Industrial and Domestic Waste Management

Research Article
Volume 6(2), 2026, 340−354
https://doi.org/10.53623/idwm.v6i2.1313

Textile Waste Reduction through Zero-Waste Cutting Subtraction Techniques: A Fit-to-Body Couture Approach for Sustainable Micro, Small, and Medium Enterprises in Indonesia

Rizka Sarah Heydarina Fathima Ahsan*, Agus Sunandar, Ajeng Atma Kusuma, Nuha Nadhifa, Galih Janggan Titian

Applied Bachelor of Fashion Design, Faculty of Vocational, State University of Malang, Malang, East Java, Indonesia

*Correspondence: rizka.ahsan.fv@um.ac.id

SUBMITTED: 25 July 2026; REVISED: 8 August 2026; ACCEPTED: 12 August 2026

ABSTRACT: The production of custom-made couture by Indonesian fashion Micro, Small, and Medium Enterprises (MSMEs) generated significant textile waste because fit-to-body construction required patterns that precisely followed the contours of the body, while conventional cutting techniques did not efficiently accommodate this requirement. Existing zero-waste and subtraction cutting techniques had primarily been applied to loose-fitting and ready-to-wear silhouettes, with limited application to fit-to-body couture. This study developed and validated a modified subtraction cutting technique designed to produce fit-to-body couture dresses while maintaining fabric waste below 5%. An exploratory experimental method was employed using a Research through Design (RtD) approach and iterative prototyping. The research process included baseline waste assessment, pattern engineering, controlled comparative testing against conventional patterns using identical amounts of fabric, and aesthetic and fit validation by an expert panel. The results showed that the selected subtraction cutting prototype successfully reduced fabric waste from 7.64% for the conventional baseline to 4.65%, representing a relative reduction of 39.14%. The prototype also achieved a “Good” rating (74.4%) in expert validation based on aesthetic and fit-to-body criteria. The final garments were subsequently produced using patchwork materials obtained from partner MSMEs, demonstrating the practical potential for utilizing textile waste. Expert feedback identified improvement of the drapery as the primary priority for final design refinement. Overall, this study demonstrated an applicable pattern-engineering approach and provided empirical evidence that fit-to-body couture could be aligned with textile waste reduction objectives in sustainable fashion production.

KEYWORDS: Subtraction cutting; zero-waste fashion; fit-to-body sewing; reduction of textile waste; sustainable fashion MSMEs

1. Introduction

Textile waste generated during the pattern-cutting process has remained a significant environmental challenge associated with the fashion industry. Fabric offcuts generated during garment production contribute to waste accumulation in landfills while also representing inefficient utilization of raw materials and the resources embedded in textile production [1, 2]. This issue is particularly relevant to micro, small, and medium enterprises (MSMEs) engaged in custom-made couture, where garments are constructed according to individual body measurements and frequently incorporate complex aesthetic features, such as layered structures and draping. The production process may also involve repeated fitting and pattern adjustments to achieve the required silhouette. Conventional cutting methods commonly employed by fashion MSMEs can consequently generate substantial fabric offcuts because patterns are primarily developed to satisfy garment fit, aesthetic, and construction requirements rather than to optimize material utilization [2].

Zero-waste pattern cutting and subtraction cutting have emerged as alternative design strategies for minimizing pre-consumer textile waste by integrating material efficiency into the garment design and pattern-development processes [3]. Studies comparing zero-waste fashion design with cutting and packing approaches have demonstrated that cutting-layout configuration is not merely a production consideration but an important determinant of overall material efficiency [4]. However, previous applications of zero-waste and subtraction cutting have predominantly focused on loose-fitting, oversized, or ready-to-wear garments [5, 6]. Such silhouettes are structurally less constrained by precise body contours and can more readily accommodate pattern configurations based on the full width of the available fabric [7]. Studies of dress production have similarly demonstrated that fabric utilization efficiency is strongly influenced by garment design characteristics and material properties; however, fit-to-body construction has received comparatively limited attention [8]. Where subtraction cutting has been explored in contexts related to couture, previous studies have generally emphasized artistic and formal experimentation [9] rather than systematically integrating material efficiency with the precision required for fit-to-body construction [10–12].

This research gap is particularly relevant to fit-to-body couture, which represents an important product category among Indonesian fashion MSMEs. Custom-made couture products commonly include dresses, gowns, and bustiers that require accurate pattern construction to achieve close conformity with the wearer's body contours [13, 14]. Despite these requirements, previous zero-waste approaches have been more extensively developed and evaluated for ready-to-wear garments [15]. Consequently, limited empirical evidence has been available regarding whether zero-waste principles can be successfully incorporated into fit-to-body couture without compromising garment aesthetics, construction quality, and fitting performance. Addressing this gap is important for extending textile waste-reduction strategies to fashion production contexts that have received comparatively little attention in previous zero-waste design research.

Accordingly, this study investigated how a modified subtraction cutting technique could be developed to achieve zero-waste-oriented material efficiency in fit-to-body couture dresses while maintaining the aesthetic and fitting standards required in custom-made fashion MSMEs. The novelty of the study lies in integrating zero-waste principles with fit-to-body couture construction, two areas that have rarely been systematically examined together. Rather than treating subtraction cutting solely as a method of artistic form exploration, this study applied subtraction elements as functional and structural components intended to shape body contours while simultaneously improving cutting-layout efficiency. The resulting pattern-development approach was evaluated using quantitative measures of material efficiency and qualitative assessments by fashion experts, thereby providing both technical and aesthetic evidence of its performance.

