Zemke, 2023; Waters, 2020). There remains a significant gap in the systematic integration of aesthetic philosophies such as Wabi-sabi and Mottainai into industrial textile production processes, particularly in screen printing. Furthermore, limited research has explored how production waste can be reinterpreted as a source of creative and economic value within industrial settings.

Addressing this gap, the present study aims to investigate how the principles of Wabi-sabi and Mottainai can be integrated into contemporary screen-printing practices as a sustainable and creative approach to waste management. Specifically, the study explores how imperfections, leftover materials, and rejected outputs can be transformed into aesthetically meaningful and commercially viable textile products. By adopting a qualitative, practice-led research approach research seeks to bridge the gap between traditional aesthetic philosophy and modern industrial practice.

This study contributes to the field of sustainable textile design by proposing a novel framework that integrates cultural aesthetics with industrial production systems. It advances sustainability discourse by positioning waste not merely as an environmental problem but as a potential source of creative innovation and value generation. In doing so, it offers both theoretical insights and practical implications for developing more sustainable, resource-efficient, and aesthetically innovative approaches to textile manufacturing.

LITERATURE

Wabi-Sabi as an Alternative Aesthetic Paradigm in Design

Wabi-sabi represents a distinctive Japanese aesthetic philosophy that values imperfection, impermanence, and irregularity as intrinsic qualities of beauty. In contrast to dominant Western industrial aesthetics characterised by precision, uniformity, and standardisation, Wabi-sabi embraces asymmetry, incompleteness, and the visible traces of material ageing (Juniper, 2011; Saito, 2007). Rooted in Zen Buddhist thought, this philosophy promotes an acceptance of natural processes and variability, positioning imperfection not as a flaw but as a

meaningful aesthetic condition.

Recent design scholarship has extended Wabi-sabi beyond traditional art contexts into contemporary design discourse. Iannelli (2021) argues that Wabi-sabi introduces an ethical-aesthetic dimension that challenges industrial norms of perfection by foregrounding authenticity and material honesty. Similarly, Avdulov (2022) conceptualises Wabi-sabi as a counter-aesthetic to mass production, enabling designers to disrupt standardised visual outputs and reintroduce individuality into industrial products. Within textile design, this perspective is particularly relevant, as surface irregularities, texture variations, and material inconsistencies can be intentionally incorporated as design features rather than defects.

Traditional textile practices such as Boro exemplify the applied dimension of Wabi-sabi, where repeated mending and patching create layered visual narratives that reflect both material history and aesthetic value. These practices demonstrate that imperfection can function as both a visual and conceptual resource, offering a critical foundation for rethinking contemporary industrial textile production.

Mottainai and the Ethics of Resource Efficiency

Complementing the aesthetic orientation of Wabi-sabi, the concept of Mottainai provides an ethical framework centred on respect for materials and minimising waste. The term conveys a sense of regret associated with the unnecessary disposal of resources, advocating practices that extend material lifecycles through reuse, repair, and recycling (Siniawer, 2014; Taylor, 2011). This philosophy aligns closely with contemporary sustainability paradigms, particularly circular economy models that emphasize resource efficiency and waste reduction.

In textile contexts, Mottainai is embodied in traditional practices such as Sashiko stitching and Boro patchwork, where garments are continuously repaired and repurposed rather than discarded. These practices reflect a systemic approach to material conservation, in which functionality and aesthetics converge to prolong product lifespans (Wallinger, 2012; Wada, 2004). More recent interpretations of Mottainai have been linked to sustainable consumption and production systems, highlighting its relevance in addressing modern environmental challenges (Jimura, 2023).

Importantly, Mottainai extends beyond individual behaviour to inform production-level decisions, suggesting that industrial processes can be reconfigured to prioritise material recovery and reuse. Despite its conceptual alignment with sustainability, its application in large-scale industrial textile systems remains underexplored.

Traditional Japanese Textile Practices as Models of Circularity

Traditional Japanese textile techniques provide tangible evidence of how aesthetic and ethical principles can be operationalized within material production systems. Practices such as Kintsugi, Sashiko, and Boro illustrate how damage, repair, and reuse can be transformed into sources of aesthetic and functional value.

Kintsugi, the practice of repairing broken ceramics with lacquer and gold, exemplifies the deliberate aestheticization of damage, transforming fractures into visible and valued design elements (Sho & Sadeghzadeh, 2020). Similarly, Sashiko stitching originated as a reinforcement technique but evolved into a decorative practice that celebrates repair as a form of design (Trowbridge & Guerrero, 2023). Boro textiles further extend this approach, representing layered constructions of reused fabric that embody both sustainability and cultural identity (Li, 2020).

These practices demonstrate that sustainability in traditional contexts is not solely driven by technological efficiency but is deeply embedded in cultural values and design philosophies. Their relevance to contemporary textile production lies in their potential to inform circular design strategies that integrate reuse, repair, and aesthetic transformation within industrial systems.

Contemporary Applications of Japanese Aesthetics in Textile and Fashion Design

The influence of Japanese aesthetic philosophies has become increasingly visible in contemporary textile and fashion design, particularly in experimental and avant-garde practices. Designers have adopted principles of

asymmetry, deconstruction, and material irregularity to challenge conventional design norms and introduce new aesthetic languages.

