

Zero Waste Fashion: Reducing Textile Waste Through Sustainable Garment Construction

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Abstract: The global fashion industry stands as one of the most environmentally damaging sectors, generating over 92 million tons of textile waste annually while less than one percent of all textiles are recycled back into clothing. This research article examines zero waste fashion as a transformative approach to mitigating textile waste through sustainable garment construction. Employing a comprehensive literature review methodology, the study analyzes zero waste pattern cutting techniques, including jigsaw cutting, subtraction cutting, modular design, and the emerging Mobius Band method. The findings reveal that zero waste fashion design can reduce pre-consumer fabric waste by approximately 35 percent, with some implementations achieving fabric utilization efficiency up to 98 percent. The integration of digital technologies, including AI-powered pattern optimization and 3D garment simulation, has significantly enhanced the accessibility and scalability of zero waste techniques. Traditional garment construction methods from various cultures such as the Japanese kimono and Indonesian kebaya offer historical precedents for zero waste principles. Despite challenges including limited design flexibility, sizing constraints, and industry resistance, the adoption of zero waste practices is accelerating through educational initiatives, technological innovation, and growing consumer demand for sustainable fashion. The article concludes that zero waste fashion represents a viable pathway toward circular economy principles in the apparel industry, offering substantial environmental benefits while maintaining aesthetic and functional quality.

Keywords: Zero Waste Fashion, Sustainable Garment Construction, Textile Waste Reduction, Pattern Cutting, Circular Economy, Sustainable Fashion Design.

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I. INTRODUCTION

The fashion industry has experienced unprecedented growth over the past two decades, with global fiber production increasing to 124 million tons in 2023, more than doubling since 2000 when it stood at 58 million tons. This expansion has been accompanied by a staggering environmental cost. The industry generates over 92 million tons of waste annually, with approximately 87 percent of global textile waste disposed of in landfills while less than one percent of all textiles are recycled back into clothing. During the fabric cutting process alone, an average of 15 percent of fabric is wasted, and textile waste from the fashion industry is currently estimated at 120 million metric tons and

growing. Eighty percent of this waste ends up in landfills or is incinerated, and the total value of unrecovered textile waste could be in the region of \$150 billion each year.

The environmental impact of textile waste extends beyond landfill accumulation. The production and disposal of clothing contribute significantly to water pollution, resource depletion, and greenhouse gas emissions. Fast fashion business models have exacerbated these problems by flooding the market with low-quality, short-lived products. In response to these pressing environmental concerns, zero waste fashion has emerged as a promising solution that addresses textile waste at its source the design and production phase.

Zero waste fashion design is a sustainable approach that aims to eliminate textile waste throughout the production process. It utilizes the pattern-cutting process as a creative tool to develop garments that use the entire width and length of fabric, leaving no waste or minimizing waste to less than 15 percent. This approach represents a fundamental shift from conventional garment construction, where pattern pieces are arranged on fabric with inevitable gaps and offcuts.

This research article examines zero waste fashion as a strategy for reducing textile waste through sustainable garment construction. The objectives are to: (1) analyze zero waste pattern cutting techniques and their effectiveness in waste reduction; (2) explore the integration of digital technologies in zero waste fashion; (3) examine historical and cultural precedents for zero waste principles; (4) identify challenges and barriers to adoption; and (5) propose future directions for research and practice.