This approach also differed from computationally driven developments in zero-waste pattern cutting that have emerged in recent years. Systems such as SNU-ZWP have been developed to transform conventional patterns into zero-waste layouts through automated rectangular adjustments [16], while parametric approaches have facilitated automated pattern generation [17]. Computer-aided design tools, including Waste Banned, have also enabled designers to make interconnected modifications to zero-waste patterns during the design process [18]. Although these developments have advanced the technical implementation of zero-waste fashion design, their application to garments requiring precise fit-to-body construction has remained limited. Comparative research on zero-waste design thinking and cutting-and-packing optimization has further indicated that existing cutting-layout approaches have not been extensively evaluated for highly fitted garment structures requiring couture-level precision [4]. Therefore, this study positioned its contribution at the intersection of material efficiency, subtraction cutting, and fit-to-body couture construction. Through a manual Research through Design approach, the study complemented rather than replaced emerging computational methods by demonstrating how subtraction cutting could function as a structural pattern-engineering strategy for simultaneously achieving body-contour conformity and improved fabric utilization.

2. Materials and Methods

2.1. Research Approach.

This study employed an exploratory experimental method based on the Research through Design (RtD) approach [19], supported by iterative prototyping [20–22]. This methodological framework was selected because the study aimed not only to examine textile waste generated during garment production but also to develop, test, and refine an alternative pattern-cutting strategy for fit-to-body couture. The RtD approach enabled design development to function as an integral part of the research process, in which knowledge was generated through systematic experimentation, evaluation, and refinement of the proposed subtraction cutting technique. Iterative prototyping was subsequently used to evaluate successive pattern configurations and identify a design capable of balancing material efficiency with the aesthetic and fitting requirements of couture garments.

The overall methodological framework is presented in Figure 1. The research process was organized sequentially to establish a clear connection between the identification of the textile waste problem, development of the proposed pattern-cutting solution, experimental evaluation, and final validation. Each stage generated information that informed the subsequent stage, while the prototyping process incorporated iterative feedback to refine the pattern configuration and garment construction. This structured workflow enabled both quantitative assessment of fabric utilization and qualitative evaluation of the resulting garment.

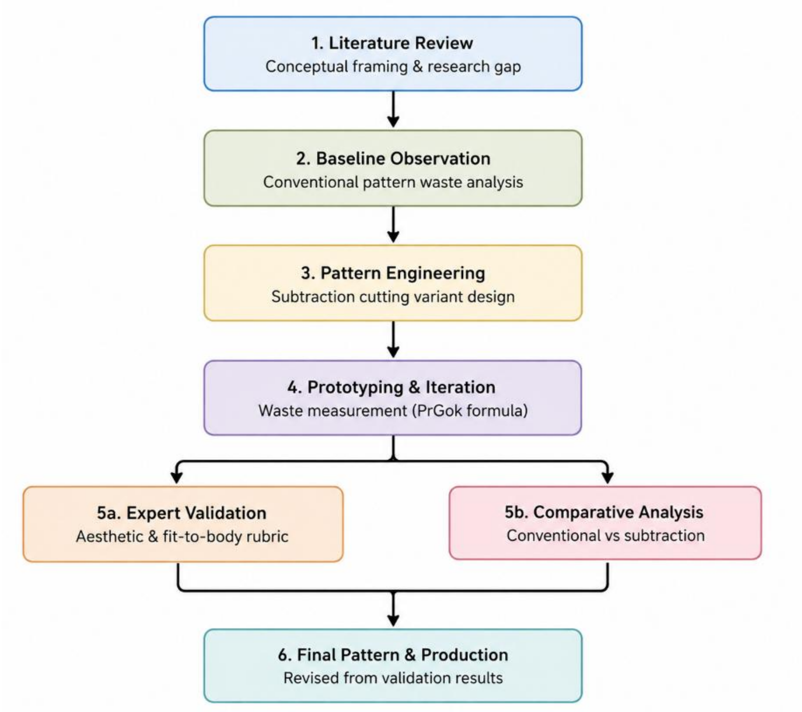

Figure 1. Research Flowchart.

As illustrated in Figure 1, the research consisted of five principal stages: (1) literature review and development of the conceptual framework; (2) baseline observation of conventional production practices among partner MSMEs and assessment of the resulting fabric waste; (3) pattern engineering and development of the subtraction cutting variants; (4) prototype experimentation, iterative refinement, and quantitative measurement of fabric waste; and (5) expert validation of garment aesthetics and fit, followed by comparative evaluation against the conventional pattern-cutting approach. The research object was a fit-to-body couture dress developed and produced in collaboration with partner fashion MSMEs. Data were collected through direct observation of conventional cutting practices, measurement and weighing of fabric offcuts, documentation of pattern-development and prototype iterations, and visual documentation throughout the prototyping and final production stages. These procedures enabled the conventional and proposed cutting approaches to be evaluated under comparable conditions, particularly with respect to material utilization, pattern configuration, garment construction, and fit-to-body performance.

Figure 2 provides a visual comparison between the conventional pattern layout and the proposed subtraction cutting layout used during the experimental stage. The conventional layout (Figure 2a) represents the baseline cutting configuration typically used for fit-to-body garment construction, in which individual pattern pieces are positioned primarily according to garment construction and fitting requirements. In contrast, the subtraction cutting layout (Figure 2b) demonstrates the alternative pattern-engineering strategy developed in this study, in which pattern configuration and fabric utilization were considered simultaneously to minimize unused material. This comparison provides the methodological basis for evaluating how changes in pattern arrangement and cutting strategy affected the quantity of fabric waste while retaining the structural requirements of the fit-to-body couture design.