McCarty et al. (1998) highlight the use of unconventional surface techniques, layering, and structural manipulation in contemporary Japanese textiles, reflecting a shift toward process-driven design. Holmes (2023) further identifies the emergence of experimental screen-printing approaches that intentionally incorporate irregular overlays and distortions, aligning with Wabi-sabi aesthetics. Zemke (2023) experiments Direct-to-garment printing (DTG) as a low-impact option relative to traditional principles of screen printing

The work of designers such as Issey Miyake and Rei Kawakubo demonstrates how these philosophies can be translated into global fashion contexts, where imperfection and non-uniformity become defining characteristics of design innovation (Au et al., 2000). These examples suggest that aesthetic philosophies can extend beyond craft-based practices into industrial and commercial domains.

However, much of this work remains situated within high-fashion or experimental design contexts, with limited application to large-scale textile manufacturing systems such as screen printing.

Sustainability in Textile Printing: Technological Approaches and Limitations

Sustainability research in textile printing has predominantly focused on technological innovations aimed at reducing environmental impact. These include the development of eco-friendly dyes, digital printing technologies, and water-efficient processing methods (Catarino, 2025). Such approaches have demonstrated measurable reductions in water consumption, chemical use, and energy demand.

Additionally, studies have explored the reuse of textile waste in production systems, highlighting the potential to integrate recycled materials into printing processes (Yildiz et al., 2024). Hoque (2024) emphasizes the environmental implications of conventional screen-printing techniques, particularly in relation to waste generation and resource inefficiency.

Despite these advancements, existing approaches remain largely techno-centric, focusing on process optimization rather than rethinking the underlying design values that drive production systems. As a result, issues such as material rejection, overproduction, and aesthetic standardization persist, limiting the effectiveness of sustainability interventions.

Industrial Scalability and Implementation Challenges

One of the critical gaps in sustainable textile research is the limited focus on scalability and real-world implementation. While many studies propose innovative materials or processes, their adoption within industrial settings is often constrained by factors such as cost, production efficiency, quality control standards, and brand compliance requirements.

In screen printing, where consistency and repeatability are essential, introducing variability or imperfection may conflict with established quality benchmarks. Furthermore, integrating reuse strategies within fast-paced production environments presents logistical challenges, including storage, material handling, and workflow adjustments.

These constraints highlight the need for approaches that not only demonstrate conceptual validity but also address operational feasibility within industrial contexts.

Consumer Acceptance and Market Implications

Another underexplored dimension in sustainable textile design is consumer perception. While sustainability-driven products are increasingly valued, the acceptance of visible imperfections remains uncertain within

mainstream markets. Traditional consumer expectations often associate quality with uniformity and flawlessness, which may conflict with Wabi-sabi-inspired design approaches.

However, emerging trends in slow fashion, sustainability, and artisanal production suggest a growing appreciation for uniqueness, authenticity, and material narratives. Products that embody individuality and visible process traces may be perceived as more valuable within certain market segments (Douglass, 2026; Terui, 2026; Wallinger, 2012).

Understanding consumer acceptance is therefore essential for translating experimental design approaches into commercially viable products, particularly in industrial contexts were market demand drives production decisions.

Research Gap and Study Contribution

The review of existing literature reveals a significant gap at the intersection of aesthetic philosophy, sustainability, and industrial textile production. While Wabi-sabi and Mottainai have been widely discussed in conceptual and craft-based contexts, their systematic integration into large-scale industrial processes, particularly screen printing, remains largely unexplored.

Moreover, current sustainability approaches in textile printing are predominantly technological, with limited attention to design-driven and culturally informed strategies. There is also a lack of research addressing the scalability, economic implications, and market acceptance of such approaches.

This study addresses these gaps by adopting a practice-led methodology to investigate how Wabi-sabi and Mottainai can be operationalized within industrial screen-printing processes. It contributes a novel framework that integrates aesthetic philosophy with material reuse strategies, offering both theoretical insights and practical implications for sustainable textile production.

METHODOLOGY

Research Design

This study adopts a qualitative, practice-led research design to investigate the integration of the Japanese aesthetic philosophies of Wabi-sabi and Mottainai into contemporary screen-printing practices. Practice-led research is particularly suitable for design-based inquiries, as it enables knowledge generation through iterative material experimentation alongside theoretical reflection (Nimkulrat, 2009; Vuletich, 2015). In this study, the creation of textile samples serves as both an investigative process and an analytical output.

To enhance methodological rigour, the research employs a multi-method qualitative approach, integrating literature analysis, field observations, semi-structured interviews, and controlled studio experimentation. This design enables triangulation between conceptual, empirical, and material data, strengthening the validity and depth of the findings.

Case Study Context

The empirical component of the study was conducted within an industrial textile printing environment, specifically at Antler Fabric Printers (Pvt) Ltd in Sri Lanka. The case was selected through purposive sampling based on its relevance to the research objectives, including its large-scale production capacity, established export-oriented operations, and identifiable material waste streams across multiple stages of the screen-printing process.

