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MATERIAL REGENERATION AND CULTURAL SUSTAINABILITY THROUGH MODULAR FASHION DESIGN: RECONCEPTUALIZING BALINESE ENDEK WEAVING SCRAPS

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The fashion industry generates textile waste throughout the production and consumption stages, while leftover Balinese endek weaving fabric is still frequently treated as production residue that remains underutilized. This study aims to develop a sustainable modular fashion design model based on leftover Balinese endek fabric by integrating the principles of less waste design, subtraction pattern, draping, Traditional Ecological Knowledge (TEK), and regenerative design. The research employed a qualitative approach using a Research Through Design strategy, involving participant observation of the design process, visual documentation, in-depth interviews with designers and artisans, analysis of pattern and prototype documentation, as well as thematic and design analysis. The findings reveal that leftover endek fabric can be classified according to size, motif, texture, grain direction, and joining potential to form structural panels, visual elements, and transitional modules. Subtraction pattern and draping enable irregular fabric remnants to be negotiated with the body, while the modular system expands possibilities for configuration, functionality, and product life cycles. These findings demonstrate that leftover endek fabric should not be viewed merely as textile waste but as a cultural material that embodies ecological, technical, and symbolic values. This article contributes to the sustainable fashion discourse by proposing the concept of tradition subtraction as a design approach that connects material efficiency, the regeneration of local textile values, and the development of a tradition-based circular economy.

Keywords: Sustainable Fashion, Textile Waste Valorization, Balinese Endek Textiles, Modular Fashion Design, Regenerative Design

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INTRODUCTION

The contemporary fashion industry operates within a persistent tension between accelerated production, intensified consumption, and a material crisis that has become increasingly difficult to ignore. Over the past two decades, global textile production and consumption have risen sharply, while most textile products continue to end up as waste because dominant fashion production systems follow a linear logic: materials are extracted, manufactured, used, and discarded (Shirvanimoghaddam et al., 2020). This issue concerns not only post-consumer waste but also pre-production waste and material remnants generated during cutting, processing, and garment manufacturing (Khairul Akter et al., 2022). Recent studies on circular-economy strategies in the textile sector show that reuse, repair, recycling, and reduction constitute key pathways for reducing fashion's ecological burden, yet their effectiveness ultimately depends on design decisions made at the earliest stages of product development (Ramírez-Escamilla et al., 2024). In Indonesia, these challenges intersect with the presence of traditional textiles that carry not only material value but also local identity, production knowledge, artisan social relations, and the ecological imprint of their places of origin. Endek weaving from Bali occupies a significant position in this context because offcuts generated during textile production and garment creation have not always been treated as valuable design resources, even though these remnants retain visual, textural, symbolic, and cultural qualities that can be further developed through sustainable design approaches.

The push toward circular fashion often stops at the discourse of material recycling, while design practices grounded in traditional textile waste remain underexamined as processes of design knowledge production. Literature on sustainable fashion demonstrates that human perceptions of recycled textiles and circular fashion are shaped by product quality, function, cultural value, and the ways sustainability is communicated to users (Wagner & Heinzl, 2020). Research on material recovery likewise emphasizes that the transition toward a circular economy in the textile industry requires strategies that extend beyond waste collection and processing, as material value must be preserved through repurposing, upcycling, and the extension of product life cycles (Papamichael et al., 2024). The challenge is that fashion design based on traditional textile remnants is often positioned as a local creative practice or alternative craft rather than as a conceptual field for examining the relationships among material, body, pattern, ecology, and cultural regeneration. Studies on circular material innovation in textiles also highlight the importance of modularity, recyclability, reusability, and design for disassembly as principles that must be considered from the conceptual stage, not after a product becomes waste (Aakanksha et al., 2026). This gap is particularly relevant to endek weaving remnants in Bali, as there is still limited research connecting less-waste design techniques, subtraction pattern cutting, draping, and modular design with Traditional Ecological Knowledge and regenerative design within a unified creation-based research framework.

Bali's endek weaving remnants cannot be understood merely as production residue, as their presence lies within a material-cultural trajectory that connects weaving knowledge, ethical resource use, artisan labor, and the local values embedded in the textile. Traditional Ecological Knowledge provides a framework for understanding ecological knowledge that emerges from long-term relationships among communities, cultural practices, local materials, and the environment, making it relevant for interpreting the use of textile remnants as a design practice that does not separate technical considerations from cultural meaning (Wright, 2020). Within Indigenous textile studies, traditional material-processing practices often demonstrate ecological intelligence through principles of minimizing waste, spiritual ties to the environment, and respect for the resources being used (Palomino, 2024). Regenerative design extends this orientation by positioning design not merely as a means of reducing negative impacts but as a process that rebuilds reciprocal relationships among communities, materials, places, and ecological systems (Toner et al., 2023). Within this framework, subtraction pattern cutting and draping can be understood not only as garment-shaping

techniques but also as methods for negotiating form within material constraints. Modular fashion design further strengthens sustainability goals by enabling garments to be reconfigured, used across functional variations, repaired, and extended in lifespan through adaptive component systems.

This research aims to develop a sustainable modular fashion design model based on endek weaving remnants from Bali by integrating principles of less-waste design, Traditional Ecological Knowledge, and regenerative design. Specifically, the study seeks to identify the potential of endek remnants as primary materials for sustainable fashion design, describe the application of subtraction pattern cutting and draping in the garment-creation process, analyze how TEK values are represented in remnant-based design practices, and explain the contribution of modularity to product sustainability and the circular economy. The research problem is structured around four key questions: how endek weaving remnants are utilized in sustainable modular fashion design; how subtraction pattern cutting and draping support less-waste design principles; how TEK and regenerative design are reflected in remnant-based fashion design; and how modular design contributes to cultural sustainability, environmental stewardship, and the circular economy. As a qualitative study employing a Research Through Design strategy, the prototype-creation process is positioned as a medium of knowledge production rather than merely an aesthetic output. This approach aligns with the view that design research generates understanding through processes of designing, material exploration, articulation of formal decisions, and critical reflection on the relationship between design practice and its socio-ecological context (Vaughan, 2017). Accordingly, the research questions do not only address what can be produced from textile remnants but also how the design process transforms the status of remnants from waste into cultural and ecological resources.