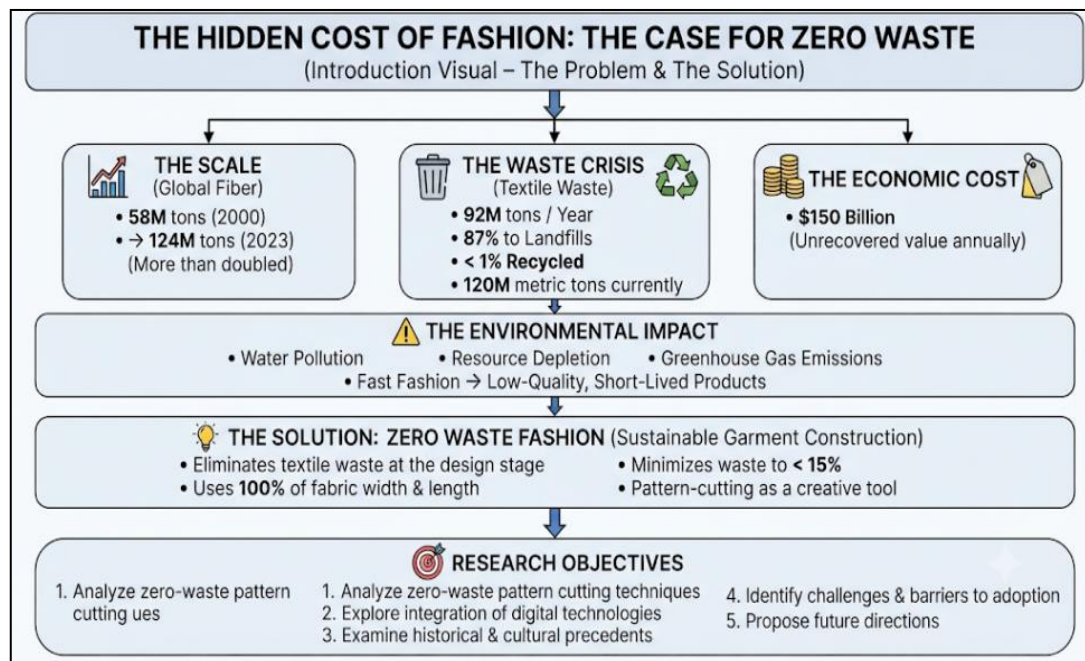


Fig 1 The Hidden Cost of Fashion: The Case for Zero Waste

This infographic illustrates the immense scale of the fashion industry's growth alongside its critical environmental and economic crises, where 87% of massive textile waste ends up in landfills. It introduces Zero Waste Fashion Design as a sustainable solution, aiming to minimize production waste to under 15% by using the entire fabric. The research objectives focus on analyzing these techniques, digital integration, and historical precedents to overcome adoption barriers.

II. LITERATURE REVIEW

➤ The Scale of Textile Waste

The fashion industry's waste problem is multifaceted, encompassing both pre-consumer and post-consumer waste. Pre-consumer waste includes leftover yarn, fabric scraps, and liquid waste from dyeing generated during the production process. Post-consumer waste consists of garments discarded by consumers after use. In 2019, the overall waste amount was reduced temporarily due to the COVID-19 pandemic, but with economic recovery, the fast fashion business is expected to grow at a rate of 19.0 percent between 2020 and 2025.

More than 90 percent of all resources extracted and used are squandered. The amount of residual fabric and textile waste produced during garment manufacture may range from 25 to 40 percent, depending on the scale of the factory. Every

second, a truckload of textile products is dumped or burned somewhere in the world. In 2025, Europe alone generated approximately 15.2 million tons of textile waste, of which 13.3 million tons was post-consumer waste. Only about 22 percent of post-consumer textiles are currently collected separately for reuse and recycling.

Significantly, over 97 percent of the textiles used in garment production are new, and only one percent of today's materials will be used in tomorrow's attire. This linear model of production and consumption is environmentally unsustainable and economically inefficient.

➤ Defining Zero Waste Fashion

Zero waste fashion design is a technique or method of making patterns by minimizing the use of fabric so that not much fabric is wasted. This method integrates pattern cutting into the design process itself, rather than treating it as a separate production stage. Zero waste fashion design aims to significantly reduce pre-consumer waste by optimizing the pattern-cutting process.

According to Rissanen and McQuillan (2023), zero waste fashion design uses the pattern-cutting process in the production stage as an opening to develop a creative way to visualize a design in its three-dimensional form. This approach targets a reduction of around 35 percent of pre-

consumer waste from the fabric-cutting stage, demonstrating its practical benefits and alignment with sustainability goals.

The zero waste approach has been applied across various garment types. A study implementing zero waste pattern cutting techniques in the production of ready-to-wear clothing achieved fabric utilization efficiency up to 98 percent, resulting in products that meet the criteria of aesthetics, comfort, functionality, and sustainability.

➤ Historical Precedents

Zero waste fashion is not a contemporary invention. Traditional clothing from various cultures has long embodied zero waste principles. The Japanese kimono, for example, is made by optimizing the length and width of the fabric with

minimal cutting and no fabric waste. The concept of using geometric shapes in creating clothes is one reason why the kimono serves as an exemplary model of zero waste clothing.

Similarly, traditional Indonesian clothing, including the kebaya, has been explored for its potential to apply zero waste fashion design methods. These historical practices demonstrate that zero waste principles are rooted in resource-conscious garment construction traditions that predate modern sustainability discourse.

The term "zero waste" in modern fashion history was first coined by Paul Palmer in the 1970s, emerging from his work on the modern waste industry focusing on upcycling.



Fig 2 Literature Review: Zero Waste Fashion

This infographic details the literature review on zero waste fashion across three key sections: the massive scale of pre- and post-consumer textile waste globally and in Europe, the definition of zero waste design integrating pattern cutting to reduce 35% of waste, and historical precedents like the Japanese kimono and Indonesian kebaya rooted in resource-conscious traditions.

III. ZERO WASTE PATTERN CUTTING TECHNIQUES

➤ Jigsaw Cutting and Tessellation

Jigsaw cutting is a pattern-cutting technique in which all pattern pieces interlock with each other, generating no waste from design production. This approach involves strategically laying out pattern pieces to nest them efficiently on rectangular fabric, closely resembling the process of assembling puzzle pieces. The puzzle cut method requires creative pattern design that diverges from the existing process of using pattern slopers.