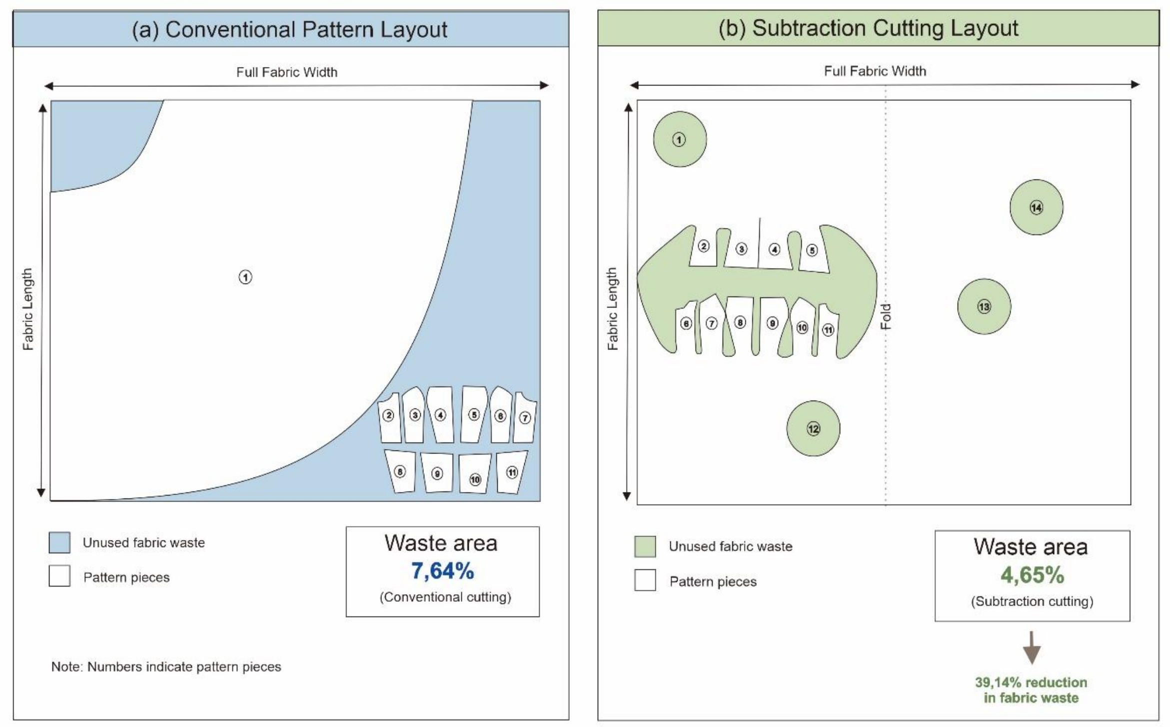

Figure 2. (a) Conventional Pattern Layout; (b) Substruction Cutting Layout.

2.2. Material Efficiency Measurement .

Material efficiency was evaluated by quantifying the amount of fabric waste generated during the cutting process. All fabric offcuts remaining after cutting were collected and measured, and the percentage of fabric waste was calculated using the PrGok formula [23]:

$$PrGok = (VKok / (KBrS + KOd + KOnp)) \times 100\%$$

where PrGok represents the percentage of fabric waste, VKok represents the total weight of fabric waste, and KBrS, KOd, and KOnp represent the weight components of the material used during the cutting process. The same measurement procedure was applied consistently to all experimental conditions to ensure comparability among the prototypes and the conventional cutting method. In this study, a fabric waste percentage below 5% was established as the target criterion for material efficiency.

2.3. Controlled Comparative Test Procedure.

A controlled comparative test was conducted to evaluate the effect of the cutting technique on fabric waste generation while minimizing the influence of differences in material quantity. The conventional pattern layout and the selected subtraction cutting prototype were therefore tested using identical quantities and dimensions of fabric. For each cutting method, two fabric sheets measuring 3.0 × 1.5 m each were used, providing an equivalent total fabric area under both experimental conditions.

Maintaining identical material quantities allowed the two cutting approaches to be compared under standardized conditions. Consequently, differences in the percentage of fabric waste could be primarily associated with differences in pattern configuration and cutting technique rather than differences in the initial amount of material. Fabric waste generated under both conditions was collected and quantified using the same PrGok formula described in Section 2.2. This procedure provided a consistent basis for comparing the material efficiency of the conventional and subtraction cutting approaches.

2.4. Expert Validation Instruments.

The aesthetic quality and fit-to-body performance of the two best-performing designs, Prototype 2 and Prototype 3, both of which achieved fabric waste levels below 5%, were evaluated by three couture experts. A structured assessment rubric consisting of 13 indicators was used, with each indicator evaluated on a four-point scale: 1 = Poor, 2 = Adequate, 3 = Good, and 4 = Excellent. The assessment comprised two principal dimensions. Seven indicators evaluated aesthetic quality, including garment proportion, fabric drape, visual balance, and overall couture appearance. The remaining six indicators evaluated fit-to-body accuracy, including the positioning of the bust point, waistline, hip line, centre-front and centre-back lines, side balance, and the neatness and functionality of the garment opening or zipper. These criteria were selected to assess whether improvements in material efficiency could be achieved without compromising the visual and structural requirements of fit-to-body couture. The prototypes were evaluated on mannequins and/or models under both static and dynamic conditions. Dynamic assessment included basic movements such as walking, sitting, and turning to examine whether the garments maintained appropriate fit, balance, and appearance during movement. The total expert assessment scores were subsequently converted into percentages and interpreted according to four performance categories: 81–100% = Excellent, 61–80% = Good, 41–60% = Adequate, and ≤40% = Poor. This validation procedure enabled the technical performance of the subtraction cutting prototypes to be evaluated alongside their aesthetic and fit-to-body qualities.

3. Results and Discussion

3.1. Comparative Analysis: Conventional Patterns and Substraction Cutting.

To determine whether the proposed subtraction cutting technique improved material efficiency, a controlled comparison was conducted against the conventional pattern-cutting method. Both approaches were tested using nearly identical quantities of fabric, thereby minimizing material quantity as a potential source of variation. Material efficiency was evaluated based on total material weight, residual waste weight, percentage of waste, relative waste reduction, and achievement of the predefined ≤5% waste target. As summarized in Table 1, the subtraction cutting approach demonstrated substantially lower residual waste than the conventional baseline, indicating that pattern configuration played an important role in determining fabric utilization efficiency. As shown in Table 1, the difference in total material weight between the two experimental conditions was only 0.03 g, representing a negligible variation in the initial amount of material. This close equivalence strengthened the comparability of the two cutting conditions and reduced the likelihood that differences in waste generation resulted from differences in material quantity. The conventional pattern generated 23.00 g of residual fabric waste, corresponding to 7.64% of the total material weight. In comparison, Prototype 2 generated only 14.00 g of residual waste, equivalent to 4.65%. Thus, subtraction cutting reduced the absolute waste percentage by 2.99 percentage points and produced a 39.14% relative reduction in fabric waste compared with the conventional baseline. Importantly, Prototype 2 achieved the predefined waste target of ≤5%, whereas the conventional pattern remained above this threshold.