The novelty of this article lies in articulating the conceptual relationships among material subtraction, garment modularity, and traditional ecological knowledge within the context of Balinese endek weaving. Most circular-fashion studies continue to emphasize waste management, recycling technologies, consumer behavior, or supply-chain models, whereas this article shifts the analytical focus to the design space itself as a site of negotiation among fabric remnants, patterns, the body, technique, and cultural value (Das et al., 2025). Although research on traditional textiles and sustainability has begun to show that local craft can serve as a source of ecological learning, cultural preservation, and design innovation, the conceptual links among textile remnants, subtraction pattern cutting, draping, and modular systems still require sharper elaboration (Hendriyana et al., 2024). In this context, the term *substraksi tradisi* is not understood as a reduction of traditional value but as a design operation that draws upon traditional material remnants to generate new configurations while honoring the cultural traces embedded in the textile. This article contributes to sustainable-fashion discourse by proposing that fashion sustainability does not arise solely from environmentally friendly materials or recycling processes but also from the capacity of design to regenerate value, extend product life cycles, uphold the dignity of local materials, and open new relationships between traditional knowledge and contemporary design experimentation.

Literature Review

Traditional Ecological Knowledge, regenerative design, and sustainable fashion form the core conceptual foundation of this research because all three reject rigid separations between materials, humans, environments, and cultural practices. TEK is rooted in ecological knowledge passed down through community experience in managing the environment, utilizing resources, and maintaining the continuity of relationships between cultural practices and natural systems (Wright, 2020). In textile and fashion studies, TEK has begun to be understood as an epistemological source that expands sustainability beyond production efficiency toward a relational ethic involving materials, place, and community (Palomino, 2024). Regenerative design moves further than conventional sustainable design because it is not only oriented toward reducing negative impacts but also toward restoring living

relationships among communities, places, local knowledge, and ecological systems that support design practices (Toner et al., 2023). Sustainable fashion then becomes the operational space where these ideas are translated into material decisions, pattern systems, production processes, use cycles, and more responsible economic models (Wagner & Heinzl, 2020). In this research, endek weaving remnants from Bali are positioned as cultural materials that retain ecological and symbolic potential, making their use through subtraction pattern cutting, draping, and modular design not merely a waste-reduction technique but a design practice that reactivates relationships among textile traditions, the body, materials, and socio-ecological sustainability.

Previous studies on sustainable fashion show that textile waste has become a central issue in global discourse, particularly through concepts such as the circular economy, zero-waste fashion, upcycling, and material recovery. Shirvanimoghaddam et al. (2020) demonstrate that circular-economy models in textiles require fundamental changes in how materials are produced, used, preserved in value, and repurposed after their first life cycle. Khairul Akter et al. (2022) emphasize that upstream material waste in the textile and apparel industries generates ecological and economic losses, making waste management necessary from the stages of manufacturing and design, not only post-consumption. Ramkalaon and Sayem (2021) show that zero-waste pattern cutting can significantly increase fabric utilization in apparel production, positioning pattern design as a strategic tool for reducing pre-production waste. Lei and Li (2021) develop a zero-waste pattern-making approach through single-piece manipulation, segmentation, reconstruction, and the use of fabric elasticity to address stylistic limitations and construction complexity. Enes and Saygılı (2023) bring together zero-waste fashion design and modular fashion design as a dual methodology that enables a single garment to produce multiple configurations, while Hwang and Lee (2023) propose a modular system based on three-dimensional digital fashion technology to enhance personalization, simplicity, and functional expansion in sustainable products. Collectively, these studies show that fashion sustainability cannot be discussed solely through environmentally friendly materials but must also address pattern construction, form flexibility, and user-driven extension of garment life cycles.

A research gap emerges because circular-fashion and zero-waste literature often frames textile waste as a technical, industrial, or consumer-behavior issue, while remnants from traditional textiles are rarely understood as a meeting ground for local ecological knowledge, cultural value, and design experimentation. Papamichael et al. (2024) show that transitioning toward a circular economy requires mobilizing textile waste to generate new material and energy value, yet such studies tend to emphasize industrial-scale recovery schemes. Das et al. (2025) likewise map the circular economy as a model for waste reduction and value creation within textile supply chains, but cultural heritage materials and artisan knowledge remain peripheral. In zero-waste studies, Kim and Na (2023) note that pattern-cutting design is still rarely adopted by brands and designers because it requires pattern creativity that diverges from conventional sloper-based processes. Zhang et al. (2024) further show that zero-waste practice requires digital design systems because changes in one pattern piece affect others, making design constraints a methodological challenge. Despite this, discussions of subtraction pattern cutting and draping as strategies for negotiating traditional textile remnants with the body remain limited. As a traditional textile that produces offcuts during production and garment creation, Balinese endek has not yet been widely examined as a research object that connects less-waste design, TEK, cultural ecology, modular fashion, and regenerative design within a unified creation-based qualitative framework.

This article positions itself within this gap by shifting the reading of textile remnants from the category of waste to the category of cultural material capable of generating design knowledge. In this context, endek remnants are not treated as supplementary materials used merely for efficiency but as starting points for exploring form, joints, modules, volume, and the relationship between the body and textile memory. Studies on upcycling grounded in

traditional technologies show that combining cultural inquiry with ecological design principles can revitalize local craft technologies while producing environmentally responsible alternative materials (Santoso & Utami, 2021). Hendriyana et al. (2024) likewise emphasize that integrating local wisdom with global innovation can produce sustainable, functional, and culturally communicative craft products. Liu and Li's (2025) study on experiential learning in sustainable fashion shows that direct engagement with traditional craft practices can shift the designer's role from product creator to cultural custodian and agent of social sustainability. Grounded in Research Through Design, this article positions modular-fashion prototyping as a medium of knowledge production, making its contribution not only the prototype itself but also a conceptual model of how TEK can be operationalized through pattern techniques, draping, modularity, and material decisions. This contribution is significant because it brings together environmental sustainability, tradition regeneration, and the circular economy at the scale of concrete design practice.