The factory setting provided access to key production units, including the design studio, screen preparation unit, colour kitchen, printing floor, and quality control section. This enabled a comprehensive examination of

workflow dynamics, resource consumption, and waste-generation patterns in a real-world manufacturing context.

Data Collection Methods

Data collection was conducted through three primary qualitative methods:

(a) Field Observations

Non-participant observations were conducted across five key production areas during multiple site visits. These observations focused on identifying process stages, material flows, and waste generation points. Particular attention was given to sampling stages and quality rejection processes, where waste accumulation was most evident.

(b) Semi-Structured Interviews

A total of 15 participants were purposively sampled to ensure representation across operational roles, including designers, machine operators, technicians, and quality inspectors. The sample size was determined based on data saturation, where recurring themes related to waste generation and process inefficiencies became consistent across participants. Interviews explored perceptions of defects, material usage, and existing waste management practices.

(c) Practice-Led Experimental Exploration

In parallel with fieldwork, a series of controlled studio-based experiments was conducted to test the practical application of Wabi-sabi and Mottainai principles. These experiments focused on manipulating printing variables, reusing leftover materials, and transforming defective outputs into new textile forms.

3.4 Experimental Process

The experimental phase consisted of approximately 25–30 textile sample iterations, developed through 12 structured experimental trials. Each trial focused on specific intervention strategies aligned with the research objectives, including:

- Variation of curing temperature and pressure to induce controlled irregularity
- Layering and overprinting techniques using rejected samples
- Reuse and recombination of leftover inks from production processes
- Repurposing previously used screens with modified compositions

The experiments were iterative, with each cycle informing subsequent trials. Visual and material outcomes were systematically documented through photographic records and process notes to ensure analytical consistency.

Data Analysis

Data were analysed using a thematic analysis approach, involving iterative coding and categorization of patterns across observational, interview, and experimental data. Initial open coding identified recurring issues, including material waste, defect generation, and process inefficiencies. These codes were subsequently grouped into higher-level themes aligned with the principles of imperfection (Wabi-sabi) and material respect and reuse (Mottainai).

To enhance analytical rigor, findings from different data sources were cross-compared through methodological triangulation, ensuring consistency between observed practices, participant perspectives, and experimental

outcomes. In addition, the experimental samples were subjected to visual-material analysis to evaluate their aesthetic qualities and alignment with the conceptual framework.

Limited quantification was incorporated to strengthen analytical clarity. Observations indicated that approximately 15–25% of prepared inks remained unused per production cycle, while a significant proportion of samples were rejected during sample and bulk capability accessing production quality inspection due to minor irregularities. These estimates, while not derived from controlled measurement, provide indicative evidence of waste patterns within the observed production context.

Ensuring Research Rigor and Trustworthiness

Several strategies were employed to enhance the credibility and reliability of the study:

Triangulation: Multiple data sources (observations, interviews, experiments) were used to validate findings across different perspectives.

Transparency: Systematic documentation of experimental procedures and decision-making processes was maintained throughout the study.

Reflexivity: As a practice-led investigation, the researcher's role in the experimental process was critically reflected upon to minimize subjective bias in interpretation.

Data Saturation: Interview sampling was continued until thematic consistency was achieved, ensuring adequate coverage of key issues.

Ethical Considerations

Ethical standards were maintained throughout the research process. Informed consent was obtained from all participants prior to interviews, and confidentiality of organizational and individual data was strictly preserved. Industrial data were anonymized where necessary to protect proprietary information.

FINDINGS AND DISCUSSION

Process Structure and Waste Concentration in Screen Printing

Field observations conducted across the production units revealed that the screen-printing process follows a sequential workflow consisting of artwork preparation, screen development, color formulation, printing, and quality inspection. While material input occurs across all stages, waste generation is disproportionately concentrated in two critical points: color preparation and quality control.

Observational analysis indicates that approximately 15-25% of prepared inks remain unused after production cycles, primarily due to overestimation during color mixing, recipe rejection and limited reuse practices. Similarly, a considerable proportion of printed samples particularly during sampling and initial production runs are rejected due to minor inconsistencies in alignment, pressure, or curing.

These findings confirm that the existing system operates under a linear production logic, in which deviations from predefined standards result in immediate rejection rather than reintegration. This establishes the foundation for exploring design-led interventions that challenge this paradigm.

Controlled Irregularity as a Design Mechanism (Wabi-sabi)

The experimental manipulations illustrated in Figure 1 demonstrate that variations in artwork designing, curing temperature, ink layering, and pressure application produce irregular surface qualities such as cracking, fading, and textural inconsistency. In conventional industrial practice, these outcomes are classified as defects and contribute to rejection rates estimated at 25-30% during sampling stages. (The acceptable variation capacity lies from 3-8% within the established industrial production context)

However, within the framework of Wabi-sabi, these irregularities can be reinterpreted as intentional aesthetic expressions. The experimental samples show that such variations are not random but can be systematically controlled and reproduced, transforming unpredictability into a design strategy.