Table 1. Comparison of material efficiency between conventional patterns (baseline) and subtraction cutting (Prototipe 2).

Parameter	Conventional Pattern (Baseline)	Subtraction Cutting (Prototipe 2)	Differences
Total Material Weight (gr)	301,05	301,08	0,03
Residual Waste Weight (gr)	23,00	14,00	9,00
Percentage of Waste (%)	7,64	4,65	2.99 points
Relative Waste Reduction (%)	–	–	39,14
Target Achievement Status (≤5%)	Waste > 5%	Waste ≤ 5% (efficient)	–

These findings are consistent with the principles of zero-waste pattern cutting, which emphasize the importance of cutting-layout configuration and pattern design in determining material efficiency [3, 2, 4]. Previous studies have demonstrated that strategic arrangement of garment components can reduce unused fabric and improve material utilization during production. Studies examining material efficiency in garment production have similarly reported that adjustments to garment design and material characteristics can contribute to measurable reductions in cutting and sewing waste [8]. The present study extends these findings by demonstrating that substantial waste reduction may also be achievable in fit-to-body couture, where precise body contouring, garment structure, and aesthetic requirements impose additional constraints on pattern development. Importantly, the results presented in Table 1 should be interpreted as evidence from a single controlled comparison (n = 1 per cutting technique) rather than as mean values derived from repeated experimental trials. Consequently, the observed 39.14% reduction represents the performance obtained under the specific experimental conditions and should not yet be generalized across different fabrics, garment designs, or production settings. Future studies should therefore include multiple experimental replicates, different textile materials, and a wider range of couture styles to assess the reproducibility and variability of the observed improvement in material efficiency.

3.2. Pattern and Prototype Engineering.

Baseline observations of the conventional cutting practices employed by the partner MSMEs indicated that the production of fit-to-body couture dresses generated a considerable amount of fabric waste. This finding highlighted the need to develop an alternative pattern-cutting approach capable of improving material efficiency while maintaining the structural, fitting, and aesthetic requirements of couture garments. Accordingly, subtraction cutting was explored as a pattern-engineering strategy in which the available fabric was incorporated more efficiently into the garment construction rather than generating substantial offcuts during the cutting process. The developed design consisted of a fit-to-body couture dress incorporating structural subtraction openings (subtraction holes) as a key pattern-engineering feature. Unlike conventional decorative cut-outs, these openings performed a structural function by creating spaces through which the fabric could be manipulated, connected, and shaped around the body. Their placement therefore contributed directly to the formation of the garment silhouette and its conformity to the body contours. Three pattern variants were developed by systematically modifying the position, size, and orientation of the subtraction openings, as well as the strategies used to manipulate the fabric around these openings. These variations were intended to identify a configuration that could simultaneously achieve an appropriate fit-to-body silhouette and minimize residual fabric waste.

Prototype development was conducted iteratively using a scaled mannequin. Initial trials were performed using *blacu* fabric as a mock-up material to evaluate the basic pattern configuration, structural openings, and silhouette formation. Subsequent iterations employed materials with characteristics closer to those intended for the final garment, allowing a more representative assessment of fabric drape, fit, and aesthetic appearance. For each prototype, two fabric sheets measuring 3.0 × 1.5 m were joined along the required edges and manipulated through the subtraction cutting process. The pattern arrangement was designed to maximize utilization of the available fabric area and minimize material discarded as offcuts, consistent with the zero-waste design principle. Following each iteration, the remaining fabric waste was collected and quantified using the material-efficiency measurement described in Section 2.2. This evaluation provided a quantitative basis for selecting the most efficient pattern variants for subsequent garment development and expert assessment. As presented in Table 2, clear differences in waste generation were observed among the three subtraction cutting prototypes.

Table 2. Fabric waste measurements for the three subtraction cutting prototypes.

Pattern Type	Waste Residue (g)	Percentage of Waste (%)	Remarks
Prototype 1	23	7.64	Exceeded the 5% target
Prototype 2	14	4.65	Achieved the <5% target
Prototype 3	15	4.98	Achieved the <5% target

As shown in Table 2, Prototype 1 generated 23 g of residual fabric waste, corresponding to 7.64%, and therefore did not satisfy the predefined 5% waste target. In contrast, Prototype 2 reduced the residual waste to 14 g (4.65%), representing the best material-efficiency performance among the three configurations. Prototype 3 generated slightly more waste at 15 g (4.98%) but nevertheless remained below the established threshold. The reduction from Prototype 1 to Prototypes 2 and 3 indicates that refinement of the position, dimensions, and orientation of the subtraction openings contributed to more efficient utilization of the available fabric. Based on these quantitative results, Prototypes 2 and 3 were selected for the subsequent stage of development and expert validation because both achieved fabric waste below the predefined 5% target. Prototype 2 demonstrated the highest material efficiency, whereas Prototype 3 was retained to determine whether its slightly higher waste level was accompanied by advantages in garment aesthetics or fit-to-body performance. This selection process ensured that the final evaluation considered not only waste minimization but also the functional and aesthetic requirements essential to couture garment production.

3.3. Prototype Production and Expert Validation.

Following the material-efficiency assessment, the selected subtraction cutting patterns were advanced to the production and validation stages. To demonstrate the practical application of the proposed approach within a circular fashion context, the garments were produced using textile remnants obtained from the production activities of the partner MSMEs. These materials consisted primarily of leftover lace and chiffon that would otherwise have remained as production waste. Rather than using new fabric, the collected remnants were assembled into patchwork sheets measuring approximately 3.0 × 1.5 m, corresponding to the dimensions used during the prototyping stage. The assembled patchwork sheets were subsequently processed using the same pattern layout and subtraction cutting procedures established during prototype development.