Research on zero waste pattern design has identified key factors in terms of fabric use, design, and composition. Regarding materials, appropriate fabric width, understanding the difference between waste minimization and minimal fabric use, and easy reuse and recycling are important considerations. In terms of design, the simultaneous progress of pattern and design work, adjustable loose silhouettes, and the use of surplus fabric for functional and decorative details have emerged as key characteristics.

➤ Subtraction Cutting

Subtraction cutting, developed by Julian Roberts, provides unexpected fluid, organic forms while achieving zero waste fabric utilization. This technique involves removing fabric from a garment rather than adding pieces together, creating unique silhouettes that challenge conventional garment construction methods. The technique expands on traditional pattern-making approaches and offers designers creative freedom while maintaining zero waste principles.

➤ Modular Design

Modular fashion design is a process in which one garment can have the appearance of different designs that can be modified by the consumer. When combined with zero waste fashion design, modular approaches offer a multiple design methodology to support sustainable fashion production. This approach extends the lifecycle of garments by allowing for reconfiguration and adaptation.

➤ The Mobius Band Method

Recent practice-led research has explored the Mobius Band structure's potential to challenge zero waste pattern-making approaches that rely on two-dimensional flat surfaces as a starting point. The Mobius Band structure provides a three-dimensional fabric space for design development, offering the potential for multiple forms and wear possibilities that cater to individual wearer needs.

The experimental work focused on optimizing the fluidity and multi-dimensional aspects of the Mobius Band using various materials, sizes, and dimensions, resulting in continuously changing surfaces and garment shapes. The

outcomes demonstrate the potential of the Mobius Band method to enhance zero waste pattern cutting by offering a three-dimensional design framework that reduces cutting lines, prevents fabric waste, preserves fabric integrity, and creates versatile garments with an innovative design approach.

➤ Traditional Techniques and Cultural Approaches

The exploration of traditional garment construction techniques offers valuable insights for contemporary zero waste practice. A study examining how traditional Turkish women's clothing techniques can be applied to contemporary garment design found that traditional methods inherently minimize fabric waste. Similarly, research on traditional Indonesian kebaya has explored the possibility of applying zero waste fashion design methods to achieve zero or less than 15 percent waste.

These studies highlight that zero waste principles are embedded in diverse cultural traditions and that contemporary designers can draw inspiration from historical practices.

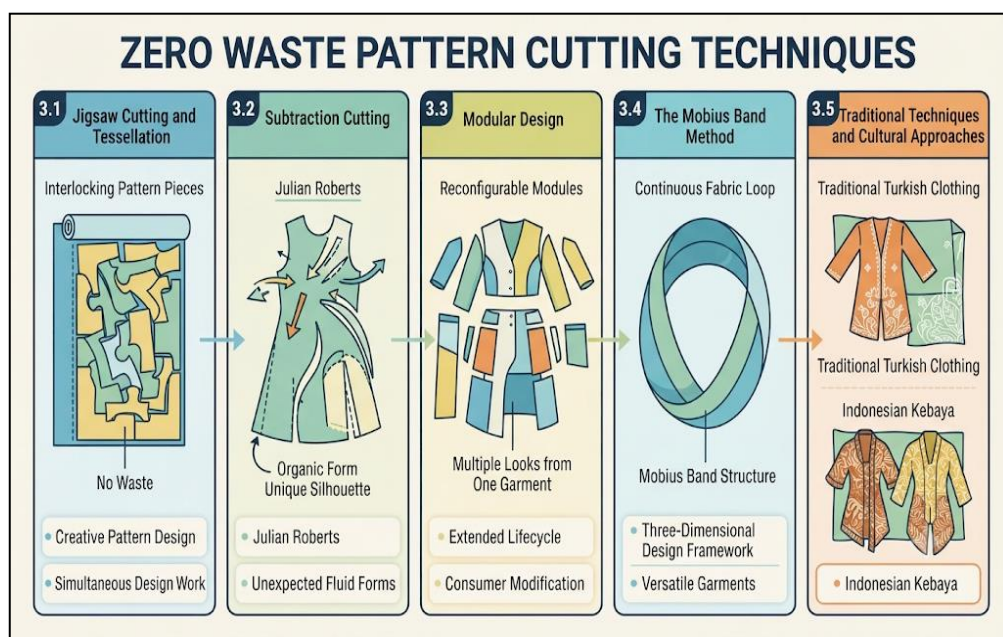


Fig 3 Zero Waste Pattern Cutting Techniques

This infographic outlines five key zero-waste pattern-cutting techniques. It highlights Jigsaw Cutting and Tessellation for interlocking pattern pieces, Subtraction Cutting by Julian Roberts for fluid silhouettes, Modular Design for reconfigurable looks, the Mobius Band method for 3D continuous structures, and traditional techniques like Turkish clothing and Indonesian Kebaya rooted in sustainable cultural practices.

IV. DIGITAL TECHNOLOGIES IN ZERO WASTE FASHION

The marriage of digital innovation and sustainable fashion has opened up exciting new possibilities for reducing textile waste. AI-powered tools and digital prototyping

software are revolutionizing how designers approach fabric utilization, enabling them to create garments with minimal waste while maintaining creative freedom. These technologies are not just theoretical concepts they are being actively implemented by both luxury and mass-market brands to transform their production processes.