Theoretical and methodological trends in previous studies show a shift from impact-evaluation-based sustainability research toward more experimental, participatory, and practice-based design approaches. In design research, the creation process becomes a site of knowledge emergence because methods, tactics, and directions of exploration often develop through the researcher's adaptation to materials, contexts, and findings as the process unfolds (Gaver et al., 2022). Co-creative qualitative approaches also highlight the importance of experience, user or community involvement, and the production of solutions grounded in real contexts, making them relevant for research involving designers, artisans, and local materials (Moser & Korstjens, 2022). Stockless and Brière (2024) show that design-based research accommodates social contexts and stakeholder needs because it takes place in real-world situations rather than fully controlled laboratory conditions. In fashion studies, zero-waste research increasingly uses pattern exploration, simulation, prototyping, and visual experimentation as methodological tools for understanding relationships among form, fabric efficiency, and sustainability (Nursari et al., 2025). These tendencies reinforce the relevance of Research Through Design in this study, as the knowledge sought emerges not only from interviews or literature but also from design decisions that arise when endek remnants are arranged, folded, cut, reduced, joined, and configured into modular garments.

The conceptual synthesis of this research is built from the layered relationships among TEK, less-waste design, subtraction pattern cutting and draping, modular fashion, the circular economy, regenerative design, and socio-ecological sustainability. TEK provides the ethical and epistemological foundation that traditional materials are not neutral, as endek textiles carry relationships among artisan knowledge, production environments, cultural values, and inherited practices of use. Less-waste design translates this ethic into principles of careful material utilization through waste reduction, avoidance of excess, and maximization of remnant potential. Subtraction pattern cutting and draping function as technical strategies for transforming the constraints of textile remnants into opportunities for form-making, as patterns no longer begin with ideal, intact fabric but with materials that already possess specific sizes, shapes, colors, motifs, and production traces. Modular fashion extends these possibilities by creating garment systems that can be reconfigured, repaired, combined, and worn in multiple variations. The circular economy provides a value framework to keep remnants within cycles of use, while regenerative design offers a conceptual direction ensuring that design processes do not stop at waste reduction but also regenerate relationships among textile traditions, artisans, users, and the environment. With this foundation, the methods section must understand the creation process not merely as a technical procedure but as a sequence of observation, visual documentation, interviews, design analysis, data triangulation, and qualitative interpretation of the relationships among material, culture, and sustainability.

RESEARCH METHOD

This study employs a qualitative approach with a Research Through Design strategy because the garment-design process is positioned as the primary medium for generating knowledge about the relationships among Balinese endek weaving remnants, less-waste design techniques, modularity, Traditional Ecological Knowledge, and regenerative design. In qualitative research, data are not treated as standalone numerical units but as contextual information that must be interpreted through experience, action, decision-making, meaning, and the social situations in which practices occur. Research Through Design is relevant because research knowledge emerges through acts of designing, material exploration, prototyping, evaluating formal decisions, and reflecting on the creation process as part of design-knowledge production. The practice-based character of design allows methods, strategies, and directions of exploration to evolve adaptively as researchers engage directly with materials, techniques, social contexts, and production constraints, as long as these changes remain documented and methodologically accountable (Gaver et al., 2022). Based on this foundation, the study does not position modular garments merely as final products but as research artefacts that record the transformation of endek remnants into a garment system that can be read ecologically, culturally, and through design.

The data sources consist of primary data, secondary data, and scholarly literature. Primary data were obtained through participatory observation during the design and creation process, visual documentation of material exploration and prototypes, and in-depth interviews with fashion designers, weavers, and Balinese endek artisans. Participatory observation was used to record design decisions that emerged directly when remnants were selected, arranged, reduced, folded, draped, joined, and configured into garment modules. In-depth interviews were conducted to explore artisans' practical knowledge, material considerations, views on remnants, experiences in endek production, and the ecological and cultural values embedded in material use. The co-creative qualitative approach positions practitioner experience and practice context as essential components for understanding the design process, particularly when research involves interactions among researchers, practitioners, users, and communities connected to the object of study (Moser & Korstjens, 2022). Secondary data were obtained from design documents, sketches, patterns, notes on design stages, archives of Balinese endek production, and visual documentation of prototypes. Scholarly literature supports the conceptual reading of sustainable fashion, less-waste design, subtraction pattern cutting, draping, modular fashion design, the circular economy, TEK, cultural ecology, and regenerative design.

Data collection was conducted through five main techniques: participatory observation, visual documentation, in-depth interviews, document study, and literature review. The research was designed to take place over three months—September to November 2025—with activities divided into remnant identification and material mapping in the first month; exploration of subtraction pattern cutting, draping, and modularity in the second month; and prototype documentation, interviews, and data verification in the third month. This timeline may be adjusted according to field schedules and artisan availability without altering the methodological structure. Instruments included design-process observation sheets, semi-structured interview guides, visual-documentation checklists, design-reflection notes, a camera for visual recording, and matrices for material and form analysis. Semi-structured interviews were chosen because they allow researchers to maintain question focus while enabling informants to elaborate on experiences, values, and practices that may not be predictable beforehand. Visual documentation is essential because design research produces not only verbal data but also data on form, texture, pattern, composition, joints, construction, and the visual transformation of materials. In descriptive qualitative research, clarity of data-collection stages, instrument accuracy, and consistency of process documentation are crucial for ensuring traceability of findings and the quality of interpretation (Villamin et al., 2025).

The inclusion criteria for this study comprise four categories. First, the textiles used must be remnants of Balinese endek weaving originating from production, cutting, or garment-design processes, not newly purchased fabric. Second, design-process data must relate directly to the application of subtraction pattern cutting, draping, less-waste design, or modular systems. Third, interview informants must have direct involvement in garment design, endek production, textile processing, or craft practices related to endek materials. Fourth, documents and literature must be relevant to sustainable fashion, textile waste, zero-waste or less-waste design, modular fashion, TEK, the circular economy, cultural ecology, regenerative design, and Research Through Design. Exclusion criteria include textile waste that cannot be identified as Balinese endek, visual documentation that does not clearly show design stages, informant statements unrelated to the research focus, and popular literature lacking adequate academic grounding. In the literature domain, articles that do not address sustainability, textile design, fashion, cultural ecology, or design methodology were excluded. Establishing such inclusion and exclusion criteria ensures that data remain aligned with the research problem and do not expand into general discussions of textile waste or sustainable fashion.