The use of patchwork materials provided an additional dimension of waste utilization beyond the reduction of cutting waste itself. While the subtraction cutting technique was intended to minimize new waste generated during pattern cutting, incorporating existing textile remnants into the final garment demonstrated the potential for recovering and reintroducing production waste into the MSME production cycle. Thus, the final production stage combined two complementary strategies: reducing waste through more efficient pattern cutting and utilizing existing textile remnants as garment materials. This approach also provided a more realistic basis for evaluating whether the developed patterns could retain the aesthetic and structural characteristics required for fit-to-body couture when applied to actual production materials. Following production, Prototypes 2 and 3 were subjected to expert validation to determine whether the improvements in material efficiency were achieved without compromising garment aesthetics and fit-to-body performance.. The overall validation results are summarized in Figure 3.

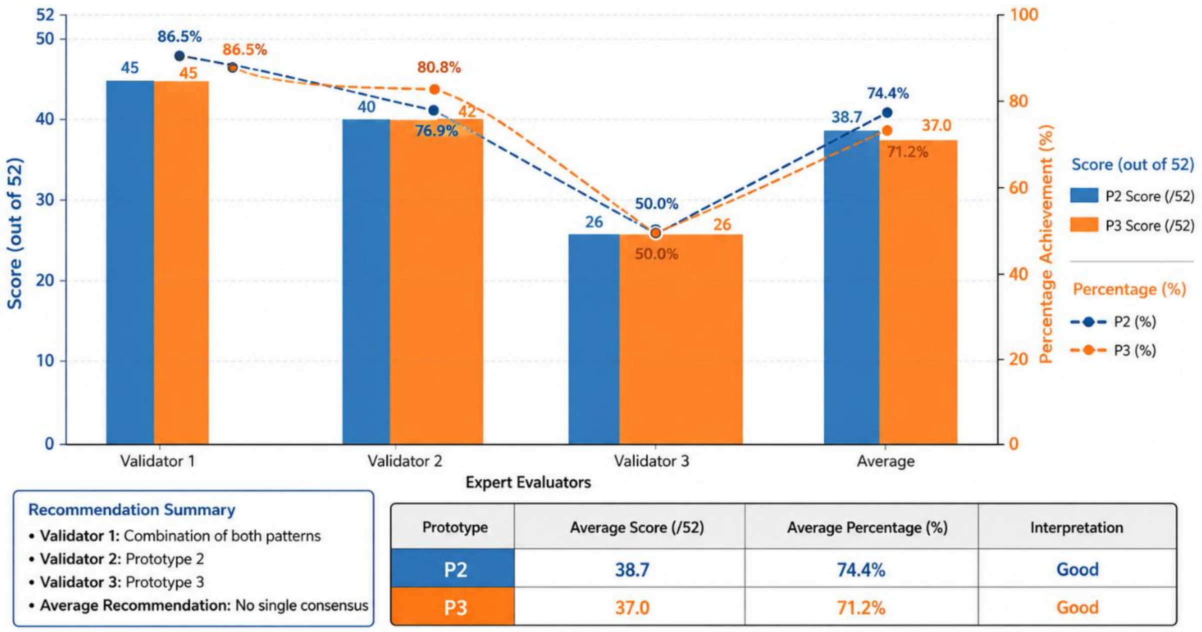

Figure 3. Expert Analyst Score Recapitulation Chart for Prototype 2 and Prototype 3.

The overall expert assessment showed that Prototype 2 achieved an average score of 74.4%, while Prototype 3 achieved 71.2%. Both values were classified within the “Good” category, indicating that the two prototypes generally satisfied the expected aesthetic and fit-to-body requirements of couture garments. Nevertheless, neither prototype reached the “Excellent” category, suggesting that further refinement was required before the design could be considered fully optimized. To identify the specific strengths and weaknesses of each prototype, the mean scores for the 13 assessment indicators are presented in Table 3. Prototype 2 performed particularly well in the fit-to-body dimension, achieving 84.7% compared with 76.4% for Prototype 3. Its strongest attributes were the accuracy of bust circumference and bust-point placement, waistline placement, and centre-front and centre-back alignment, with each receiving an average score of 3.67. These results indicate that the subtraction configuration used in Prototype 2 provided relatively effective control over key anatomical reference points required for fitted couture construction.

Table 3. Average expert score for each Prototype 2 and Prototype 3 scoring indicators

No.	Indicator	P2 Average	P3 Average
1	Balance of body proportions and clothing	2,67	3,00
2	Proportion of the bustier-skirt and the position of the subtraction	2,67	2,33
3	The fabric fall flexibility follows the contours of the body	2,33	3,00
4	Stability of falling fabric as the body moves	2,67	2,33
5	Finesse finishes and construction details	2,00	2,33
6	Exclusive/high selling value impression (couture value)	3,00	2,33
7	Originality of the aesthetic value of subtraction elements	3,00	3,33
8	Accuracy of chest circumference and bust point placement	3,67	2,67
9	Waist line accuracy	3,67	3,67
10	Hip line accuracy	3,00	3,33
11	Center front/back accuracy	3,67	2,67
12	Left-right side balance	3,00	3,00
13	Tightness and neatness of the opening/zipper	3,33	3,00

In terms of aesthetic performance, the difference between the prototypes was relatively small, with scores of 65.5% for Prototype 2 and 66.7% for Prototype 3. Prototype 3 performed slightly better in the originality and aesthetic value of the subtraction elements, receiving an average score of 3.33 compared with 3.00 for Prototype 2. It also achieved higher scores for the flexibility of fabric drape and accuracy of the hip line. These differences demonstrate a potential trade-off between technical fit and aesthetic expression: Prototype 2 provided stronger fit-to-body performance, whereas Prototype 3 showed certain advantages in drape and the visual expression of the subtraction elements.

