Exploring the Potential of Textile Waste as Sustainable Material Through Upcycling Approaches

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Abstract*— The textile industry, a pivotal sector in Indonesia, produces substantial amounts of waste annually due to increasing production demands. This waste, predominantly derived from post-consumer and pre-consumer sources, is often inadequately managed, resulting in severe environmental repercussions. This study explores the feasibility of repurposing textile waste into sustainable materials through an innovative upcycling approach. Utilizing the gathering and combining method, the research integrates textile remnants with various adhesive agents, including PVAc glue, Fox Green glue, and homemade adhesives, to create novel composite materials. The experimental process involved comprehensive analysis of the composites' physical, mechanical, and aesthetic properties. The results demonstrate the transformative potential of textile waste into value-added materials suitable for diverse applications within the creative industries, such as furniture design, fashion accessories, and architectural components. This study underscores the dual benefits of economic and environmental sustainability by implementing circular economy principles within the textile sector. Moreover, it addresses critical challenges, including technological limitations and societal adoption, offering actionable insights for sustainable waste management practices. By advancing innovative methodologies and material solutions, this research is expected to contribute to the broader discourse on sustainable development and resource efficiency, providing valuable guidance for policymakers, industry practitioners, and academia in fostering an environmentally responsible textile ecosystem.

Index Terms—*sustainable materials, textile waste, upcycling, waste management.*

I. INTRODUCTION

The waste problem in Indonesia has become an increasingly urgent issue, particularly due to the rising amount of waste generated each year. According to data from the National Waste Management Information System [1], Indonesia produces approximately 33 million tons of waste annually. This increase not only burdens the environment but also highlights the inability of the existing waste management system to address these challenges. This situation calls for sustainable solutions to mitigate the negative impacts of waste on the environment and public health [2].

Municipal solid waste is one of the major problems in Indonesia, where the volume of waste continues to increase every year along with population growth and community consumption activities. Based on data on the percentage of waste types, food waste occupies the highest position with 27.50%, followed by mixed waste (20.42%), plastic (19.41%), paper (14.54%), wood (9.25%), textile (4.90%), and noncombustible waste (3.98%) [3]

Despite the substantial potential of textile waste for conversion into new materials, recycling efforts in this sector remain significantly underdeveloped compared to other waste streams in Indonesia. Textile fibers, whether derived from natural sources such as cotton or synthetic materials like polyester, can be repurposed for a wide range of applications, including sustainable building materials, composite products, or eco-friendly fashion items [2]. Consequently, prioritizing the reduction and utilization of textile waste is imperative as a critical component of sustainable development strategies. The concept of a circular economy is one of the solutions to the problem of textile waste. In a circular economy, textile waste can be transformed into new, valuable products, thereby reducing dependence on virgin raw materials and minimizing environmental impacts. This approach also has the potential to create new economic opportunities through the development of recycling industries and the use of sustainable materials [4].

An upcycling approach can be used to reduce textile waste. The exploration of upcycling methods for textile waste can include the collecting and combining technique, a process in which materials are collected or combined without a clear connection, resulting in new products from the amalgamation of materials [5]. Textile waste can be combined with chemicals such as resin, putty, or cement to create unique textures and physical properties. Alternatively, various organic materials such as sago flour, gum rosin, and others can be utilized and integrated with textile waste to increase its environmental friendliness [6].

This research aims to explore the potential utilization of textile waste as a sustainable new material. The exploration includes identifying types of textile waste, developing effective recycling methods, and utilizing the resulting new materials. Thus, this study is expected to provide solutions for reducing the environmental impact of textile waste and support sustainability efforts in the textile and fashion industries.

This approach aims to transform textile waste, which has long posed a challenge, into an opportunity by developing innovative and sustainable materials. Additionally, this research aspires to enhance public and industry awareness regarding the significance of improved waste management practices while providing a foundation for formulating more effective and efficient policies and strategies for managing textile waste in the future.

II. METHODS AND MATERIALS

A. *Materials*

Figure 1. 1 Piles of pre-consumer textile waste

The object of this study is pre-consumer textile waste produced by several textile businesses in Bandung City. This waste comprises unused fabric remnants from production processes as well as industrial by-products. The research focuses on the utilization of textile waste with diverse characteristics, including natural and synthetic fibers, along with varying sizes and textures. Textile waste, particularly fabric scraps, is identified as a major environmental management challenge due to its non-biodegradable nature and its potential to contribute to pollution if not properly managed.

These wastes require a specialized approach for processing due to their complexity and diversity. The upcycling method, employing the gathering & combining technique, has been selected in this study as an innovative solution to transform waste into higher-value and more sustainable alternative materials. By applying the upcycling method, this research aims not only to reduce the volume of textile waste but also to create materials with both aesthetic and functional value. The study further explores the use of adhesives such as PVAc glue, Fox Green glue, and homemade glue in the production process of alternative materials, with the objective of generating high-quality products that align with the needs of the creative industries in Bandung.