The units of analysis consist of Balinese endek weaving remnants, the modular-garment design process, the resulting prototypes, and the knowledge narratives of designers, weavers, and endek artisans. Remnants were analyzed based on size, motif, color, texture, joining potential, fiber direction, construction possibilities, and their capacity to enter a modular system. The design process was analyzed through technical decisions made during material selection, subtraction pattern cutting, draping, module assembly, form configuration, and garment finishing. Prototypes were analyzed as material artefacts that demonstrate relationships among less-waste principles, wearability flexibility, form transformability, and the potential for extending product life cycles. Informants were positioned as sources of practical knowledge that help explain how endek is produced, how remnants are typically treated, and how cultural and ecological values can be interpreted through material use. Design-based research conducted in real-world contexts must consider stakeholder needs, positions, and experiences because design practice does not occur in a neutral space but within specific social, material, and institutional networks (Stockless & Brière, 2024).

Data analysis was conducted through thematic analysis, design analysis, data triangulation, and conceptual interpretation. Thematic analysis was used to interpret interview results and observation notes through coding, theme grouping, and meaning-making regarding informants' views on remnants, endek values, production practices, material efficiency, and understandings of sustainability. Design analysis was used to assess relationships among garment form, modular structure, subtraction pattern cutting, draping, fabric joints, material efficiency, and the product's capacity for reconfiguration. Analyses of zero-waste and less-waste pattern practices must consider relationships among patterns, the body, fabric efficiency, and garment construction because pattern decisions determine the amount of waste generated from the earliest stages of production (Ramkalaon & Sayem, 2021). In modular fashion, analysis also considers the capacity of a garment or garment component to generate multiple looks, functions, and usage possibilities, as modularity can extend product lifespan and shift users from passive consumers to active participants in garment configuration (Enes & Saygılı, 2023). Triangulation was conducted by comparing observation data, visual documentation, interviews, and design documents to ensure that interpretations do not rely on a single data source. Conceptual interpretation was then directed toward reading the relationships among TEK, less-waste design, subtraction pattern cutting, draping, modular fashion, the circular economy, and regenerative design in the use of Balinese endek remnants.

Data validity was maintained through process traceability, documentation consistency, source triangulation, and design reflection. Each stage of material exploration was recorded to show the rationale for fabric selection, methods of cutting or reduction,

draping decisions, module formation, form changes, and the technical and cultural considerations that emerged during the design process. Visual documentation served as material evidence that allows readers to trace relationships among data, process, and prototypes. Source triangulation was conducted by comparing accounts from designers, weavers, artisans, observation notes, and design artefacts. Design reflection was used to evaluate how creative decisions relate to research objectives, particularly in addressing remnant utilization, the effectiveness of less-waste design, the representation of TEK, and the contribution of modularity to cultural, environmental, and circular-economic sustainability. This strategy ensures that Research Through Design maintains methodological rigor: the creative process is recognized as a source of knowledge, yet it must remain documented, analyzed, and traceable as research data.

RESULT AND DISCUSSION

Result

The findings of this study reveal five main themes that emerged from the coding and categorization process: mapping endek weaving remnants as primary design materials, the application of subtraction pattern cutting and draping in garment formation, modular construction as a system of form transformation, the readability of sustainability values through material-use processes, and the reuse of design residues. These themes were derived from observations of the design process, visual documentation of prototypes, design notes, interviews with designers and artisans, and examinations of sketches, patterns, and creation stages. All data indicate that Balinese endek remnants do not appear as homogeneous materials but as collections of pieces with varying sizes, motifs, grain directions, colors, textures, and edge conditions. These variations influenced early decisions in material grouping. Medium-sized pieces tended to be placed as main garment panels, elongated pieces were used as ties or connectors, while smaller pieces were considered for visual accents, structural reinforcement, or additional modules. Observation notes show that fabric sorting occurred before establishing the basic form, making material characteristics the starting point for determining design direction rather than merely following a completed sketch. This pattern aligns with studies in sustainable textile design that position material characteristics as determinants of efficiency, lifespan, and product recovery potential within the design cycle (Kapsali & Hall, 2022). Visual data also show that endek motifs were not treated as neutral decorative surfaces; motif placement influenced decisions about where fabric panels should be positioned on the body. At this stage, the findings identify three main material categories: structural pieces, visual pieces, and transitional pieces that connect primary panels with other modular components.

The first theme shows that Balinese endek remnants undergo a material-classification process before entering the design stage. This classification includes piece size, fabric thickness, motif integrity, color compatibility, fiber condition, and joining potential. Observational data indicate that remnants with intact motifs were more frequently selected as visible main panels, while pieces with fragmented motifs were used in areas requiring folds, layering, or seams. Irregularly shaped pieces were not immediately discarded but mapped according to their constructive potential. Some pieces were used as edges, lining panels, or detachable connectors. In interviews, artisans explained that endek remnants typically result from cutting processes for specific products and are often stored because their sizes are considered insufficient for full garments. This indicates that the status of “remnant” is shaped more by conventional production standards than by the loss of material value. These findings intersect with studies on upstream material waste in the apparel industry, which show that production remnants often lose economic value because they do not re-enter the design or manufacturing cycle (Khairul Akter et al., 2022). In this study, remnants were sorted not merely by usability but by their capacity to form structure, surface, joints, and modules. These categories then informed subsequent design stages, particularly when subtraction pattern cutting and draping were applied.