Despite these strengths, finishing quality emerged as a common weakness. The quality of finishing and construction details received the lowest average score for both prototypes, with values of 2.00 for Prototype 2 and 2.33 for Prototype 3. This result indicates that improving material efficiency alone was insufficient to ensure couture-level quality. Particular attention remained necessary for seam finishing, construction precision, and the management of fabric drape, especially where multiple patchwork components and subtraction openings interacted within the garment structure.

The quantitative assessment was supported by qualitative feedback from the three experts. Although their comments differed in detail, all identified aspects of drapery construction and garment shaping that required further refinement. Validator 2 recommended smoothing the front-skirt drapery to achieve a more natural fall, while Validator 3 observed that the drapery of the main material required greater lift and three-dimensional volume. Validator 1 additionally noted that the upper chest area of Prototype 2 appeared overly angular. The convergence of these observations indicated that drapery control, structural shaping, and finishing represented the principal priorities for subsequent design refinement.

No unanimous preference for a final prototype emerged from the expert panel. Validator 1 recommended combining and refining features from both prototypes, Validator 2 preferred Prototype 2, and Validator 3 preferred Prototype 3. This variation suggests that the final design should not necessarily be selected solely according to the highest overall numerical score. Instead, the strengths of both prototypes could inform further refinement, particularly by combining the stronger fit-to-body performance of Prototype 2 with the aesthetic and draping characteristics observed in Prototype 3.

The expert-validation findings should nevertheless be interpreted cautiously because the assessment involved only three experts (n = 3). Considerable inter-expert variation was also observed, particularly because Validator 3 assigned an overall score of 50.0% to both prototypes, substantially lower than the scores provided by Validator 1 (86.5–92.3%) and Validator 2 (76.9–80.8%). Therefore, the validation results should be regarded as preliminary evidence of aesthetic and functional performance rather than definitive confirmation of broader professional acceptance. Future studies should involve a larger and more diverse expert panel and, where possible, incorporate wearer-based assessments to evaluate comfort, mobility, fit stability, and aesthetic acceptance under actual use conditions.

3.5. Discussion.

Overall, the findings demonstrated that the developed subtraction cutting technique substantially improved material efficiency while maintaining acceptable aesthetic and fit-to-body performance. In the controlled comparison, the technique achieved a 39.14% relative reduction in fabric waste, while expert evaluation classified the aesthetic and fit-to-body performance within the “Good” category. These results indicate that improved material efficiency can be achieved in fit-to-body couture without substantially compromising the structural and aesthetic requirements of the garment.

Compared with the zero-waste approach based on the SNU-ZWP algorithm, which reported significant improvements in fabric utilization efficiency for non-fit-to-body garments [16], the 39.14% relative waste reduction achieved in the present study demonstrates that substantial improvements can also be obtained through a manual, prototyping-based approach applied to more structurally complex couture garments. This comparison suggests that material efficiency is not necessarily dependent on the level of automation employed during pattern development. Rather, the configuration and optimization of the cutting layout remain important determinants of fabric utilization efficiency [4]. This finding is particularly relevant to small-scale fashion enterprises that may have limited access to advanced computational design technologies.

The observed relationship between garment design and fabric utilization is consistent with the findings of Enes and Kipoz [8], whose case study of a summer-dress production line demonstrated that adjustments to garment design and material characteristics could measurably reduce waste generated during cutting and sewing. However, whereas their study focused primarily on ready-to-wear production, the present study extended this principle to fit-to-body couture, where precise conformity to body contours imposes greater constraints on pattern configuration and garment construction. The findings also complement the work of Lee [24], who investigated three-dimensional virtual textile applications as an alternative strategy for improving material utilization and supporting zero-waste fashion development. Together, these studies demonstrate that textile waste reduction can be approached through multiple design pathways, ranging from computational and virtual methods to manual pattern-engineering strategies.

Expert validation further demonstrated that the proposed technique was capable of maintaining acceptable garment quality despite the substantial improvement in material efficiency. Both prototypes were classified within the “Good” category for aesthetic and fit-to-body performance, although neither reached the highest assessment category. This result positions subtraction cutting as a promising approach for integrating zero-waste principles into fit-to-body couture, an area that has received comparatively limited attention in previous zero-waste fashion research. Earlier studies have predominantly addressed loose-fitting and ready-to-wear silhouettes [7, 24, 4] or emphasized the artistic exploration of couture forms without specifically addressing the precision required for body-contoured construction [25]. The present findings therefore extend the application of subtraction cutting from primarily aesthetic experimentation toward a pattern-engineering strategy that simultaneously considers material efficiency, garment structure, and body fit.

From a sustainability perspective, the findings have practical implications for fashion MSMEs. Reducing fabric waste during couture production can decrease the quantity of textile residues requiring disposal while improving the utilization of purchased materials. Furthermore, the incorporation of existing lace and chiffon remnants into patchwork materials for final garment production demonstrated an additional pathway for utilizing pre-consumer textile waste. The combination of waste prevention through efficient cutting and waste utilization through patchwork production provides a more integrated approach to material management and supports broader circular-economy principles within small-scale fashion production. Nevertheless, the convergence of expert feedback regarding drapery and finishing quality indicates that material efficiency and aesthetic performance do not automatically improve simultaneously. Achieving low-waste fit-to-body construction may introduce challenges in controlling three-dimensional drape, seam quality, and garment finishing, which should therefore remain priorities during subsequent design refinement.

The findings also provide several practical implications for the implementation of subtraction cutting by fashion MSMEs. First, from the perspective of production efficiency and material cost, the 39.14% relative reduction in fabric waste observed in the controlled test indicates the potential to improve raw-material utilization per garment. This is relevant to the findings of Piller [26], who reported that Australian fashion MSMEs adopting circular design pathways could achieve both cost-related advantages and opportunities for market differentiation. However, because the present study did not directly measure production costs, the economic benefit should be regarded as a potential implication rather than a demonstrated cost saving.