B. *Research Method*

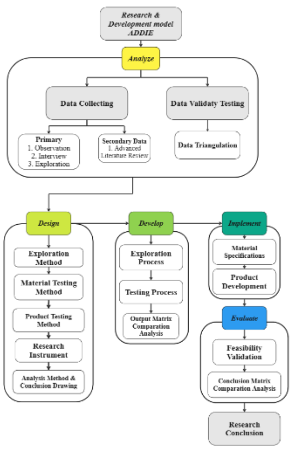


Figure 1. 2 Research Method

The Research and Development (R&D) method is a deliberately and systematically designed research approach aimed at developing new products or improving existing ones, with the goal of producing accountable results. This study adopts the R&D approach using the ADDIE model. The ADDIE model (Analyze, Design, Development, Implementation, Evaluation), as shown in Figure 1.2, serves as a framework for research and development to design and develop products [7].

C. *Exploration Method*

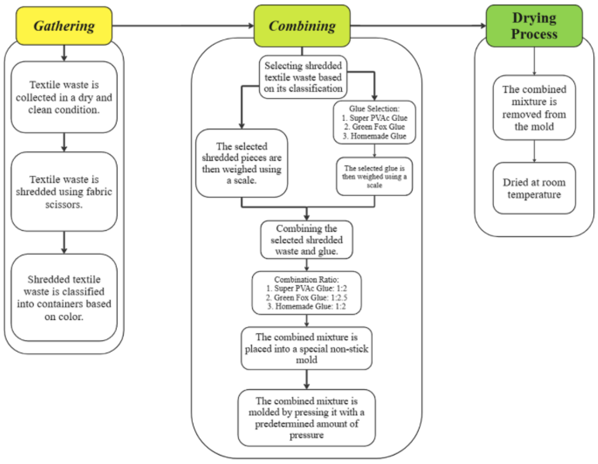


Figure 1. 3 Exploration Method

The Upcycling Exploration Method using the "Gathering and Combining" technique, as illustrated in Figure 2.3, comprises several stages. In the "Gathering" stage, textile waste is collected in a dry and clean condition. The waste is then cut into small pieces using fabric scissors and classified by color into separate containers.

The "Combining" stage begins with selecting fabric pieces based on their classification, followed by weighing them using a scale. An adhesive is then chosen from three available options: PVAc Super Glue, Fox Green Glue, and Homemade Glue, each with its own mixing ratio. The ratios are 1:2 for PVAc Super Glue, 1:2.5 for Fox Green Glue, and 1:2 for Homemade Glue. The weighed fabric pieces are mixed with the selected glue according to the specified ratio and placed into specially designed non-stick molds.

D. *Testing Method*

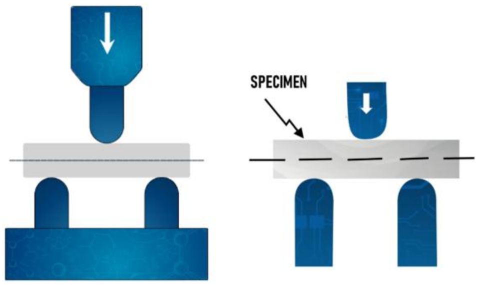


Figure 1. 4 Flexural Testing Scheme

The Flexural Test is a method used to evaluate the mechanical properties of a material when subjected to bending or flexural loading. This process involves placing a sample (typically of brittle or semi-brittle material) on supports and applying a load at a specific point to induce bending. The test measures various properties such as flexural strength, flexural strain, and flexural modulus, providing valuable insights into the material's response to bending forces in real-world applications [8].

E. Product Development Method

a. Theme Determination

Theme determination is a crucial initial step in the design process, as the theme serves as a conceptual foundation guiding all stages of product development. This phase involves identifying objectives, target audiences, and the context in which the product will be utilized. According to [9], selecting an appropriate theme can enhance the visual appeal and functionality of the product, thereby meeting user needs and expectations.

b. Idea Generation

The idea generation process begins with brainstorming activities, aimed at gathering creative ideas from various individuals involved in product development. This method is effective in boosting creativity and generating diverse design solution alternatives [10]. Brainstorming employs approaches such as mind mapping or initial sketching to visualize ideas comprehensively. These approaches enable the identification of innovative solutions relevant to the predetermined theme.