The second theme concerns the application of subtraction pattern cutting as a technique for creating spatial openings within the fabric. Process documentation shows that subtraction pattern cutting involved removing specific areas of fabric to create space for the body, seams, or more dynamic drape possibilities. Fabric pieces were not shaped through conventional pattern cutting that fully follows body measurements from the outset; instead, they were tested through field reduction, cut-outs, folding, and positional adjustments on the mannequin. In several stages, removed sections were not discarded but kept for testing as small modules, surface applications, or additional connectors. This workflow produced a design trajectory that moved from material to form rather than from sketch to material. Design notes show that reduction decisions were made after observing motif direction, drape behavior, and the potential for combining multiple pieces. In zero-waste pattern-cutting studies, the shift from conventional patterns to fabric-efficiency-based patterns requires attention to the relationship between garment form and material layout, as waste often emerges from the gap between garment design and panel arrangement on the fabric (Zhang et al., 2024). The findings here show that subtraction pattern cutting was used to minimize this gap through direct intervention on the available remnants. Removed sections were documented visually so their status as new residues could be monitored throughout the design process.

The third theme shows that draping functioned as a form-testing technique that helped align remnant characteristics with the body. Draping was conducted on a mannequin by placing fabric pieces gradually, observing drape direction, determining anchor points, and marking areas that needed to be secured, folded, or joined. Visual data show that the irregular sizes of endek remnants produced varied silhouettes when placed on the body. Longer pieces created vertical or diagonal lines, while shorter pieces tended to form layered accents or small panels. In several trials, draping produced forms not present in the initial sketches, especially when motif direction and fabric edges visually guided panel placement. These findings show that draping was used as a tool for reading fabric response to the body rather than merely as a final visualization stage. Studies on zero-waste pattern cutting and fashion-design approaches show that draping can serve as an exploratory process because it helps designers understand relationships among pattern, volume, the body, and material efficiency (Nursari et al., 2025). In this study, draping was also used to determine modular points—sections that could be detached, rotated, layered, or replaced with other modules. Each positional change was documented through process photographs to show the progression from initial arrangement to prototype.

The fourth theme concerns modular construction that emerged through the grouping of panels, joints, and detachable elements. Documentation shows that modular garments were built from several combinable components, such as main panels, supplementary panels, ties, outer layers, and movable accents. Modularity was applied not only to the final form but also to the management of remnants from the outset. Pieces of similar size were grouped as repetitive modules, while pieces of varying sizes were used as transitional modules to connect body sections or close construction gaps. Some modules were designed to transform the garment from one configuration to another. These findings show that modularity functioned both as a mechanism for form transformation and as a strategy for remnant utilization. Studies on zero-waste and modular fashion design show that combining these approaches allows a single garment to be worn in multiple configurations, making the product efficient in production and flexible in use (Enes & Saygılı, 2023). In this study, similar principles appear in efforts to create garments that do not end in a single fixed form. Prototype documentation shows that repositioning modules produced variations in silhouette, motif composition, and functional elements.

The fifth theme reveals a pattern of reusing residues generated during the design process. Remnants produced after subtraction pattern cutting were not immediately removed from the workflow but reclassified as potential new components. Some residues were used as

seam details, decorative layers, edge finishes, or fastening elements. These findings indicate the presence of an internal cycle within the design process: remnants from endek production were transformed into garments, and new residues from garment design were reintegrated into the product. Observation notes show that the smaller the fabric piece, the more limited its structural function, yet visual and finishing functions remained possible. This aligns with circular-economy studies in textiles that emphasize the importance of preserving material value through reuse, repurposing, and recovery before materials exit the production cycle entirely (Papamichael et al., 2024). In the documented prototype (Figure 1), small residues appear as compositional accents rather than forced additions. This process generated data on the hierarchy of material use—from main panels, supplementary panels, and joining modules to residual accents.



Figure 1. Contextual Design Prototypes in Fashion Design Using a Traditional Subtraction Approach

(Source: Experimental Design, 2025)

The sixth theme concerns the relationship between endek motifs and visual-composition decisions. Prototype documentation shows that motif direction became an important factor in arranging modular panels. Motifs placed in parallel created a more stable visual field, while rotated or cut motifs produced a more fragmentary appearance. Visual data indicate that some panel joints brought together motifs that were not always symmetrical, yet visual continuity could still be achieved through color compatibility or line rhythm. Coding in the visual category produced three tendencies: motif alignment, motif contrast, and motif fragmentation. Motif alignment was used when fabric pieces still allowed the pattern to be read clearly. Motif contrast appeared when two pieces of different colors or directions were

juxtaposed to create a visual boundary. Motif fragmentation occurred when small remnants were used even though their motifs were no longer fully legible. Studies on traditional textiles and sustainability show that local textile materials often carry cultural identity through motifs, production techniques, and contexts of use, making their visual treatment inseparable from material meaning rather than surface appearance alone (Hendriyana et al., 2024). In this study, the recorded data remain at the level of visual description—how motifs were positioned, joined, and reconfigured within the prototype.

The seventh theme shows that the design process unfolded through iterative and non-linear stages. The initial stage involved collecting and sorting remnants, followed by size and motif classification, exploration of field reduction through subtraction pattern cutting, form testing through draping, module formation, garment-configuration assembly, prototype documentation, and recording of new residues. However, observational data show that several stages returned to earlier steps when form configurations were unstable or when panel joints were not yet suitable. For example, after draping, some pieces were reclassified because motif placement did not support the desired form. After module formation, some joints were re-evaluated to ensure detachability. This iterative character aligns with practice-based design research, which notes that goals, tactics, and design decisions may evolve during the research process as designers learn from materials and design situations (Gaver et al., 2022). In this study, the iterative process was documented through design notes and process photographs, making form changes part of the findings rather than deviations from procedure.

The eighth theme concerns the role of interviews in clarifying the status of remnants and their practical use. Designer informants explained that endek remnants pose challenges in size and field limitations but remain usable when designs are not forced to follow conventional garment patterns. Artisan informants emphasized that remnants often emerge from specific production needs, especially when fabric dimensions no longer match the requirements of primary products. Informants also noted that using remnants requires careful attention because endek motifs are not always easy to combine when pieces originate from different production batches. These statements were categorized into three main codes: size limitations, motif potential, and technical-adjustment needs. Semi-structured interviews in design research help gather practical experience and contextual knowledge that may not be visible in visual artefacts, especially when the design process involves specific actors, materials, and production situations (Moser & Korstjens, 2022). In this study, interview data were not used to evaluate design success but to describe how practitioners understand remnants, technical constraints, and their possible uses.