Second, the proposed technique offers potential advantages in terms of accessibility and scalability. Unlike computational approaches such as SNU-ZWP and Waste Banned, the subtraction cutting method developed in this study did not require specialized software, automated algorithms, or advanced digital infrastructure. It may therefore be more accessible to MSMEs with limited technological resources, particularly those whose production systems continue to depend heavily on manual pattern making and craftsmanship. This observation is consistent with Nagano [27], who emphasized the importance of craftsmanship and small-scale production capabilities within fashion MSMEs in Japan. Nevertheless, broader scalability should be evaluated through implementation across different garment types, materials, production volumes, and levels of worker expertise.

Third, the use of patchwork materials during the production stage provided a practical demonstration of reduction and reuse strategies within a circular economy framework. Previous studies have identified these strategies as important components of the transition toward more circular textile production among MSMEs [28, 29]. These studies have also highlighted limitations in infrastructure, technological capacity, and technical knowledge as important barriers to circular-economy adoption by smaller enterprises [28, 29]. Because the subtraction cutting approach developed in this study is primarily based on pattern-engineering and manual prototyping, it could provide a relatively accessible technical strategy for custom-made couture MSMEs seeking to reduce material waste without requiring substantial investment in advanced technology. However, further research involving a larger number of MSMEs, garment designs, materials, and repeated production trials is necessary before its economic feasibility and scalability can be established.

4. Conclusions

This study demonstrated that a modified subtraction cutting technique could be developed to produce fit-to-body couture dresses while achieving the predefined zero-waste efficiency target. The controlled comparative test showed that the proposed technique achieved a 39.14% relative reduction in fabric waste compared with the conventional pattern-cutting method under nearly identical material conditions. The subtraction cutting approach also enabled the formation of body contours while maintaining cutting-layout efficiency. Expert validation classified the developed prototypes within the "Good" category for both aesthetic quality and fit-to-body performance, with Prototype 2 demonstrating particularly strong performance in fit-to-body precision. Furthermore, the production of garments using patchwork materials derived from textile remnants generated by partner MSMEs demonstrated the practical potential of integrating the proposed technique with waste reuse strategies in sustainable couture production. Several limitations should be considered when interpreting these findings. First, only three pattern variants were developed and evaluated; therefore, the applicability of the technique to a broader range of garment designs remains to be established. Second, the controlled comparison between the conventional pattern and subtraction cutting was conducted only once ($n = 1$ per technique) using a single material condition and garment style. Consequently, the observed waste reduction should be interpreted as preliminary evidence rather than a generalized performance value. Third, the aesthetic and fit-to-body validation involved a limited expert panel ($n = 3$), with considerable variation among individual expert assessments. Future research should therefore include repeated experimental trials, a wider range of textile materials and couture designs, larger and more diverse expert panels, and wearer-based evaluations. Further investigation of production costs, scalability, and practical implementation within different fashion MSMEs would also strengthen the evidence for the broader application of subtraction cutting as a sustainable pattern-engineering strategy.

Acknowledgments

The author would like to thank the State University of Malang, LPPM for funding this research on the internal fund scheme of the State University of Malang NON APBD 2026 and MSME partners who have collaborated in this research.

Author Contribution

Rizka Sarah H.F. Ahsan: Conceptualization, Methodology, Supervision, Analysis, and Writing. Agus Sunandar: Conceptualization and Supervision. Ajeng Atma Kusuma: Conceptualization, Data Collection, Data Analysis, and Writing. Nuha Nadhifa dan Galih Janggan Titian: Methodology and Data Collection.

Competing Interest

The authors declare that they have no competing interests

References

[1] Liauw, F. (2023). Limbah perca sebagai penggerak inspirasi industri fashion masa depan. *Jurnal Sains, Teknologi, Urban, Perancangan, Arsitektur, 5,* 1347–1358. https://doi.org/10.24912/stupa.v5i2.24283.

[2] Gadi, A.C.Z. (2023). Penerapan teknik zero waste pattern dan pola konstruksi untuk busana ready to wear. *Jurnal Muara Ilmu Sosial, Humaniora, dan Seni*, *6,* 741–749. https://doi.org/10.24912/jmishumsen.v6i3.18207.2022.

[3] Kimbarlina, V.; Enrico, E. (2023). Produk fashion dari limbah untuk mendukung kegiatan sustainable fashion. *Fólio,* 2. https://doi.org/10.37715/folio.v2i2.3478.

[4] ElShishtawy, N.; Sinha, P.; Bennell, J.A. (2022). A comparative review of zero-waste fashion design thinking and operational research on cutting and packing optimisation. *International Journal of Fashion Design, Technology and Education, 15,* 187–199. https://doi.org/10.1080/17543266.2021.1990416.

[5] Carrico, M.; Dragoo, S.L.; McKinney, E.; Stannard, C.; Moretz, C.; Rougeaux-Burnes, A. (2022). An Inquiry into Gradable Zero-Waste Apparel Design. *Sustainability*, *14*, 452. https://doi.org/10.3390/su14010452.

[6] Nursari, F.; Simamora, R.M.; Arumsari, A. (2024). Zero-Waste Kebaya Design: Integrating the 'FRANGIPANI' Method to Enhance Sustainability and Utilize Leftover Lace. *Panggung*, *34.* https://doi.org/10.26742/panggung.v34i3.3211.

[7] Zdonek, I.; Podgórska, M.; Hysa, B. (2025). The Sustainable Fashion Value Proposition of Companies Identifying with the Zero Waste Movement. *Sustainability*, *17*, 887. https://doi.org/10.3390/su17030887.

[8] Enes, E.; Kipöz, Ş. (2020). The role of fabric usage for minimization of cut-and-sew waste within the apparel production line: Case of a summer dress. *Journal of Cleaner Production*, *248*, 119221. https://doi.org/10.1016/j.jclepro.2019.119221.