- This finding represents a critical shift from defect elimination to defect redefinition, where:
- Irregularity becomes a design variable rather than a production error
- Rejection rates can be reduced through expanded acceptance criteria
- Visual diversity enhances product differentiation

Thus, Wabi-sabi operates not merely as a conceptual philosophy but as an operational design tool within industrial production systems.

Figure 1. Experimental textile samples demonstrating controlled irregularity aligned with Wabi-sabi aesthetics (Source: Author)

Ink Waste as a Resource: Material Reuse and Re-composition (Mottainai)

Figures 2 and 3 provide direct evidence of ink accumulation and experimentation with ink reuse. Observations confirm that leftover inks are among the most significant sources of waste, often discarded due to concerns about color consistency and storage limitations.

Figure 2. Accumulated leftover and unused inks in the color kitchen (Source: Author)

Experimental recombination of these inks demonstrates that they can be effectively reused to create new compositions through layering and multi-color interactions. Across experimental trials, reused inks accounted for approximately 20–30% of total material input, indicating substantial potential for reducing reliance on virgin materials.

These experimentations provide successful print generation approaches to address the niche market opportunities focusing on personalized aesthetical variations with a limited operational and skill capability inputs within production floor.

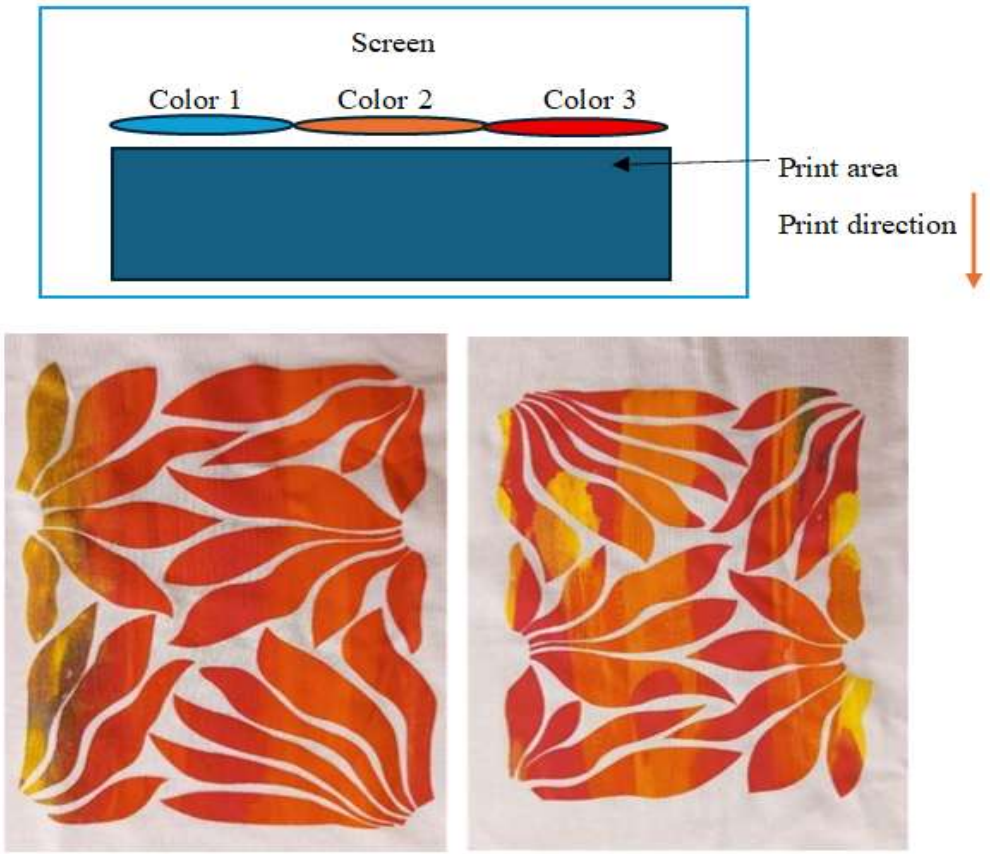


Figure 3. Leftover and unused inks reused multicolor print experiment (Source: Author)

From a production perspective, this intervention offers four key advantages:

- Reduction of material waste at the source
- Cost efficiency through decreased ink consumption
- New opportunity exploration through repurposing of old screens
- Aesthetic variability, supporting non-standardized design outputs

Transformation of Defective Outputs into Secondary Products

As illustrated in Figures 4, defective prints generated during quality inspection represent a major loss of material and embedded labor value. These defects, typically caused by misregistration, uneven application, or curing inconsistencies, are conventionally categorized as non-recoverable waste.

Figure 4. Examples of defective screen-printed textile samples rejected during quality inspection (Source: Author)

However, experimental interventions demonstrate that these rejected outputs can be successfully transformed through techniques such as overprinting, foil application, and layered surface modification. Notably, the "sticky flaw" observed in defective prints was exploited to enhance foil adhesion, enabling the creation of visually distinctive surfaces as shown in figure 5.

Figure 5. Repairing experiment used silver and clear rainbow foils taking advantage of the "sticky-flaw" of the rejected print to make it adhere foil layer by amending the normal foil pressing conditions (Source: Author)

Experimental results indicate that approximately 60–70% of rejected samples used in trials were successfully repurposed into aesthetically viable products, suggesting a high recovery potential.