Once ideas are gathered, design exploration is conducted to produce several design alternatives. This process considers aesthetics, functionality, and sustainability as primary parameters. Product exploration aids in mapping the visual characteristics of design styles, which are vital in the design process. The generated ideas are then selected based on technical feasibility, market appeal, and potential application as real products. The selected idea is further developed into a more detailed design concept. This stage involves determining initial specifications related to materials, shape, size, and product function, providing clear guidance for fabrication or prototyping in subsequent stages.

c. Prototype Creation

The prototype creation stage requires preparing materials and tools that align with the specified design. The appropriate selection of materials ensures not only alignment with the design but also affects the quality and functionality of the resulting prototype. According to [11], selecting the right techniques and materials in traditional manual prototyping is critical for achieving optimal outcomes in terms of cost, execution time, and complexity.

After material and tool preparation, the next step is fabricating the prototype based on the chosen design concept. The fabrication process may involve cutting, assembling, or other manual techniques, depending on the complexity and design requirements. As noted by [12], prototypes serve as tools for exploration and evaluation in the design process, allowing for testing of functional aspects and user interaction with the product.

F. Research Instrument

The research instrument is a tool used to collect data for assessing the feasibility of materials derived from textile waste exploration and the resulting products. The instrument is designed to ensure that the materials and products developed meet quality standards in terms of strength, sustainability, aesthetics, and functionality. Validation is conducted through a checklist observation by material experts and product designers to obtain objective and comprehensive evaluations based on predetermined aspects.

In this study, two primary instrument tables are utilized: the Material Expert Validation Instrument and the Product Designer Validation Instrument. The Material Expert Validation Instrument aims to evaluate the feasibility of materials in terms of strength, durability, sustainability, ease of production, safety, and the potential for material innovation in specific product applications. Meanwhile, the Product Designer Validation Instrument focuses on aspects such as material compatibility with the design concept, aesthetics, ease of processing, durability during production, support for design sustainability, and material flexibility for various types of products.

No.	Observed Aspects	Very Feasible	Feasible	Fair	Less Feasible	Not Feasible
1.	Strength of the material in withstanding loads and pressure according to application requirements					
2.	Durability of the material against environmental conditions					
3.	Sustainability of the material in supporting environmentally friendly principles					
4.	Ease of material production and processing					
5.	Safety of the material for the environment and users					
6.	Potential of the material for use in various innovative product applications					

Table 2.1 Validation Instrument by Material Expert

No.	Observed Aspects	Very Feasible	Feasible	Fair	Less Feasible	Not Feasible
1.	Suitability of the material with the intended design concept					
2.	Visual aspects of the material in terms of color, texture, and pattern					
3.	Ease of the material in the processes of forming, cutting, or sewing					
4.	Durability of the material in the production or design processes					
5.	Potential of the material to support sustainability values in design					
6.	Flexibility of the material to be applied in various types of design products					

Table 2.2 Validation Instrument by Product Designer

Each aspect is assessed using the following criteria: Very Feasible, Feasible, Moderately Feasible, Less Feasible, and Not Feasible. This evaluation aims to provide a clear overview of the quality of the materials and products produced, enabling improvements or further development as needed.

G. Data Analyzing Method

This study employs the Matrix Comparison Analysis method to analyze the data generated and subsequently draw conclusions from the analysis. Matrix Comparison Analysis is a highly beneficial and widely used method for presenting large amounts of information in a compact and structured format. This method facilitates the identification of a more balanced presentation by aligning information, both in visual and textual forms [13].

Matrix Comparison Analysis is particularly effective in identifying balanced presentations by aligning information in two dimensions, whether through images or text [13]. The matrix consists of rows and columns that represent two different dimensions, making it easier to compare data. This method is especially useful for organizing and analyzing large datasets comprehensively, enabling a more in-depth and structured understanding.

The data compared in this study include various aspects of the exploration results from the methods used, as well as the outcomes of material testing. Conclusions are then drawn based on the findings obtained from the analysis.

III. RESULT AND DISCUSSION

A. Analyze

1) Observation Data

The observation was conducted on Jl. Tamim, Bandung, which is known as a traditional market and a center for denim fabrics, offering more affordable prices compared to other places. In addition to denim, Jl. Tamim also provides a variety of other fabrics, such as cotton, canvas, and satin. Along Jl. Tamim, there are numerous tailors and garment shops, including Tailor Jeans, Warung Jeans, Rere Teddy Collection, and others. These garment shops offer clothing production services using various types of materials, including denim.

Jalan Tamim, a renowned fabric hub in Bandung, operates from Monday to Sunday and employs predominantly male workers. On Jalan Tamim, customers can easily select a suitable tailor or garment shop and engage warmly with the workers. Textile waste on Jalan Tamim is primarily composed of pre-consumer waste, which is generated during the manufacturing processes of fibers (both natural and synthetic), as well as the production of yarn, finished textiles, technical textiles, nonwoven fabrics, clothing, and footwear. This includes fabric scraps, fabric edges, cutting remnants, rejected materials, and/or lower-grade clothing and sellable fabric pieces. The textile waste is typically stored in garbage sacks and mixed with other waste at each shop or garment workshop along Jalan Tamim in Bandung.