The ninth theme shows that the modular-garment prototype produced several identifiable form characteristics. The first is layered form, created by stacking multiple fabric pieces on the body. The second is asymmetrical form, resulting from differences in remnant size and decisions to place motifs in non-parallel orientations. The third is adaptive form, emerging from modular elements that can be moved or repositioned. The fourth is fragmentary form, produced by combining several small pieces into a single visual field. In studies on zero-waste pattern making, form manipulation, segmentation, reconstruction, and the use of fastening devices can generate construction variations while maintaining fabric efficiency (Lei & Li, 2021). The findings here show that layered, asymmetrical, adaptive, and fragmentary forms emerged from the relationship between remnant availability and technical decisions during the design process. In the final documentation stage, the prototype was not read as a single fixed form but as a set of possible configurations depending on module placement and wearing method.

The tenth theme concerns the interconnectedness of design data and documentation data. Process photographs show material changes from sorting to prototype completion, while design notes explain the technical reasoning behind selection, reduction, joining, and module arrangement. Initial sketches served as form guidelines, but several final decisions emerged

through direct observation of the fabric on the mannequin. Documentation data show differences between initial concepts and final forms, particularly in motif placement, panel proportions, and joining systems. In descriptive qualitative research, data traceability is essential because readers must be able to see the relationship among data sources, analytical processes, and the presented findings (Villamin et al., 2025). In this study, traceability was achieved through a combination of process photographs, material notes, interview results, and prototype documentation. The collected data were then organized into a matrix containing remnant types, piece functions, applied techniques, resulting forms, and residues generated during the design process.

The eleventh theme shows that sustainability appears in the data as a category of practice rather than an abstract claim. These practical categories include reducing fabric disposal, reusing fabric pieces, integrating residues into garment details, forming reconfigurable modules, and documenting material processes. Observational data indicate that every fabric piece was evaluated before being deemed unusable. The sustainability categories most frequently noted in the design records were material efficiency, form flexibility, and product-function extension. Studies on circular-economy strategies in the textile industry show that reduction, reuse, repair, and recycling are key categories for understanding sustainability practices in textile and fashion products (Ramírez-Escamilla et al., 2024). In this study, the most dominant categories were reduction and reuse because the design process focused primarily on minimizing waste and reusing *endek* remnants. Repair did not emerge as a major category because the prototype remained in the design stage, while recycling was not a focus because the remnants were not broken down into new fibers. These findings indicate the boundaries of the sustainability categories that could be documented within the scope of this research.

The twelfth theme concerns the readability of ecological and cultural values within the primary data. Interview notes show that informants view *endek* textiles as materials with higher value than ordinary fabrics because they are tied to weaving processes, Balinese identity, and artisan labor. Visual documentation shows that decisions to preserve motifs, use small pieces, and assemble modules were made to ensure that the material remained recognizable as *endek*. Observational data also indicate that the design process did not obscure the fabric's character through excessive layering or complete motif coverage. In regenerative-design studies, integrating local ecological knowledge is essential because design is directed toward building relationships among communities, places, and material systems that support everyday life (Toner et al., 2023). In this study, ecological and cultural values were recorded through descriptive categories such as respect for material, motif preservation, the involvement of artisan knowledge, and efforts to return remnants to functional use within garments. These categories constitute the empirical findings that show how the design process generated relationships among remnant materials, design techniques, and the cultural context of Balinese *endek*.

Discussion

The findings confirm that the use of Balinese *endek* weaving remnants in sustainable modular-garment design cannot be understood merely as a technical act of reducing textile waste. At the empirical level, remnants appear as non-uniform materials: their sizes vary, motifs are partially cut, grain directions are not always ideal, and their original functions no longer align with conventional garment-production standards. Yet it is precisely from these non-ideal conditions that the design process begins. Sorting remnants by size, motif, texture, edge condition, and joining potential shows that they still retain structural capacity and functional value. These findings directly relate to the research objective: developing a sustainable modular-fashion design model based on *endek* remnants by integrating less-waste design, Traditional Ecological Knowledge, and regenerative design. Within the circular-fashion framework, material value does not disappear when fabric no longer meets initial production standards, because circular economy principles require materials to remain

in use for as long as possible through reuse, repair, recovery, and reconfiguration (Ramírez-Escamilla et al., 2024). However, the case of *endek* reveals something more specific than general circularity principles: remnants are preserved not only because they retain economic value but also because they carry traces of artisan labor, local motifs, and Balinese textile identity. Thus, the first research question is answered through the finding that remnants can be applied in modular garments when the design process begins with reading the material rather than imposing conventional garment patterns onto fabric that has lost its ideal form.

Traditional Ecological Knowledge helps interpret these findings as a knowledge practice situated between material, culture, and environment. TEK is not merely a label indicating that *endek* is a traditional textile; it functions as an analytical tool for understanding why remnants must be treated as entities that still possess ecological and cultural dignity. When designers classify fabric pieces, preserve readable motifs, and reintegrate small residues into garment details, these actions reflect a material ethic aligned with TEK: resources are not understood as passive substances but as components of socio-ecological relationships that must be maintained. Studies on Indigenous textiles show that traditional textile practices often contain ecological knowledge through community respect for materials, avoidance of waste, and the linking of object production with cosmology and the environment from which they originate (Palomino, 2024). In this study, TEK shifts from a concept typically referring to ecological knowledge rooted in natural landscapes to one referring to material-based ecological knowledge embedded in textiles. *Endek* remnants become a site where artisan knowledge, motifs, production techniques, and resource-use ethics converge within design practice. In this way, TEK not only explains the origins of material value but also helps unpack how that value is regenerated when remnants enter a modular-garment system.