This introduces a secondary production loop, where:

- Waste is reintegrated rather than discarded
- Material and labor value are partially recovered
- New product categories (e.g., limited or experimental designs) can emerge

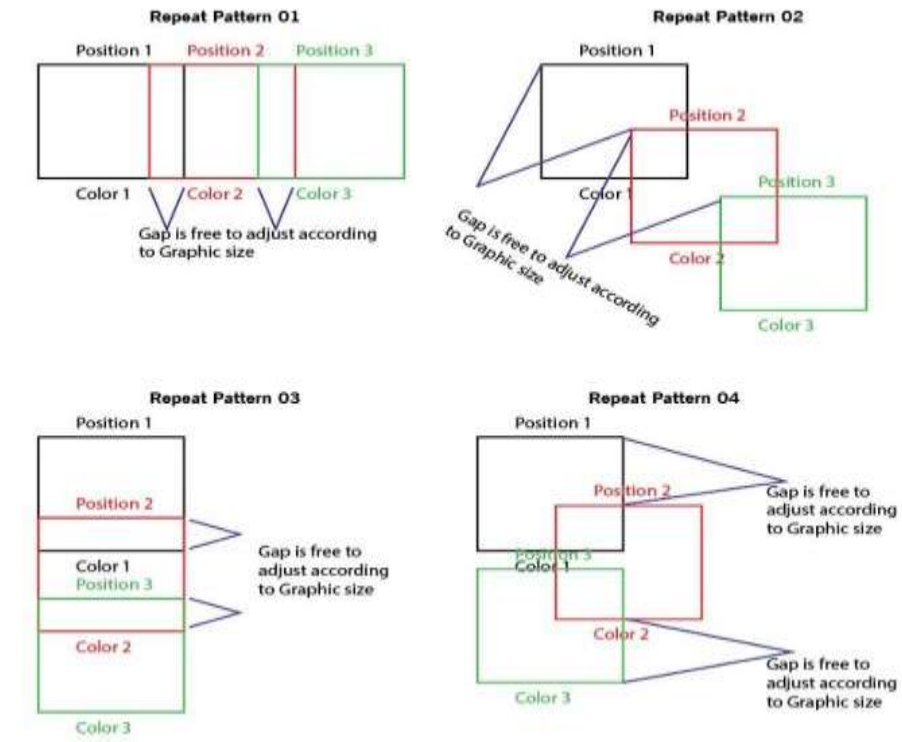
This dual application of Wabi-sabi and Mottainai demonstrates how imperfection and reuse reinterpreted as aesthetic opportunities rather than failures functioning synergistically within circular design systems.

Extension of Production Tool Lifecycle: Screen Reuse

Figures 6, 7, and 8 highlight the underutilization of screen-printing resources. Screens from previous production runs are often stored and eventually discarded despite remaining structurally functional.

Figure 6. Stored screen-printing frames from previous production batches (Source: Author)

Experimental reuse of these screens through overlapping prints, positional variation, and altered color applications demonstrates that they can be effectively reintegrated into new production cycles. This reduces the need for new screen preparation, which involves both material consumption and labor input.



This approach reinforces the principle of Mottainai, promoting maximum utilization of available resources while supporting creative experimentation.

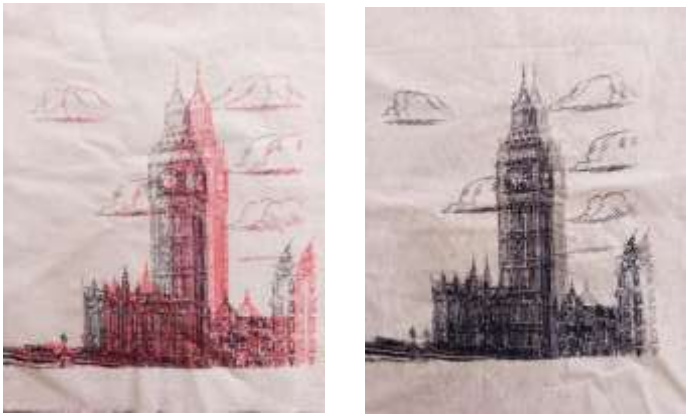


Figure 7. Overlapping screen two color pigment print experiment and one-color pigment print strike variation experiment (Source: Author)

Figure 8. multicolor print experiment with single screen usage with different screen position repeating (Source: Author)

This strategy contributes to sustainability by:

- Extending the lifecycle of production tools
- Reducing preparation costs and time
- Enabling flexible and adaptive design processes

Thus, Mottainai is extended beyond materials to encompass production infrastructure, reinforcing a holistic approach to resource efficiency.

Integrated Impact: Toward a Circular Design-Oriented Production Model

The combined findings demonstrate that integrating Wabi-sabi and Mottainai principles enables a systemic shift from a linear production model toward a circular, design-oriented approach.