Figure 3.1 First Observation Data

Figure 3.2 Observation Results on Textile Waste Sizes

Based on the observation results presented in Figure 3.2, pre-consumer textile waste is categorized into three main size groups: large, medium, and small. The textile waste varies in length, while the width is generally uniform across all categories.

2) Interview Data

Interviews were conducted with two informants, both business practitioners in the textile industry located on Jalan Tamim, Bandung.

Figure 3.3 Interview

Based on the information obtained from the two interviews, with Mr. Wendy from Tailor Jeans and Mr. Teddy from Teddy Collection on Jalan Tamim, significant differences in textile waste management practices within the garment industry were observed. Large-sized textile waste holds substantial economic value as it can be repurposed into fashion products with added value. Conversely, small textile waste is often discarded and accumulates in production areas, highlighting the need for better and more sustainable waste management strategies. These differences in waste management not only pose environmental challenges but also create opportunities for innovation in developing more eco-friendly alternative materials.

B. Design & Develop

1) Exploration Process

The exploration of textile waste utilization was conducted using three different types of adhesives to compare various aspects of the resulting materials.

Figure 3.4 Gathering and Combining

2) Exploration Output

Figure 3.5 Exploration Output

The use of three types of adhesives during the exploration stage aimed to generate the following findings:

1. Production Costs:

Using Homemade Glue, which has the lowest production cost, can produce sustainable alternative materials comparable to those created with PVAc Super Glue and Fox Green Glue.

2. Visual Appearance

Homemade Glue and PVAc Super Glue: Observations suggest that the resulting shapes appear neat and well-formed. The fabric's texture remains visible, and the colors do not change compared to the original fabric before exploration. Fox Green Glue, the resulting shapes are less neat and well-formed. While the fabric's texture is still visible, the colors appear more faded compared to the original fabric prior to exploration.

These findings demonstrate that waste utilization can be achieved using the Upcycling method through the Gathering & Combining technique. The use of Homemade Glue, made from tapioca flour, water, and vinegar, in textile waste utilization exploration can produce sustainable alternative materials with the following benefits:

1. Economic Sustainability:

The use of Homemade Glue reduces production costs in creating alternative materials.

2. Environmental Sustainability:

Homemade Glue minimizes environmental pollution by avoiding the use of chemical-based adhesives.

3. Social Sustainability:

Implementing the upcycling method through the Gathering & Combining technique creates new business opportunities, which in turn generates new employment opportunities.

3) Testing Process

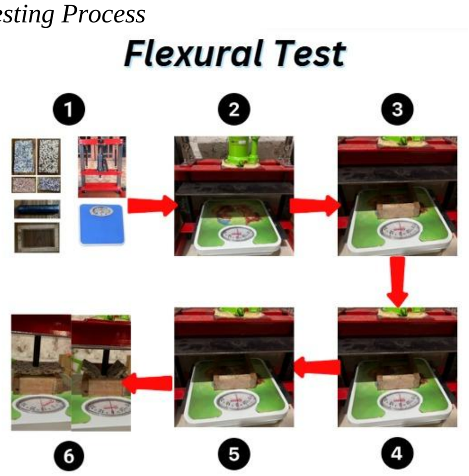


Figure 3.6 Testing Process

The following outlines the steps involved in the material testing process using a flexural test:

1. Material and Equipment Preparation
2. Setting the Scale on the Hydraulic Press
3. Placing the Mold on the Scale
4. Positioning the Explored Textile Waste Material on the Mold
5. Placing the Cylindrical Metal on the Material
6. Applying Pressure Gradually

4) Testing Output

Figure 3.7 Testing Output

The results of the flexural test indicate that utilizing textile waste through the upcycling method with the gathering & combining technique can produce alternative materials with adequate mechanical strength. This technique effectively processes small-sized textile waste, often considered valueless, into materials with stable structures and sufficient strength for various product applications. One of the advantages of this material is the use of homemade glue as an adhesive, which is not only environmentally friendly due to its lack of harmful chemicals but also demonstrates comparable strength to adhesives like PVAc Super or Fox Green Glue. This proves that combining textile materials with natural adhesives supports sustainability principles without compromising the quality of the resulting material.

In addition to being an innovative solution for reducing textile waste, the alternative materials produced through the gathering & combining technique offer significant potential for developing functional and eco-friendly products. Previously discarded textile waste can now be processed into key components for practical materials such as textile boards or furniture elements. An added advantage of using homemade glue is a production process that is safer for the environment and more cost-effective than other chemical-based adhesives. Thus, these findings address the issue of small textile waste while also creating sustainable design innovations that promote responsible and efficient waste management.