One of the most promising developments in this space is the SNU-ZWP (Zero-Waste Pattern) generation system, a groundbreaking tool that automatically converts conventional garment patterns into zero-waste layouts. What makes this system particularly impressive is its ABCD methodology, which stands for Arrangement-Based Conventional pattern Dilation. This approach intelligently rearranges pattern pieces to eliminate gaps and offcuts, ensuring that every inch

of fabric serves a purpose. The system goes a step further by incorporating a three-dimensional garment simulator, allowing designers to visualize how their zero-waste patterns will look on a real human body before any fabric is cut. This eliminates the need for multiple physical prototypes, saving both materials and time.

The effectiveness of the SNU-ZWP system has been validated through rigorous evaluation, demonstrating significant improvements in pattern design efficiency while opening up new avenues for creative expression. Designers are no longer constrained by traditional pattern-making limitations they can now explore innovative silhouettes and shapes that were previously difficult or impossible to achieve with conventional methods. This dual benefit of sustainability and creativity is exactly what the fashion industry needs to move toward a more responsible future.

Major brands across the spectrum, from high-end luxury houses to fast fashion giants, are embracing these

digital tools to enhance their pattern efficiency and minimize waste. Sportswear companies, in particular, have been early adopters of AI-based cutting software and simulations, recognizing that even small improvements in fabric utilization can translate into substantial environmental and economic benefits. These industry-wide adoptions underscore the transformative power of AI and digital prototyping in advancing sustainable fashion practices.

Beyond optimizing new production, digital technologies are also enabling creative solutions for repurposing fabric offcuts. Researchers have developed systematic approaches to identify offcut-friendly garment designs, using computational methods to evaluate how leftover materials from regular manufacturing can be transformed into new, stylish garments. This approach extends the lifespan of textiles and adds value to materials that would otherwise end up in landfills, creating a more circular and resource-efficient fashion industry.

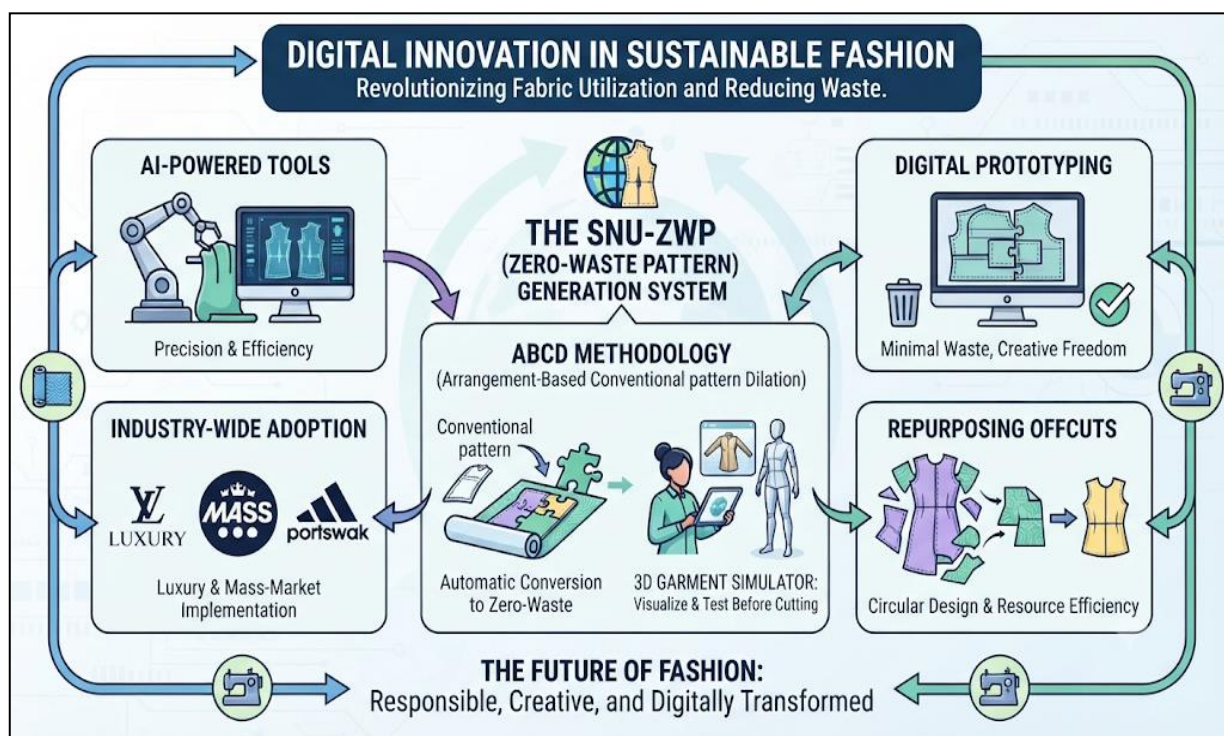


Fig 4 Digital Innovation in Sustainable Fashion

This infographic highlights how AI tools and digital prototyping revolutionize sustainable fashion. It features the SNU-ZWP system and its ABCD methodology, which automatically converts conventional patterns into zero-waste layouts while using 3D simulations. Furthermore, it details industry-wide adoption across luxury and mass markets, alongside computational methods for repurposing fabric offcuts into valuable circular garments.