Intervention	Waste reduction potential	Resource Efficiency	Industrial Feasibility
Controlled irregularity	15-25% reduction in rejected samples	Reduces defect-based wastes	High
Ink reuse	Repurposing 20-30% of ink wastes	Lowers material input	High
Defect repurposing	Recovery of 60-70% of rejected inputs	Recovers material and labor value	Moderate
Screen reuse	Reduced tool replacement and labor input	Extends resource lifecycle	high

Table 1. Summary of Intervention Outcomes

Experimental results demonstrate a successful circulatory production capability model with limited input of labor and resources synergically repurposing underutilized and discarded resources. The originally discarded inks occupying 15-25% of initial production input stocks can be repurposed into a new product to recover 20-30% of lost revenue. Defect repurposing although show a moderate industrial potential, can lead to address niche market potential explorations with personalization and environmental conscious goal lead customer groups. Thus, mottainai and wabi-sabi aesthetics shows successful potentials of adaptation into sustainable screen-printing models.

These interventions collectively demonstrate that sustainability can be achieved through design-led reconfiguration rather than solely technological intervention.

Discussion: Reframing Industrial Sustainability Through Aesthetic Philosophy

The findings extend existing sustainability discourse by illustrating that cultural-aesthetic frameworks can function as practical mechanisms for industrial transformation. While previous research has emphasized technological solutions (Catarino, 2025; Hoque, 2024), this study demonstrates that value redefinition rather than process optimization alone can significantly influence resource efficiency.

By aligning with circular economy principles (Sandin & Peters, 2018), the study introduces a design-driven approach to circularity, in which waste is reintegrated through creative transformation rather than through external recycling systems.

However, the implementation of such approaches is constrained by:

- Standardized quality control systems
- Brand compliance requirements
- Operational limitations in large-scale production

Furthermore, the commercial viability of imperfection-based design is closely linked to consumer acceptance, where irregularity must be repositioned as a marker of value rather than a defect. Through reinterpreting imperfections as aesthetic value and waste materials as resources, it becomes possible to align environmental sustainability with creative innovation.

DISCUSSION

Reframing Sustainability: From Technological Efficiency to Design-Led Intervention

The findings of this study challenge the prevailing techno-centric approach to sustainability in textile printing, which primarily focuses on material substitution, process optimization, and resource-efficient technologies (Catarino, 2025). While such approaches have demonstrated measurable environmental benefits, they often operate within the constraints of existing production logics, where uniformity, precision, and defect elimination remain dominant priorities.

In contrast, this study demonstrates that sustainability can also be achieved through design-led interventions that redefine the perception of waste and imperfection. By operationalizing Wabi-sabi and Mottainai within screen-printing processes, the research shifts the focus from eliminating defects to reinterpreting them as aesthetic and material assets. This aligns with emerging perspectives in sustainable design that advocate value reconfiguration over purely technical solutions.

Alignment with Circular Economy and Material Efficiency Frameworks

The integration of material reuse, defect repurposing, and tool lifecycle extension observed in this study reflects key principles of the circular economy, particularly the emphasis on resource efficiency, waste minimization, and value retention (Sandin & Peters, 2018). However, unlike conventional circular strategies that rely heavily on recycling and material recovery technologies, the approach presented here introduces design-driven circularity, in which waste is reintegrated through creative transformation rather than industrial reprocessing.

For instance, the reuse of leftover inks and the transformation of defective outputs into value-added products demonstrate how material loops can be closed within the production system itself. This reduces reliance on external recycling processes while maintaining the integrity and value of materials. Such findings extend existing research by illustrating how aesthetic frameworks can function as operational mechanisms for circular production, rather than merely conceptual ideals.

Industrial Applicability and Operational Implications

A key contribution of this study is its demonstration of practical applicability in an industrial context. Unlike many sustainability approaches that require significant technological investment or process restructuring, several of the identified interventions such as ink reuse and screen repurposing can be implemented with minimal disruption to existing workflows.

From an economic perspective, these interventions have the potential to:

- Reduce material procurement costs through reuse
- Minimize losses associated with rejected outputs
- Introduce differentiated product lines with higher perceived value

However, adopting such strategies requires a shift in the production mindset. Industrial systems are traditionally optimized for consistency and standardization, and the introduction of controlled variability may conflict with established quality assurance protocols. Therefore, successful implementation depends on developing adaptive quality frameworks that accommodate aesthetic irregularity without compromising functional performance.

Barriers to Implementation in Industrial Contexts

Despite the demonstrated potential, several barriers may limit the large-scale adoption of these approaches. First, quality control systems in industrial textile production are designed to minimize variability, and redefining defects as acceptable or desirable may require significant changes in evaluation criteria.

Second, brand compliance and client expectations pose constraints, particularly in export-oriented production environments where strict specifications govern product acceptance. The incorporation of irregular or non-standardized outputs may not align with existing market requirements.

Third, operational challenges such as material handling, storage of reusable inputs, and workflow adjustments must be addressed to ensure efficiency. Without systematic integration, reuse practices may introduce complexity rather than streamline production.

These barriers highlight that while the proposed approach is conceptually viable, its implementation requires organizational, technical, and cultural adaptation within industrial systems.