Subtraction pattern cutting and draping demonstrate that less-waste design is not merely a quantitative target for reducing waste but a way of thinking that transforms the relationship among the body, pattern, and material. The findings show that subtraction pattern cutting was used to create space for the body and seams through field reduction, while removed pieces were not immediately discarded but reintegrated into the design as accents, ties, or small modules. In conventional pattern logic, remnants often emerge as a consequence of fitting garment panels onto a fabric field assumed to be intact. In the subtractive logic emerging from this study, remnants are the starting condition, and patterns are built through negotiation with material constraints. Studies on zero-waste pattern cutting show that material efficiency requires integrating form design and panel layout from the outset, because waste often results from the separation between garment imagination and the reality of the fabric field (Ramkalaon & Sayem, 2021). This study extends that argument by showing that with traditional materials already in remnant form, efficiency depends not only on layout but also on the designer's ability to read irregularity as a source of form. Draping then allows the body to become a testing ground for material. Fabric is not simply cut to match body measurements; it is allowed to reveal its drape direction, tension, folds, and volumetric possibilities. Here, the body is not an abstract measurement within a pattern but a material field where remnants are negotiated directly.

Comparison with previous studies shows that this research aligns with zero-waste and modular-fashion literature while also complicating several dominant assumptions. Enes and Saygılı (2023) show that zero-waste fashion design and modular fashion design can be combined to produce garments with multiple appearance possibilities, shifting sustainability from production to use. This study confirms that direction through findings that panels, ties, layers, and accents can be reconfigured within the modular prototype. However, this study also shows that modularity does not function solely as a strategy for user-oriented aesthetic variation. In the case of *endek* remnants, modularity first becomes a method for organizing material irregularity. Pieces too small to form full garments acquire new functions when placed as structural modules, visual modules, or transitional modules. Hwang and Lee (2023)

emphasize modular systems as strategies for enhancing personalization, simplicity, and functional expansion in zero-waste fashion supported by digital technology. The *endek* case reveals a different direction: modularity emerges from manual interpretation of material limitations, fragmented motifs, and relationships among small panels. Thus, this study does not reject technology-based modular models but expands them through remnant-based modularity grounded in local craft knowledge.

Regenerative design provides a sharper framework for distinguishing between merely reducing waste and revitalizing material relationships. The findings show that the design process did not stop at reusing remnants but also sought to preserve the readability of *endek* through its motifs, colors, textures, and joining systems. In regenerative design, the goal is to rebuild reciprocal relationships among communities, places, ecological systems, and local knowledge rather than simply mitigating existing damage (Toner et al., 2023). The findings of this study indicate that regenerative design in *endek*-based fashion operates at a specific scale: not the restoration of ecosystems in a broad sense, but the regeneration of relationships among remnant materials, artisan knowledge, design processes, and circular-economic possibilities. Remnants that previously occupied a marginal position in production processes regain a central role as sites of form exploration. At this point, regenerative design complicates the circular-economy framework. Circular economy tends to emphasize keeping materials valuable within production and consumption systems, whereas regenerative design demands attention to the quality of relationships formed through those material flows. In the case of *endek*, materials that re-enter the product cycle do not automatically become regenerative. Material becomes regenerative when the design process maintains its connection to cultural context and does not erase traces of tradition through overly standardized forms. To clarify these findings within the discussion, see Figure 2.

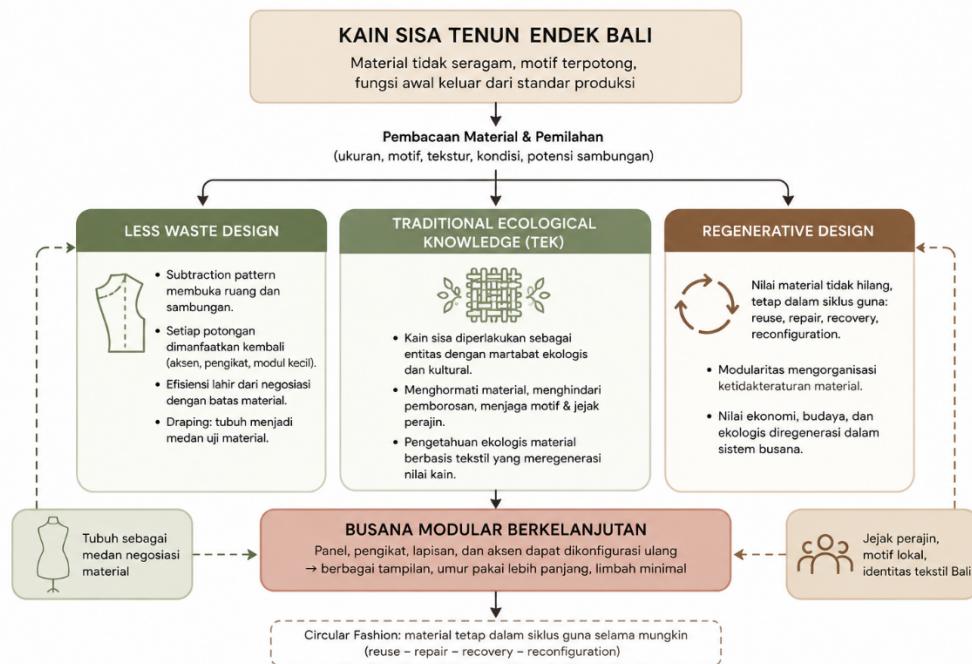


Figure 2. Regenerative Design Model

(Resource: Research Teams, 2025)

Cultural ecology helps explain that the design practices in this study operate within an adaptive relationship between material culture and the ecological conditions of production. *Endek* weaving does not appear merely as a motif applied to modern garments but as the outcome of a system of knowledge, labor, technique, and local values. When *endek* remnants

are used through subtraction pattern cutting and draping, an adaptive process occurs between textile tradition and contemporary sustainability needs. This adaptation is not identical to preserving old forms in a fixed manner. It is closer to directed transformation—when traditional materials enter new design formats without losing their readability as part of Balinese textile culture. Studies on integrating local wisdom into sustainable craft products show that cultural sustainability requires dialogue among traditional techniques, design innovation, and contemporary market relevance (Hendriyana et al., 2024). The data in this study show this dialogue at the material level: fragmented motifs are not always concealed, small pieces are not automatically treated as defects, and seams are not understood solely as technical solutions. Seams become traces of adaptation. Here, cultural ecology functions as an analytical tool for understanding that modular-garment design not only produces new forms but also reorganizes relationships among tradition, resources, and shifting production practices.