5) Output Matrix Comparation Analysis

Aspect	Super PVAc Glue	Green Fox Glue	Homemade Glue
Form	Appears solid, neat, and can produce shapes as per the mold.	Appears solid, less neat, and can produce shapes as per the mold.	Appears solid, neat, and can produce shapes as per the mold.
Color	The color of the initial textile waste does not fade after the mixing process with glue.	The color of the initial textile waste fades after the mixing process with glue.	The color of the initial textile waste does not fade after the mixing process with glue.
Texture	The texture of the material can still be seen and felt and does not mix with the glue's texture; the material feels dry.	The texture of the material can still be seen and felt but is less cohesive with the glue; the material feels dry.	The texture of the material can still be seen and felt and does not mix with the glue's texture; the material feels dry.
Strength Against Pressure	Adequate to withstand the pressure during the testing process on the material based on the mass of the tested material.	Adequate to withstand the pressure during the testing process on the material based on the mass of the tested material.	Adequate to withstand the pressure during the testing process on the material based on the mass of the tested material.
Water Resistance	The glue used as a binder has low water resistance.	The glue used as a binder has low water resistance.	The glue used as a binder has low water resistance.
Production Cost	With Rp. 23,500/1000 grams, it can produce alternative materials from 500 grams of shredded textile waste.	With Rp. 28,500/1000 grams, it can produce alternative materials from 500 grams of shredded textile waste.	With Rp. 12,500/1000 grams, it can produce alternative materials from 500 grams of shredded textile waste.
Environmental Pollution	The glue still contains chemical compounds, so it has the potential to cause pollution to the environment if not disposed of properly.	The glue still contains chemical compounds, so it has the potential to cause pollution to the environment if not disposed of properly.	The glue does not contain chemical compounds, reducing the potential for environmental pollution when using this glue for textile waste processing.

Figure 3.8 Output Matrix Comparation Analysis

Based on the matrix analysis, alternative materials based on textile waste using various types of glue have advantages in shape formation and utilizing the original color of textile waste, enabling the production of aesthetic and versatile materials. However, water resistance is a significant weakness. Even so, these materials are strong enough to withstand pressure and have relatively affordable production costs, making them an environmentally friendly option for interior applications such as decorative panels, crafts, and lightweight furniture. For exterior purposes, further development is needed, particularly in water resistance and additional protection aspects.

C. *Implement*

1) *Material Specifications*

Characteristics	Description
Form	Can be shaped into any desired form as needed with the help of molds, making it easily adaptable to the desired design.
Color	The color depends on the textile waste being processed and can be adjusted by playing with the color mixing process of the waste material.
Texture	The texture of the material is still visible but can be conditioned (e.g., pressed or left rough) depending on the type of adhesive and usage requirements.
Strength Against Pressure	Able to withstand pressure based on the mass of the material, making it suitable for lightweight to medium-strength applications.
Water Resistance	Water resistance is relatively limited; additional treatment may be required to improve the material's function in damp environments.
Production Cost	Production costs vary depending on the type and amount of textile waste; relatively affordable overall and can be adjusted based on production scale.

Table 3.1 Specifications of Alternative Materials from Exploration Results

Based on the specifications of the alternative material derived from textile waste, as shown in Table 3.1, this product holds significant potential for application in various interior elements, such as decorative panels, tables, stools, and craft boards. Its characteristics dense, neat, and easily molded make it highly suitable for products that require both aesthetics and functionality. For example, decorative panels can be used to adorn interior walls with unique designs that retain the fabric's texture. Additionally, products like tables or stools can benefit from the material's strength under pressure, making them safe for light to medium household use. With added finishes such as anti-fungal coatings and varnish, these products can achieve greater durability in typically dry and stable indoor environments.

However, this material is less suitable for exterior applications due to its limited water resistance. When used outdoors, exposure to moisture or extreme weather can compromise the structure and aesthetics of the material. Therefore, its use is more ideal for interior products, such as wall panels, lightweight furniture, storage solutions, or decorative room accessories that are not directly exposed to water or high humidity. For instance, a small table or stool made from textile waste could be used in living rooms or bedrooms as eco-friendly furniture.

With its customizable shapes and colors, this material also supports interior design trends that prioritize sustainability without sacrificing aesthetic value. To meet exterior application needs, further development is required, such as adding waterproof protective layers or using adhesives with greater moisture resistance.

2) *Product Development*

a. Product Development Theme

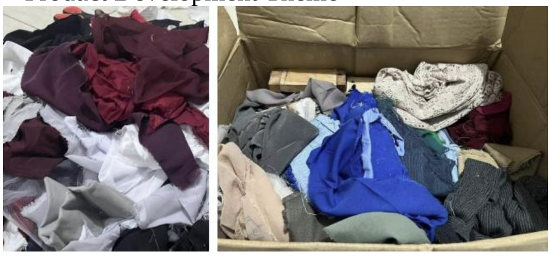


Figure 3.9 Piles of Textile Waste

Textile waste, particularly fabric scraps, often poses a significant environmental problem due to its increasing volume and inadequate management. In certain areas, such as Gang Tamim in Bandung, known as a textile hub, this waste accumulates and is frequently underutilized. Observing this condition, the idea emerged to transform textile waste into alternative materials that can be repurposed effectively.