Consumer Acceptance and Market Dynamics

The success of design-led sustainability approaches is closely linked to consumer perception. Traditional market expectations often equate quality with uniformity and flawlessness, which may conflict with Wabi-sabi-inspired aesthetics. However, evolving consumer trends, particularly within sustainable and slow fashion movements, indicate a growing appreciation for authenticity, uniqueness, and material narratives (Terui,2026 & Douglass,2026).

Products that visibly embody processes of reuse, imperfection, and transformation may be perceived as more meaningful and environmentally responsible. This creates opportunities to position such products in niche or premium market segments.

Nevertheless, broader market acceptance remains uncertain and requires further empirical investigation. Understanding consumer attitudes toward imperfection-based design is therefore essential for translating experimental outcomes into commercially viable products.

Theoretical Contribution: Bridging Aesthetic Philosophy and Industrial Sustainability

This study contributes to sustainable design theory by bridging the gap between cultural-aesthetic philosophy and industrial production systems. While Wabi-sabi and Mottainai have been widely discussed in relation to craft practices and conceptual design (Sung et al., 2021), their application within large-scale manufacturing has remained limited.

By demonstrating how these philosophies can be operationalized within screen-printing processes, the study extends their relevance beyond cultural discourse into practical sustainability strategies. It positions aesthetic values not merely as symbolic influences, but as functional drivers of resource efficiency and innovation.

Toward Hybrid Production Models

The findings suggest that a complete shift from standardized industrial production to variability-driven systems may not be feasible. Instead, a more practical approach lies in the development of hybrid production models, where standardized processes coexist with controlled areas of experimentation and variability.

Such models allow manufacturers to maintain efficiency and consistency while integrating sustainable practices through selective interventions. This approach provides a balanced pathway for aligning environmental objectives with industrial constraints.

Consumer Acceptance and Market Implications

The successful implementation of design-led sustainability strategies in industrial textile production depends not only on technical feasibility but also on consumer perception and market acceptance. Conventional consumer expectations in the textile and apparel industry are largely shaped by ideals of uniformity, precision, and flawlessness, where visible irregularities are typically interpreted as indicators of poor quality.

The findings of this study challenge these assumptions by demonstrating that imperfections-such as irregular textures, layering inconsistencies, and tonal variations can be intentionally designed and repositioned as aesthetic features. However, the extent to which such products are accepted in mainstream markets remains contingent upon shifting consumer value systems.

Emerging trends in sustainable fashion, slow fashion, and craft-based design suggest a growing consumer appreciation for authenticity, uniqueness, and material narratives. Products that visibly reflect processes of reuse, transformation, and imperfection may be perceived as more environmentally responsible and culturally meaningful. In this context, Wabi-sabi-inspired aesthetics can create emotional and symbolic value, differentiating products from mass-produced alternatives.

From a market perspective, this creates opportunities for:

- Product differentiation through uniqueness and non-replicability
- Premium positioning, where perceived value is linked to sustainability and craftsmanship
- Niche market development, particularly among environmentally conscious consumers

However, several challenges remain. Large-scale commercial adoption may be constrained by consumer trust, as irregularity must be clearly communicated as intentional rather than defective. Additionally, established retail standards and brand expectations may limit the acceptance of non-uniform products within conventional supply chains.

Therefore, the transition toward imperfection-based sustainable design requires not only production-level changes but also strategic communication and consumer education. Labelling, storytelling, and transparency regarding production processes may play a critical role in shaping consumer perceptions and enhancing acceptance.

Future research should incorporate empirical consumer studies, including perception analysis, willingness-to-pay assessments, and market segmentation, to evaluate the commercial viability of such design approaches across different contexts.

Consumer Acceptance and Market Viability

The implementation of design-led sustainability strategies in industrial textile production is critically dependent on consumer acceptance, as market perception ultimately determines the commercial viability of such approaches. In conventional textile markets, product quality is strongly associated with uniformity, precision, and defect-free finishes, and deviations from these standards are typically interpreted as production failures.

The findings of this study challenge this dominant perception by demonstrating that irregularities such as tonal variation, misregistration, and surface inconsistencies can be intentionally incorporated as aesthetic features aligned with Wabi-sabi. However, the acceptance of such imperfection-based design depends on a shift in consumer value frameworks, where uniqueness and authenticity are recognized as indicators of quality rather than defects.

Emerging trends in sustainable and slow fashion suggest a growing segment of consumers who value transparency, craftsmanship, and environmental responsibility. In these contexts, products that visibly embody reuse and transformation may generate greater symbolic and emotional value, particularly when supported by clear sustainability narratives. This creates opportunities to position such textiles in differentiated or premium market segments, where perceived value extends beyond functional performance.

Despite this potential, several constraints must be acknowledged. First, consumer trust is a critical factor; irregularity must be communicated as intentional and design-driven rather than accidental. Second, retail and brand standards, particularly in export-oriented production, may limit the acceptance of non-uniform outputs. Third, variability in design may introduce challenges to product consistency, affecting scalability in mass-production contexts.

To address these challenges, effective implementation requires strategic communication mechanisms, including product labelling, storytelling, and transparency in production processes, to reframe consumer understanding of quality and sustainability.