V. INTEGRATING CIRCULAR ECONOMY PRINCIPLES

Zero waste fashion is deeply intertwined with circular economy principles, which seek to rebuild environmental, economic, and societal value through three foundational pillars: reducing waste, circulating materials, and restoring ecological systems. Unlike the traditional linear model of "take-make-dispose," the circular approach envisions textiles as valuable resources that should be kept in use for as long as possible through repurposing, recycling, and upcycling. This paradigm shift is not merely an environmental necessity but also an economic opportunity, as it challenges the fashion

industry to rethink its entire value chain from design to disposal.

The apparel sector is increasingly recognizing that the key to sustainable development lies in effective waste recovery initiatives. Programs such as take-back schemes and closed-loop recycling systems are being carefully evaluated for their ability to divert textile waste from landfills and reintroduce materials back into production cycles. These initiatives represent a tangible shift toward accountability, where brands are beginning to take responsibility for the entire lifecycle of their products rather than washing their hands once garments leave the store shelves.

However, the path to circularity is not without its challenges, particularly in emerging economies. A recent study examining the obstacles unique to the Indian fashion industry identified several circular design principles including lean manufacturing, modular construction, and the use of recyclable materials as effective strategies for minimizing waste during production. The research, which

gathered insights from twenty-two industry stakeholders, painted a nuanced picture of the circular economy landscape in India. While the potential for transformation is immense, participants highlighted significant barriers such as infrastructural gaps, lack of standardized recycling facilities, and the economic constraints faced by small and medium-sized enterprises. Yet, these challenges also present opportunities for innovation and collaboration across the supply chain.

To guide this transition, industry bodies have introduced the 6R Approach Redesign, Reduce, Reuse, Remanufacture, Recycle, and Regenerate as a comprehensive framework for enhancing resource efficiency and circularity within the textile sector. This structured approach provides a roadmap for businesses to systematically address every stage of the product lifecycle, from conceptualization to end-of-life management. By embracing these principles, the fashion industry can move beyond incremental improvements and toward a truly regenerative system that benefits both people and the planet.

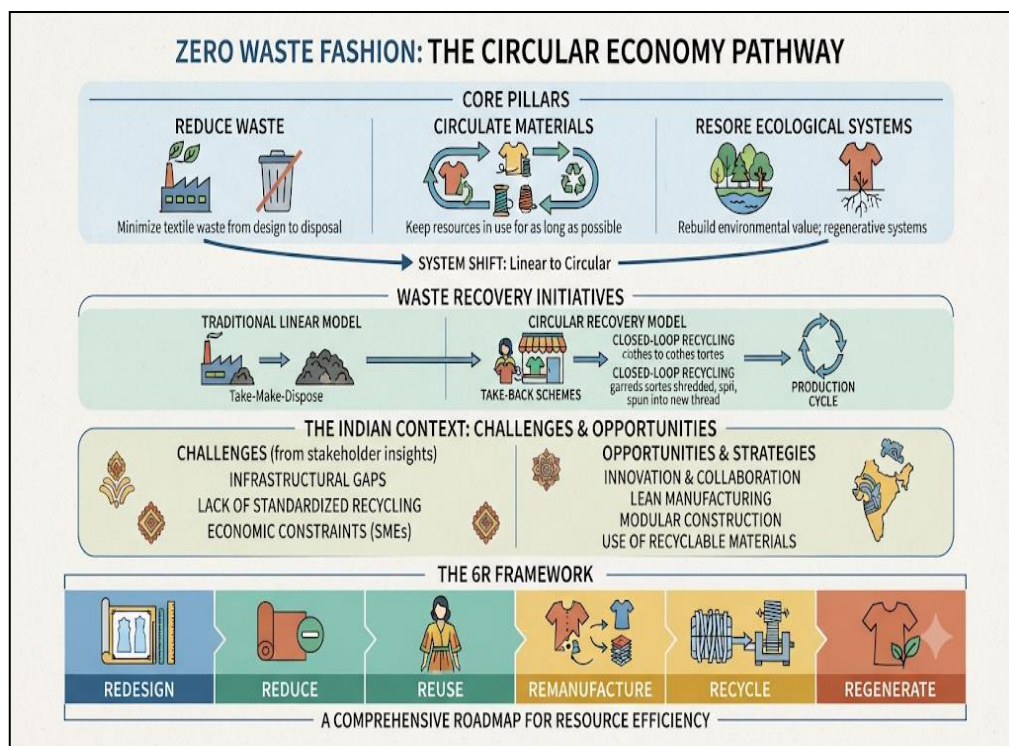


Fig 5: Zero Waste Fashion: The Circular Economy Pathway

This infographic details the circular economy framework for sustainable fashion. It outlines three core pillars reducing waste, circulating materials, and restoring ecosystems—alongside waste recovery initiatives. Furthermore, it examines the Indian context's challenges and opportunities, concluding with the comprehensive 6R framework of Redesign, Reduce, Reuse, Remanufacture, Recycle, and Regenerate to achieve full resource efficiency.