[9] Sztankovics, I. (2025). Design and Realization of a Cutting Force Measuring System to Analyze the Chip Removal Process in Rotational Turning. *Metrology*, *5*, 5. https://doi.org/10.3390/metrology5010005.

[10] Dewi, V.K. (2022). Penerapan zero waste fashion pada busana demi couture dengan teknik sashiko. *Moda Fashion Journal*, *4*, 22–38. https://doi.org/10.37715/moda.v4i1.2199.

[11] Devetak, T.; Pavko Čuden, A. (2025). Sustainable Fashion in Slovenia: Circular Economy Strategies, Design Processes, and Regional Innovation. *Sustainability*, *17*, 8890. https://doi.org/10.3390/su17198890.

[12] Ruuska, A.; Häkkinen, T. (2014). Material Efficiency of Building Construction. *Buildings*, *4*, 266-294. https://doi.org/10.3390/buildings4030266.

[13] Afifah, S. (2025). Peningkatan Desain Promosi UMKM melalui Pelatihan Penggunaan Canva untuk Iklan Produk. *Progresif*, *5*, 125–136.

[14] Indriani, R.A.R.F.; Marsinah, M.; Hanadya, D.; Auliana, N.U.; Purwanto, M.B. (2024). Perjalanan Songket: Transformasi Menghidupkan UMKM Di Kota Palembang. *Cakrawala: Jurnal Pengabdian Masyarakat Global*, *3*, 209–216. https://doi.org/10.30640/cakrawala.v3i2.2643.

[15] Liu, Y.; Zhang, Y.; Quan, X.; Zhang, J.; Zhao, H.; Chen, S. (2011). Effects of an Electric Field and Zero Valent Iron on Anaerobic Treatment of Azo Dye Wastewater and Microbial Community Structures. *Bioresource Technology*, *102,* 2578–2584. https://doi.org/10.1016/j.biortech.2010.11.109.

[16] Jin, P.; Fan, J.; Zheng, R.; Chen, Q.; Liu, L.; Jiang, R.; Zhang, H. (2023). Design and Research of Automatic Garment-Pattern-Generation System Based on Parameterized Design. *Sustainability*, *15*, 1268. https://doi.org/10.3390/su15021268.
[17] Dey, E.K.; Tawhid, M.N.A.; Shoyaib, M. (2015). An Automated System for Garment Texture Design Class Identification. *Computers*, *4*, 265-282. https://doi.org/10.3390/computers4030265.
[18] Ueda, K. (2026). From Craft to Code and Back: Biodegradable Polyester, Institutional Co-Design, and Garment Practice in Nishijin Weaving. *Arts*, *15*, 34. https://doi.org/10.3390/arts15020034.
[19] Pedgley, O. (2025). Considerations for Planning, Conducting, and Disseminating Research Through Design (RTD). *Designing*, *1*, 47–52. https://doi.org/10.1177/30497671251392169.
[20] Sjolund, K.; Murphy, A.R.; Linsey, J. (2025). Evaluation of Self-Directed Usage of Parallel and Iterative Prototyping Strategies by First-Year Engineering Students. *Proceedings of the Design Society*, *5*, 1595–1604. https://doi.org/10.1017/pds.2025.10173.
[21] Ahsan, R.S.H.F.; Hidayati, N.; Maulana, J.; Kusuma, A.A.; Prastika, J.H.; Mulyawan, N.R. (2025). Pelatihan Digital Art Untuk Merancang Koleksi UMKM Fashion di Kota Malang. *I-Com: Indonesian Community Journal*, *5*, 1211–1221. https://doi.org/10.70609/i-com.v5i3.7686.
[22] Kusuma, A.A. et al. (2025). Transformasi desain fesyen virtual 3d dengan teknologi artificial intelligence luma. *JIPI: Jurnal Ilmiah Penelitian dan Pembelajaran Informatika*, *10*, 2700–2713.
[23] Maksimov, S.; Jordeva, S.; Zhezhova, S.; Mojsov, K.; Janevski, A. (2022). Methodology for determining the quantity of textile waste from the cutting process. *Tekstilna Industrija*, *70*, 29–36. https://doi.org/10.5937/tekstind2201029m.
[24] Young-seon, L. (2017). Development of zero-waste fashion design using subtraction cutting method - focused on cotton jersey. *Journal of the Korean Society of Fashion Design*, *17*, 21–35. https://doi.org/10.18652/2017.17.2.2.
[25] Sovitriana, R.; Budilaksono, S.; Dewi, E.P.; Trisnawati, N.; Nurina, N.; Nasution, E.S. (2024). Pelatihan Perilaku Digital Marketing Ibu-Ibu UMKM Produk Ikan Laut Dan Olahan Krupuk Di Pantai Carita Kabupaten Pandeglang Banten. *Jurpikat (Jurnal Pengabdian Kepada Masyarakat)*, 5, 220–228. https://doi.org/10.37339/jurpikat.v5i1.1353.
[26] Metropolitan, S.; Bentley, T.; Piller, L.W. (2026). Designing for circularity: sustainable pathways for Australian fashion small to medium enterprises. *Journal of Fashion Marketing and Management*, 27, 287–310. https://doi.org/10.1108/JFMM-09-2021-0220.
[27] Nagano, A. (2022). Value Propositions for Small Fashion Businesses: From Japanese Case Studies. *Sustainability*, *14*, 3502. https://doi.org/10.3390/su14063502.
[28] Nguyen, M.H.; Islam, S.; Swee, C.; Tan, L. (2026). An examination of barriers and enablers to circular economy transition among small and medium-sized enterprises in the Vietnamese fashion and textile industry. *Cleaner Production Letters*, 10, 100125. https://doi.org/10.1016/j.clpl.2025.100125.
[29] Liepa, I.; Atstaja, D. (2025). A Comparative Analysis of Circular Economy Index in Urban and Rural Municipalities. *Urban Science*, *9*, 321. https://doi.org/10.3390/urbansci9080321.