Figure 3.10 Exploration Result Material

The exploration process involves various processing techniques to produce materials with functional properties such as strength, flexibility, and durability. The results of this exploration demonstrate that textile waste can be transformed into high-quality materials suitable for various creative applications, offering significant opportunities for the development of sustainable products. After recognizing the potential of alternative materials derived from textile waste, the next step is to identify common problems encountered in daily life.

Figure 3.11 Messy Desk Condition

One common issue often encountered is a messy desk, which can disrupt productivity and comfort. Addressing this problem requires a solution in the form of an organizer product designed using materials derived from textile waste exploration. The primary concept behind this product development is to create a sustainable product that not only utilizes textile waste but also provides tangible benefits in daily life.

b. Design Ideation Process

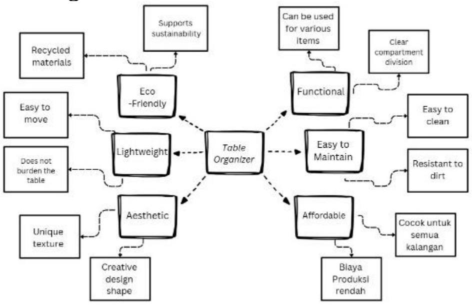


Figure 3.12 Mind Map: Desk Organizer

The mind map above represents a brainstorming process to generate design ideas for a Desk Organizer focused on utilizing recycled materials from textile waste. This product is designed to be eco-friendly, lightweight, and functional, featuring clear compartments for various items and easy maintenance. Additionally, aesthetics are a key focus, with unique textures and creative designs enhancing the space. With low production costs, this product is accessible to all segments of society, making it a practical, economical, and appealing sustainable solution to address the issue of messy desks.

Figure 3.13 Moodboard for Design Ideas

After completing the mind mapping process, the next step is to create a moodboard as a visual reference to support the product design direction. The moodboard above depicts an elegant and modern vibe through a combination of elements such as black and white marble patterns with gold accents, along with solid colors like red, black, gray, and white. Geometric elements, such as red cubes and architectural structures, convey a bold and minimalist impression, while images of cosmetic racks highlight the focus on aesthetic functionality for the organizer.

The material and texture references displayed, such as marble and metal, reflect exclusivity, while the use of contrasting colors demonstrates dynamism and boldness in design. This moodboard serves as a guide for creating a desk organizer product that is not only functional but also sophisticated and capable of providing visual appeal in a workspace or study area.

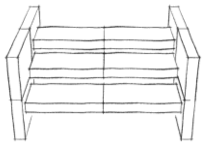
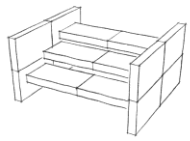
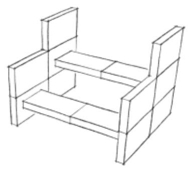
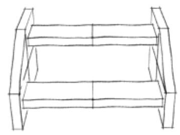
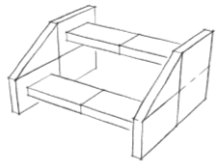
No	View 1	View 2
1.		
2.		
3.		

Table 3.2 Design Alternatives

After completing the mind mapping and moodboard creation processes, the next step is to generate several design alternatives for a rack-shaped desk organizer. At this stage, three design alternatives have been developed, each with different rack shapes and configurations. The first alternative features a tiered rack with sturdy right and left sides, emphasizing symmetry and stability. The second alternative presents a design with more open compartments and taller vertical sides, allowing for the storage of larger items. The third alternative offers a more dynamic design with slanted side angles, creating a modern and ergonomic impression.

These three designs are created to accommodate functional needs while maintaining aesthetics aligned with the sustainability concept. This process helps in selecting the best design that meets practical, visual, and eco-friendly criteria.

c. Prototype Development

Figure 3.14 Selected Design

After undergoing various design ideation processes, a desk organizer design was selected that integrates aesthetics and functionality, aligning with the criteria outlined in the mind map and inspired by the moodboard. This design adopts neutral colors such as black, white, and gray, combined with dynamic patterns to create an elegant yet modern impression. The tiered rack structure with clearly defined compartments is designed to facilitate neat and efficient item storage. The slanted side design not only adds a dynamic appearance but also ensures the product's stability, making it lightweight yet sturdy. The primary material used is recycled textile waste, supporting the sustainability concept without compromising aesthetic value. This design serves as a practical solution for organizing a cluttered desk while representing an innovative, eco friendly product.