VI. CASE STUDIES AND APPLICATIONS

➤ Traditional Kimono as Zero Waste Model

The Japanese kimono stands as one of the most elegant and enduring examples of zero waste garment construction in human history. For centuries, this iconic garment has been crafted by optimizing the length and width of fabric with minimal cutting and virtually no waste. The kimono's genius lies in its geometric simplicity—it is constructed almost entirely from straight lines and rectangular shapes, allowing artisans to use every inch of the woven cloth. This is not a modern sustainability trend but a time-honored tradition that

demonstrates how resource-conscious design can be both practical and beautiful. The kimono reminds us that zero waste principles are not a recent invention but rather a return to the wisdom of our ancestors who understood the value of materials long before sustainability became a global concern.

➤ Contemporary Zero Waste Implementations

Today's designers are building on these traditional foundations with impressive results. In one notable study, researchers applied zero waste pattern cutting techniques to produce a hoodie blouse and achieved fabric utilization efficiency of up to 98 percent. What makes this achievement particularly remarkable is that the final product did not compromise on aesthetics, comfort, or functionality it was a genuinely wearable garment that met all the criteria consumers expect from modern clothing. This demonstrates that sustainability and quality are not mutually exclusive.

Research on zero waste fashion design in the men's shirt industry has yielded similarly encouraging results. Emerging designers experimenting with these techniques consistently produced textile waste well below the 15 percent threshold, proving that with creativity and commitment, significant waste reduction is achievable. While different studies employed varying methodologies, the outcomes were remarkably consistent: zero waste design works. These

findings suggest that even small shifts in how patterns are conceived and executed can have a meaningful impact on reducing the industry's environmental footprint.

➤ Upcycling and Offcut Repurposing

Beyond optimizing new production, the transformation of fabric offcuts into new garments offers an important complementary strategy. Research exploring offcut repurposing has confirmed that clothing created from leftover materials is not only technically viable but also aesthetically appealing. This approach adds value by extending the lifespan of textiles and reducing the demand for virgin resources.

Initiatives like Project Sundri in Mumbai demonstrate the human dimension of this work. Starting with just ten women in 2024, this community-based project empowers local artisans by providing training and employment opportunities in upcycling textile waste. The project has since expanded to include thirty more women who now stitch with the precision and consistency required to compete in the open market. Beyond environmental benefits, Project Sundri shows how sustainable fashion can uplift communities, create livelihoods, and preserve traditional skills proving that zero waste is not just good for the planet but good for people too.