Compared with circular fashion literature, which often focuses on value chains, consumer behavior, and business models, this study offers a more micro level emphasis on design decisions. Brydges (2021) argues that circular economy principles in the fashion industry must be applied across the entire supply chain, not only at the waste stage. The findings of this study confirm this by shifting the point of intervention to the earliest design stages, when remnants are selected, classified, subtracted, draped, and modularized. However, this study also shows that the micro scale does not imply minimal contribution. Small decisions about motif direction, residue use, seam placement, and module mobility determine whether material retains value or returns to waste. Abbate et al. (2023) map three major clusters in textile sustainability research: consumer behavior, circular economy initiatives, and supply chain challenges. This study sits between the second and third clusters but adds a dimension often overlooked: the material politics of design processes. Material politics here does not refer to formal institutional conflict but to the way production standards determine what counts as waste, what is considered valuable, and what is given the opportunity to re enter product cycles. *Endek* remnants that do not meet conventional garment production standards gain new value when design standards shift from panel uniformity to modular composition.

The scientific contribution of this article lies in the concept of *substraksi tradisi* (tradition subtraction) as a framework for interpreting the use of traditional textile remnants. Subtraction in this study does not refer to reducing tradition but to design operations that reduce, open, perforate, join, and reconfigure traditional materials so they can enter new formal cycles. This concept expands zero waste fashion discourse by linking waste reduction with cultural value regeneration. In many zero waste studies, the primary focus is on fabric field efficiency and residue reduction. This study shows that in traditional textiles, residues carry additional layers of meaning. *Endek* pieces are not merely material units but visual fragments of a cultural system. Kapsali (2022) emphasizes that sustainable textile design must move beyond substance and energy based approaches toward attention to structure and information. The *endek* case shows that such information is not only biological or technical but also cultural. Motifs, colors, weave directions, and joining methods carry information about material origins and how it has been treated. Thus, *substraksi tradisi* can be read as a conceptual contribution linking less-waste design with local material semiotics.

This study also offers practical contributions for designers, artisans, and creative-industry ecosystems working with traditional textiles. For designers, the findings show that remnants do not need to wait for industrial recycling processes to gain new value. They can enter the design process directly through material classification, subtraction pattern cutting, draping, and modularization. For artisans and *endek* producers, the findings open possibilities for managing remnants as a distinct material category that can be sorted from the production stage rather than accumulated as unplanned residue. Abdelmeguid et al. (2024) emphasize that transitioning toward circular fashion requires collaboration, education,

product strategies, business models, and technological integration across the value chain. In the *endek* context, these recommendations can be translated locally through remnant-documentation systems, grouping pieces by size and motif, and collaboration among weavers, artisans, and designers to create modular products. For policymakers, the findings highlight the need to support design ecosystems that connect traditional-textile preservation with sustainability innovation. Policies that focus solely on promoting *endek* as regional identity are insufficient if they do not address remnant management, production systems, and circularity-based design development.

The limitations of this study must be understood proportionally. Using a qualitative Research Through Design approach, its strengths lie in process depth, traceability of design decisions, and conceptual interpretation of prototypes rather than statistical generalization. The number of prototypes, remnant variations, and informants determines the depth of findings but is insufficient for concluding economic effectiveness, market acceptance, or environmental impact quantitatively. Studies on human perception of recycled textiles and circular fashion show that user acceptance is strongly influenced by perceived quality, function, socio-cultural value, and communication of product benefits (Wagner & Heinzl, 2020). This study has not yet examined in depth how end users evaluate comfort, aesthetic value, wearability, or willingness to purchase modular garments made from *endek* remnants. Another limitation is the absence of measurable waste-reduction calculations, such as material-use percentages, remaining residues, or efficiency comparisons with conventional patterns. Thus, the study's claims are stronger in conceptual modeling and design process description than in numerical environmental impact assessment.

Future research can extend these findings in three directions. First, experimental studies can measure material-efficiency levels of subtraction pattern cutting and draping using *endek* remnants, including fabric-use percentages, final residues, and comparisons with conventional patterns. Second, user-centered research can examine acceptance of modular garments made from remnants in terms of comfort, configurability, visual appeal, and perceived cultural value. Third, policy and business-model research can explore how *endek* remnants can be managed as resources within Bali's creative-economy value chain. Coscieme et al. (2022) show that circular business models in fashion and textiles require technical innovation, social innovation, education, behavioral change, and policy support. In this context, developing modular designs based on *endek* remnants can move toward a broader system: *endek* remnant banks, digital catalogs of fabric pieces, collaborations between design studios and weaving centers, less-waste pattern-cutting training for young artisans, and material-documentation standards that keep remnants traceable. These recommendations must be tested through further research to ensure they do not remain normative ideas but evolve into applicable models of design, production, and distribution within tradition-based creative industries.

CONCLUSION

The article's primary contribution lies in positioning *endek* remnants as cultural materials that carry ecological knowledge rather than as mere textile waste. The concept of *substraksi tradisi* (tradition subtraction) shows that reducing, perforating, joining, and modularizing fabric can serve as strategies for regenerating traditional value within contemporary garment forms. In this way, less-waste design, Traditional Ecological Knowledge, circular economy, and regenerative design do not stand as separate concepts but operate together within a creative process that links material efficiency, the preservation of local textile value, and the extension of product lifespan.

Future research should examine the effectiveness of this model through quantitative measurements of material-use percentages, final residue amounts, the durability of modular constructions, and user responses regarding comfort and aesthetic value. Design practice can

also be expanded through collaboration among designers, weavers, artisans, fashion studios, and cultural-policy institutions so that *endek* remnants do not remain as production residue but are managed as creative resources within a tradition-based sustainable-fashion ecosystem.

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