Figure 3.15 3D Render of Product Application

The next step involves the 3D rendering process to visualize how the product would look and function in a real-world environment. In the image above, the Desk Organizer is shown storing various items such as perfume bottles and small accessories, demonstrating the product's flexibility and effectiveness as an organizer. Placing the product next to a computer monitor illustrates how this rack integrates seamlessly into a workspace or personal desk without disrupting primary activities. The unique textile patterns add an aesthetic touch, creating harmony between the product and other elements in the room. This rendering process not only validates the practicality of the design but also enhances its visual appeal, making the product suitable for a variety of user needs and lifestyles.

Figure 3.16 Product Manufacturing Process

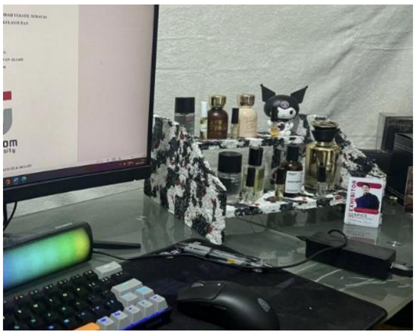


Figure 3.17 Final Product Usage

In Figure 3.17, the Desk Organizer is shown being used to organize various items such as perfume bottles, ID cards, and small accessories that were previously scattered. This product successfully creates a tidier and more organized workspace. The textile patterns on the rack not only serve as aesthetic elements but also add a unique character to the workspace. Additionally, its size and design are proven to be ideal, taking up minimal space and remaining comfortable to use alongside work devices like a monitor and keyboard. This stage demonstrates that the product not only fulfills functional needs but also enhances workspace aesthetics, making it an optimal solution for a cluttered desk.

Based on the product development results, the materials derived from textile waste exploration show great potential as innovative and sustainable solutions. Through the upcycling method using the gathering & combining technique, previously valueless textile waste has been successfully transformed into alternative materials that are strong, functional, and visually appealing.

This material has been applied to the desk organizer product, designed to meet the need for sustainability. With its tiered structure and ergonomic design, this product not only simplifies item organization but also introduces aesthetic elements that align with the concept of a modern workspace. This development process proves that utilizing textile waste can result in high-value products while supporting economic, environmental, and social sustainability.

D. *Evaluate*

1) *Feasible Validation*

a. Material Expert Feasibility Validation

The feasibility validation assessment was conducted by a material expert and Lecturer in Electrical Engineering at Bandung State Polytechnic, Rachmat Sobar, M.Si. The feasibility evaluation was carried out using a scale ranging from Very Feasible to Not Feasible.

The analysis provided by the validator, a Material Expert, is as follows:

No.	Observed Aspects	Very Feasible	Feasible	Fair	Less Feasible	Not Feasible
1.	Strength of the material in withstanding loads and pressure according to application requirements	✓				
2.	Durability of the material against environmental conditions			✓		
3.	Sustainability of the material in supporting environmentally friendly principles	✓				
4.	Ease of material production and processing		✓			
5.	Safety of the material for the environment and users	✓				
6.	Potential of the material for use in various innovative product applications	✓				

Sumber: (Dokumen Pribadi, 2024)

Table 3.3 Material Feasibility Assessment Analysis Results

The validation results above indicate that the material produced through the upcycling method using the gathering & combining technique has met the criteria of "very feasible."

b. Product Designer Feasibility Validation

The product feasibility validation assessment was conducted by a product designer, Divindo Agabel, who works as a Senior Product Designer at PT Arung Bahari Nusantara. The feasibility evaluation was measured using a Likert scale with criteria ranging from "Very Feasible" to "Not Feasible."

No.	Observed Aspects	Very Feasible	Feasible	Fair	Less Feasible	Not Feasible
1.	Suitability of the material with the intended design concept	✓				
2.	Visual aspects of the material in terms of color, texture, and pattern		✓			
3.	Ease of the material in the processes of forming, cutting, or sewing		✓			
4.	Durability of the material in the production or design processes		✓			
5.	Potential of the material to support sustainability values in design	✓				
6.	Flexibility of the material to be applied in various types of design products	✓				

Sumber: (Dokumen Pribadi, 2024)

Table 3.4 Product Feasibility Assessment Analysis Results

The validation results above indicate that the product made from materials derived through the upcycling method using the gathering & combining technique has met the "very feasible" criteria.

Based on the validation assessment data from the Material Expert and Product Designer, it can be concluded that the material and product developed are deemed highly feasible as sustainable alternative materials, as they have achieved the "Very Feasible" rating across the observed aspects.

2) *Matrix Comparation Analysis*

The Matrix Comparation Analysis in this study aims to evaluate the results of product development using a matrix-based data comparison approach. The analysis involves comparing data from various development stages, ranging from material exploration to product feasibility assessment, to draw conclusions regarding the success of the resulting material in meeting the three pillars of sustainability: economic, environmental, and social.