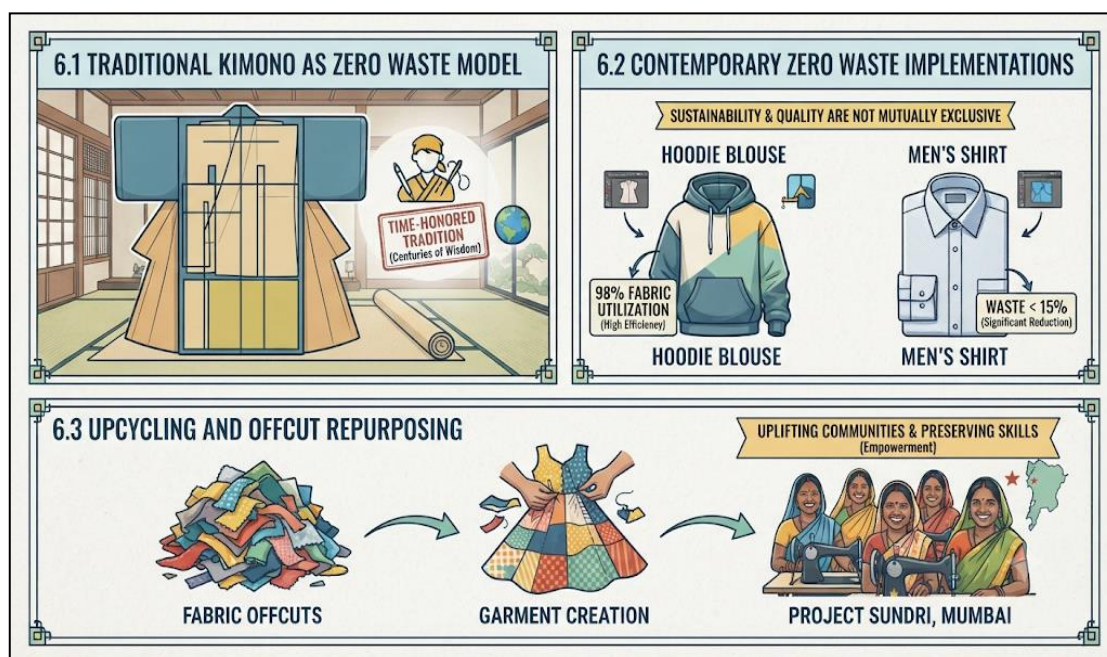


Fig 6 Tradition to Innovation: Zero Waste Implementations and Upcycling

This infographic illustrates traditional and modern zero-waste fashion practices. It highlights the geometric simplicity of the Japanese kimono, contemporary zero-waste garment implementations achieving up to 98 percent fabric utilization for items like hoodies and shirts, and community-driven upcycling initiatives like Project Sundri in Mumbai, which transforms fabric offcuts while empowering local artisans.

VII. CHALLENGES AND BARRIERS

Despite its undeniable environmental benefits, zero waste fashion continues to face significant hurdles on the path to widespread adoption. While the concept is elegant in theory, putting it into practice within the complex machinery of the global fashion industry presents formidable challenges that cannot be overlooked.

Perhaps the most fundamental barrier lies in the creative process itself. Zero waste pattern design demands a complete reimagining of how garments are conceived, requiring designers to think simultaneously about form, function, and fabric utilization in ways that diverge sharply from conventional pattern-making. This is not simply a matter of tweaking existing methods; it demands a paradigm shift in design thinking. The traditional separation between design and production in the fashion industry further complicates matters. Designers often create with little regard for material efficiency, leaving it to pattern makers and factory workers to deal with the waste afterward. This compartmentalized workflow has become so deeply entrenched that reconfiguring it requires not just new skills but a cultural transformation across organizations.

Sizing presents another significant obstacle. Zero waste patterns, by their very nature, are less flexible when it comes to accommodating the full spectrum of body sizes. Maintaining zero waste principles while offering garments that fit diverse body types is a complex design puzzle that has yet to be fully solved. This is particularly challenging for brands that serve a wide customer base across multiple markets.

Material considerations add another layer of complexity. Not all fabrics are equally suited to zero waste cutting techniques; factors such as fabric width, drape, and pattern repeat all influence how effectively materials can be utilized. Designers must carefully select materials that align with zero waste principles while still meeting aesthetic and functional requirements, adding an extra constraint to an already challenging process.

Economic barriers cannot be underestimated. Transitioning to zero waste practices requires investment in new equipment, comprehensive retraining of staff, and fundamental process redesign. In an industry driven by speed and cost reduction, the upfront investment required for such changes can seem daunting, particularly for small and medium-sized enterprises operating on tight margins. The fashion industry's relentless focus on minimizing costs and maximizing speed often means that conventional, waste-heavy methods continue to prevail simply because they are familiar and economically predictable. Overcoming these entrenched practices will require not just technological solutions but a fundamental shift in how the industry values sustainability over short-term profit.

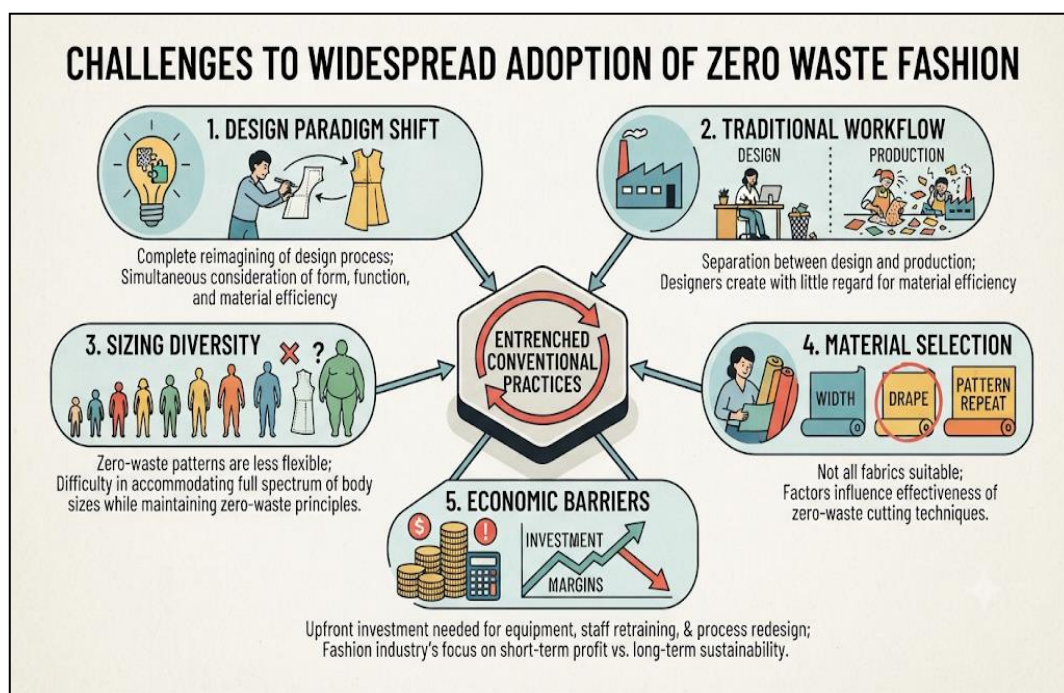


Fig 7 Challenges to Widespread Adoption of Zero Waste Fashion

This infographic outlines five major hurdles preventing the widespread adoption of zero waste fashion: a required design paradigm shift, entrenched traditional workflows, challenges with sizing diversity across varied body types, specific material selection constraints like drape and width, and economic barriers involving high upfront investments versus short-term profit margins.