Future research should incorporate empirical consumer studies, such as perception analysis, willingness-to-pay assessments, and market segmentation, to evaluate the acceptance of imperfection-based textile products across different cultural and commercial contexts. Such investigations are essential for bridging the gap between experimental design innovation and large-scale industrial adoption

Limitations

Despite its contributions, this study has several limitations that should be acknowledged when interpreting the findings.

First, the empirical investigation was conducted within a single industrial case study, which may limit the generalizability of the results across different textile production contexts, technologies, or geographic regions. While the selected case provides in-depth insights into screen-printing practices, variations in production scale, organizational structure, and technological capability may influence the applicability of the proposed interventions.

Second, the study adopts a primarily qualitative, practice-led approach, and although limited quantification has been incorporated, the findings are not supported by controlled experimental measurement or statistical validation. Estimates related to waste reduction and material reuse are indicative rather than definitive, and should therefore be interpreted as exploratory.

Third, the experimental component was conducted at a pilot scale, focusing on iterative sample development rather than full-scale industrial implementation. As a result, operational factors such as production speed, labour constraints, and system integration were not tested under real-time manufacturing conditions.

Fourth, economic feasibility and cost–benefit analysis were not systematically evaluated. While the study identifies potential cost savings from material reuse and waste reduction, the absence of a detailed financial analysis limits the ability to assess industrial viability quantitatively.

Finally, constraints related to brand compliance, intellectual property, and production standardization restricted the extent to which experimental outputs could be tested within actual market channels. These constraints highlight the gap between experimental feasibility and commercial adoption.

Future Research

Building on the findings and limitations of this study, several directions for future research are identified to advance both theoretical understanding and industrial application.

First, future studies should incorporate quantitative methods to evaluate the environmental and economic impacts of design-led interventions. This includes the controlled assessment of waste-reduction percentages, material efficiency, energy usage, and cost implications under real production conditions.

Second, there is a need for pilot-scale industrial implementation studies that test the proposed strategies within live manufacturing environments. Such studies would provide insights into operational feasibility, workflow integration, labour implications, and scalability across different production systems.

Third, further research should investigate consumer perceptions and market acceptance using empirical methods such as surveys, experiments, and willingness-to-pay analyses. Understanding how different consumer segments respond to imperfection-based design is essential for translating experimental outcomes into commercially viable products.

Fourth, comparative studies across different textile technologies and cultural contexts would help evaluate the adaptability of Wabi-sabi and Mottainai principles beyond screen printing. This would strengthen the generalizability and cross-context relevance of the proposed framework.

Fifth, interdisciplinary research integrating design, engineering, and sustainability science could further refine the operationalization of aesthetic philosophies within industrial systems. Such collaborations may lead to the development of hybrid models that balance standardization with controlled variability.

Finally, future work should explore communication and branding strategies that effectively convey the value of imperfection-based sustainable products. This includes labelling systems, storytelling approaches, and transparency mechanisms that can enhance consumer trust and market acceptance.

CONCLUSION

This study investigated the integration of the Japanese aesthetic philosophies of Wabi-sabi and Mottainai into contemporary screen-printing practices as a design-led approach to sustainability. Moving beyond conventional techno-centric solutions, the research demonstrates that sustainability in textile production can be achieved by reconfiguring design values, in which imperfection and waste are repositioned as sources of aesthetic and material value.

Drawing on a qualitative, practice-led methodology that combined industrial observations, semi-structured interviews, and iterative experimental exploration, the study identified five key intervention areas within the screen-printing process: controlled irregularity, ink reuse, repurposing of defective outputs, reuse of screen resources, and aesthetic reinterpretation of production errors. The findings indicate that these interventions can contribute to measurable improvements in resource efficiency, including estimated reductions in material waste and increased utilization of previously discarded inputs.

Importantly, the study demonstrates that integrating Wabi-sabi and Mottainai enables a shift from a linear "produce–inspect–discard" model toward a circular, design-driven production system. This approach not only reduces environmental impact but also generates value-added textile products characterized by uniqueness and material narrative, offering opportunities for product differentiation and enhanced market positioning.

From an industrial perspective, the research highlights that several of these strategies, particularly material reuse and screen repurposing, can be implemented with minimal disruption to existing production systems. However, successful adoption requires addressing key challenges related to quality standardization, operational integration, and brand compliance. Furthermore, the commercial viability of imperfection-based design is closely linked to consumer acceptance, necessitating shifts in perception supported by effective communication and market positioning strategies.

Theoretically, this study contributes to sustainable design discourse by bridging the gap between cultural-aesthetic philosophy and industrial production systems, demonstrating that Wabi-sabi and Mottainai can

function as practical frameworks for resource efficiency and innovation. Methodologically, it reinforces the value of practice-led research in generating applied knowledge within design contexts.

Overall, the study establishes that design-led sustainability offers a viable and scalable pathway for transforming textile production systems. Aligning environmental objectives with creative and economic value generation provides a foundation for future research and industrial experimentation to advance more circular, adaptive, and culturally informed approaches to manufacturing.

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