No.	Type of Data	Findings
1.	Exploratory Data	The upcycling method using the gathering & combining technique shows that small textile waste can be processed into alternative materials that are strong and stable. This technique adds value to previously discarded waste, creating sustainable alternative materials suitable for developing various products.
2.	Flexural Test Data	The results of the flexural test indicate that the alternative material has adequate mechanical strength for various applications. This material has proven capable of withstanding certain pressures without cracking or breaking, making it suitable for developing new products.
3.	Product Development Data	Product development based on alternative materials resulted in a desk organizer product that successfully integrates aesthetic, functional, and sustainable aspects. The product design is not only visually appealing but also provides practical solutions for daily use, meeting modern consumer needs.
4.	Feasibility Assessment Data	The feasibility assessment showed an average score of 90%, covering economic, social, and environmental aspects. The material and resulting products are deemed highly feasible for use as they meet sustainability criteria and have promising market potential.

Conclusion:

This research demonstrates that the upcycling method using the gathering & combining technique can create alternative materials that meet the three pillars of sustainability. These materials have a positive impact on the following aspects:

1. Economic: Low production costs and market opportunities.

2. Environmental: Reduction of textile waste. **3.** Social: Increased awareness and job opportunities in the creative sector.

Table 3.5 Comparison Matrix Analysis for Drawing Conclusions

IV. CONCLUSION

This study successfully identified that the upcycling method using the gathering & combining technique is an effective approach for processing textile waste, particularly small-sized waste, into sustainable alternative materials. This technique produces materials with adequate mechanical strength, aesthetics, functionality, and broad application potential. The test results show that textile waste-based materials meet the three aspects of sustainability: economic, through market potential; environmental, through waste reduction and the use of eco-friendly materials; and social, by increasing public awareness and creating new business opportunities.

This research is expected to serve as a recommendation for more effective and sustainable textile waste management. Future steps include developing fabrication processes on a larger scale using advanced tools and machinery to improve production efficiency and conducting material testing based on international standards such as ISO or ASTM. It is also suggested to explore a wider variety of textile waste types, expand the application of alternative materials to products such as furniture or construction components, and test the durability of materials over the long term. Furthermore, it is crucial to involve stakeholders, including industries and local communities, to strengthen social and economic impacts.

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REFERENCES

[1] S. Goldberg, “The End of The Trash,” *National Geographic*, 2020.

[2] S. Y. Ningsih, S. Evelina, and Jessieca, “Pelatihan Pemanfaatan Limbah Tekstil Sebagai Produk dengan Nilai Guna Baru Bagi Komunitas Craftalova Fabric Club,” 2019.

[3] Z. Zhen *et al.*, “Experimental study on characteristics of municipal solid waste (MSW) in typical cites of Indonesia,” *Progress in Energy & Fuels*, vol. 8, no. 1, p. 13, Apr. 2020, doi: 10.18282/pef.v8i1.716.

[4] N. Pensupa *et al.*, “Recent Trends in Sustainable Textile Waste Recycling Methods: Current Situation and Future Prospects,” Oct. 01, 2017, *Springer International Publishing*. doi: 10.1007/s41061-017-0165-0.

[5] L. Lee and E. Yim, “Characteristics of Upcycle Designs in Product and Fashion Design,” *Fashion business*, vol. 19, no. 4, pp. 1–20, Sep. 2015, doi: 10.12940/jfb.2015.19.4.1.

[6] R. Susilo and A. Karya, “Pemanfaatan Limbah Kain Perca untuk Pembuatan Furnitur,” 2013.

[7] A. F. Slamet, *Model Penelitian Pengembangan (R n D)*. Malang: Institut Agama Islam Sunan Kalijogo Malang, 2022.

[8] M. M. Costa, “Material Testing.” Accessed: Dec. 23, 2024. [Online]. Available: https://biopdi.com/articles/

[9] P. H. Bloch, “Seeking the Ideal Form: Product Design and Consumer Response,” *J Mark*, vol. 59, no. 3, pp. 16–29, Jul. 1995, doi: 10.1177/002224299505900302.

[10] A. Ardian and D. R. Djatmiko, “Penerapan Model Pembelajaran Brainstorming untuk Meningkatkan Kreativitas Mahasiswa pada Mata Kuliah Praktik Fabrikasi,” *Jurnal Pendidikan Teknologi dan Kejuruan*, vol. 17, no. 1, pp. 61–76, 2008.

[11] D. Pereira, J. Lanutti, C. L. Paschoarelli, and O. Pinheiro, “Comparison of traditional manual prototyping techniques and their importance to design,” *Design, Art, and Technology (dat)*, vol. 2, no. 2, 2017.

[12] M. Buchenau and F. J. Suri, “Experience Prototyping,” 2000.

[13] D. W. Soewardikoen, *Metodologi Penelitian: Desain Komunikasi Visual*. 2021.