VIII. FUTURE DIRECTIONS

The future of zero waste fashion depends on a powerful convergence of three interconnected forces: technological innovation, educational transformation, and policy support. Each of these pillars must be strengthened if zero waste principles are to move from niche practice to industry standard.

On the technological front, developments like the SNU-ZWP system are opening exciting new possibilities. These AI-powered pattern generation tools can automatically transform conventional designs into zero waste layouts, removing much of the guesswork and trial-and-error that currently limits adoption. But this is just the beginning. Further research into three-dimensional design frameworks, such as the Mobius Band method, promises to expand the creative possibilities of zero waste fashion even further. By moving beyond two-dimensional thinking, designers can explore forms and silhouettes that were previously impossible to achieve without waste. As these technologies mature and become more accessible, they have the potential to democratize zero waste design, making it feasible for brands of all sizes rather than just a handful of pioneering designers.

Education must keep pace with these technological advances. Currently, most fashion design curricula treat sustainability as an afterthought rather than a core principle. Integrating zero waste fashion design into fashion education is essential for building capacity among emerging designers who will shape the industry's future. When students learn to think about pattern efficiency and material utilization from their very first design projects, these principles become second nature rather than something to be retrofitted later. Educational initiatives can help overcome the knowledge gap that currently limits adoption, creating a new generation of

designers for whom zero waste is not a compromise but a starting point.

Policy support plays a critical role in accelerating this transition. Government policies that promote circular economy principles and textile waste reduction can create the enabling conditions for zero waste fashion to flourish. Industry guidelines, such as those launched by ABFRL and GIZ in India, provide practical frameworks for implementation that businesses can follow. These policy interventions signal that sustainability is not optional but expected, encouraging investment and innovation in sustainable practices.

Consumer awareness is the final piece of this puzzle. As people become more conscious of sustainability issues beyond simple environmental impact, their expectations for brands evolve. Growing consumer demand for sustainable fashion is already driving industry change, and this pressure is only going to increase. When consumers ask questions about how their clothes are made and where waste goes, brands listen. This rising awareness creates a virtuous cycle: consumer demand drives industry innovation, which in turn makes sustainable options more accessible and affordable, leading to even greater consumer engagement. The future of zero waste fashion is not just about better technology or smarter policy it is about creating a cultural shift where sustainability becomes the expectation, not the exception.



Fig 8 Convergence for the Future of Zero Waste Fashion

This infographic illustrates the powerful convergence of four interconnected forces required to transition zero waste fashion from a niche practice to an industry standard. It highlights technological innovation, educational transformation, policy support like ABFRL and GIZ guidelines, and rising consumer awareness driving the cultural shift toward long-term sustainability.

IX. CONCLUSION

Zero waste fashion represents a transformative approach to reducing textile waste through sustainable garment construction. The fashion industry's current trajectory of waste generation is environmentally unsustainable, with over 92 million tons of textile waste produced annually and less than one percent recycled back into clothing. Zero waste fashion design offers a viable pathway to address this crisis by eliminating waste at the

design and production stage. The analysis of zero waste pattern cutting techniques including jigsaw cutting, subtraction cutting, modular design, and the Mobius Band method reveals that significant waste reduction is achievable without compromising aesthetic or functional quality. The integration of digital technologies, such as AI-powered pattern optimization and 3D garment simulation, has enhanced the accessibility and scalability of zero waste techniques.

Historical and cultural precedents, including the Japanese kimono and traditional Indonesian clothing, demonstrate that zero waste principles are rooted in resource-conscious garment construction traditions. Contemporary applications confirm that zero waste fashion can achieve fabric utilization efficiency up to 98 percent. Despite challenges including design limitations, industry resistance, and sizing constraints, the adoption of zero waste practices is accelerating through technological innovation, educational initiatives, and growing consumer demand. The circular economy framework provides a broader context for zero waste fashion, emphasizing waste reduction, material circulation, and ecological restoration.

Future research should focus on developing automated zero waste pattern generation systems, exploring three-dimensional design frameworks, and investigating the scalability of zero waste practices in mass production contexts. Policy support and educational initiatives will be essential for mainstreaming zero waste fashion. Ultimately, zero waste fashion represents not merely a technical solution to textile waste but a fundamental reimagining of the relationship between design, production, and consumption in the apparel industry.

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